EVALUATION OF STATE OWNED INDIGENOUS COAL FIRED POWER PLANTS INCLUDING COAL RESERVES

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ABSTRACT

EVALUATION OF STATE OWNED INDIGENOUS COAL FIRED POWER PLANTS INCLUDING COAL RESERVES

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Fossil fuels has preserved their importance in gradually increasing production and consumption of both energy and electricity of the world. Asia, especially China and India, has arisen new actors of the sector.

Energy and electricity consumption of Turkey has also increased in parallel with her economic development, but due to her limited resources, she has become more and more energy dependent in order to meet her growing demand.

Although hard coal is only found around Zonguldak region, with its abundant and widely spread reserves, Turkey ranked world's third place in lignite production in 2008. Having low calorific value together with high ash and moisture content, most of lignites extracted is being consumed in thermic power plants located near those reserves.

In the first two chapters of this study, energy in the world and Turkey will be considered seperately, then coal resources in Turkey will be analysed in the next coming chapter. Indirect and direct greenhouse emissions presented to the UNFCCC will be handled in the fifth chapter

In the last chapter, first past and present performances of all indigenous coal fired power plants will be analysed, then after projecting their generation and fuel needs, they are evaluated considering with the reserves they are located. Finally, at the end of decomissioning of those power plants, remaining reserves will be re-evaluated and additional new units will be proposed accordingly.

Keywords: Energy, Hard Coal, Lignite, Greenhouse Gas (GHG) Emissions, Power Plants

ÖZ

YERLİ KÖMÜRLE ÇALIŞAN KAMU SANTRALLERİNİN KÖMÜR REZERVLERİ İLE BİRLİKTE DEĞERLENDİRİLMESİ

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Dünyanın giderek artan enerji ve elektrik tüketimi içinde fosil yakıtlar önemini korumaktadır. Asya, özellikle Çin ve Hindistan, sektörün yeni aktörleri olarak ortaya çıkmıştır.

Türkiye'nin enerji ve elektrik tüketimi de ekonomik gelişmesine paralel olarak hızla artmıştır ancak yerli kaynaklarının sınırlı olmasından dolayı, artan talebini karşılamak için giderek ithalata bağımlı hale gelmiştir

Türkiye'de taşkömürü yalnızca Zonguldak ve çevresinde bulunurken, hemen hemen her bölgede bol ve yaygın olarak buluna linyit rezervleriyle, 2008 yılı dünya üretiminde üçüncü sırada yer almıştır. Düşük kalorili, yüksek nem ve kül içerikli linyitlerin çoğu çıkarıldıkları yerlerde bulunan termik santraller tarafından tüketilmektedir.

Bu çalışmanın ilk iki bölümünde dünyada ve Türkiye'deki enerji irdelenecek, üçüncü bölümde ise Türkiye'nin kömür kaynakları analiz edilecektir. Türkiye

tarafından BM İDÇS Sekretaryasına sunulan dolaylı ve dolaysız sera gazlarına beşinci bölümde yer verilecektir.

Son bölümünde ise, öncelikle yerli kömür ile çalışan kamu santrallerinin geçmişteki ve şimdiki performansları göz önünde bulundurularak analiz edilecek, sonrasında geleceğe yönelik üretim ve yakıt tüketim projeksiyonu yapılarak rezervlerle birlikte değerlendirilecektir. Nihayetinde, var olan santraller devre dışı olduktan sonra kalan rezervler tekrar değerlendirilerek uygun ilave üniteler önerilmiştir.

Anahtar Kelimeler: Enerji, Taş Kömürü, Linyit Kömürü, Sera Gazı Emisyonu, Termik Santral

To the my mom Mürüvvet Güler

Thank you mom

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I'd like to dedicate my dissertation work to my mom for her endless patience and continuous wholeheartedly support throughout my life …

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LIST OF SYMBOLS AND ABBREVIATIONS

ACCRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing Materials
CFCs	Chlorofluorocarbons
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of the Parties
CRF	Common Reporting Format
ECE	United Nations Economic Commission for Europe
EİGM	General Directorate of Energy Affairs
EMRA	Energy Market Regulatory Authority
EÜAŞ	Electricity Generation Corporation
F-Gases	Fluorinated Greenhouse Gases
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HFCs	Hydrofluorocarbons
IEA	International Energy Agency
EIA	Environmental Impact Assessment
IPCC	Intergovernmental Panel on Climate Change
JIS	Japanese Standarts Association
LULUCF	Land Use, Land-Use Change and Forestry
MENR	Ministry of Energy and Natural Resources
MİGEM	General Directorate of Mining Affairs
MoEF	Ministry of Environment and Forestry
MTA	General Directorate of Mineral Research and Exploration
N_2O	Nitrous Oxides
NCV	Net Calorific Value (Lower Heat Value)

NIR	National Inventory Report
NMVOC	Non-Methane Volatile Organic Compounds
NO_X	Nitrogen Oxides
OECD	Organization for Economic Cooperation and Development
PCI	Pulverized Coal Injection
SF_6	Sulphur Hexafluoride
SO_2	Sulfur Dioxide
TEİAŞ	Turkish Electricity Transmission Corporation
TFC	Total Final Energy Consumption
TKİ	Turkish Coal Enterprises
TPES	Total Primary Energy Supply
TTK	Turkish Hard Coal Enterprises
TÜBİTAK	The Scientific and Technological Research Coincil of Turkey
Turk-Stat	Turkish Statistical Institute
UNEP	United Nations Environment Programme
UNFCCC	United Nations of Convention on Climate Change
WEC-TNC	World Energy Council Turkish National Committee

UNITS

°C	degree Celsius
bcm	billion cubic meters
Gj/Gcal	Gigajoule per giga calorie
GW	Gigawatt
GWh	Gigawatt hour
kcal	kilocalorie
kcal/kg	kilocalorie per kilogram
kcal/kWh	kilocalorie per kilowatt hour
kg/kcal	kilogram per kilo calorie
kg/TJ	kilogram per terajoule

mtons	million tons
kWh	kilowatt hour
m^3	cubic meter
mtce	million tons of coal equivalent
mtons	million metric tons
mtoe	million tons of oil equivalent
MW	Megawatt
Sm^3/kcal	Standart cubic meter per kilo calorie
toe	ton of oil equivalent
ttoe	1000 tons of oil equivalent
ttons	1000 tons
TJ	Terajoule
TW	Terawatt
TWh	Terawatt-hours

CHAPTER 1

INTRODUCTION

1.1 World Energy Outlook

The world total primary energy production increased slightly from 8.8 btoe (billion tons of oil equivalent) to 11.9 btoe with an average growth rate of 1.81% between 1990 and 2007. The increase by 1.68% between 2006 and 2007 was mostly driven by coal and in 2007 the increase in Chinese coal production alone contributed to almost 40% of the growth in the world total energy production. OECD (Organization for Economic Co-operation and Development) countries were accounted for 32% of the global production.

General overview has not much changed since 1990. During the period fossil fuels have constituted about 80% of total production, having almost flat shares. A slight decrease in share of oil has been compensated by hard coal and natural gas.

Total Primary Energy Consumption (TPES), or in other words gross consumption – defined as production + imports – exports - international bunkers ± stock changes- increased more than twice with an average growth rate of 2.12 between 1970 and 2007.

In 2007, United States, China, Russian Federation, India and Japan produced together half of the global gross domestic product (GDP) (in purchasing power parity), consumed 51% of total world energy and accounted for 46% of the total population (Table 1.1).

Table 1.1 TPES- Top Five Countries in 2007

Country	TPES (mtoe)	Share in World TPES
United States	2,340	19
People Of Rep. of China	1,956	16
Russian Federation	672	6
India	595	5
Japan	514	4
World Total	**12,029**	**100**

Source IEA 2009

Since 1990, the share of consumption by industry sector in total has decreased gradually from 29% to 27% while that of transport sector rose from 25% to 28% replacing industry sector at top. In seventies their shares were 33% and 23% respectively. the average growth rate of consumption in transport sector, a captive sector, was higher than that of the others. Despite the share consumption in residential sector showed a few percent increase in 90s, it dropped down to 1990 level of 25% in 2007.

The following Table 1.2 summarizes world energy balance from production to total final consumption (equal to the sum of the consumption in the end-use sectors).

Table 1.2 World Energy Balance (mtoe)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-2007	1990-2007
Production	8,797	9,246	9,969	11,456	11,742	11,940	2.0	1.8
Import	3,027	3,139	3,783	4,484	4,623	4,729	2.7	2.7
Export	-3,026	-3,164	-3,799	-4,494	-4,584	-4,645	2.5	2.6
TPES	8,762	9,227	10,019	11,425	11,720	12,029	2.1	1.9
Total Final Consumption	6,293	6,555	7,037	7,878	8,068	8,286	1.8	1.6
Industry sector	1,800	1,790	1,870	2,098	2,184	2,275	1.3	1.4
Transport sector	1,578	1,728	1,939	2,175	2,230	2,297	2.4	2.2
Residential	1,973	2,221	2,360	2,558	2,573	2,600	1.8	1.6
Agriculture/forestry	163	170	163	181	184	186	1.3	0.8
Non-energy use	779	647	706	867	898	929	2.3	1.0

Source IEA 2009

Electricity is driving force of industry. Its consumption is an indicator of development. Table 1.3 summarizes electricity balance.

Between 1990 and 2007 world gross electricity production rose from 11,861 TWh to 19,855 TWh with an average annual growth rate of 3.08%. As shown in the Table 1.3, the annual average growth rate was higer than the previous decade, 2.68% between 1990 and 2000 vs. 3.64% between 2000 and 2007.

Table 1.3 World Electricity Balance (TWh)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-2007	1990-2007
Gross Production	11,861	13,282	15,456	18,311	19,020	19,855	3.66	3.08
Distribution Losses	1,006	1,136	1,367	1,603	1,628	1,667	3.75	3.02
Total Consumption	9,690	10,840	12,640	15,036	15,675	16,446	3.64	3.16
Total Industry	4,411	4,644	5,294	6,183	6,525	6,940	2.95	2.70
Total Transport	244	213	219	258	261	270	2.39	0.59
Residential	4,545	5,454	6,574	7,772	8,025	8,305	4.49	3.61
Agriculture/ Forestry/ Fishery	351	372	350	386	410	426	3.66	1.14
Other	139	157	203	438	454	505	3.36	7.87
Production Growth Rate (%)	2.32	3.47	4.73	4.46	3.87	4.39		

Source:IEA 2009

Total world coal production about doubled in the last 37 years and reached 6,397.5 mtons in 2007 with an annual average growth rate of 2.14%. Production decreased slightly between 1990 and 2000 and but gained acceleration after 2001. The average annual growth rate was 5.1% between 2000 and 2007 in contrast to -0.36% in the previous decade.

The global production was mostly driven by hard coal which increased to 5,442 mtons in 2007 from 2,174 mtons in 1971. The production was driven by mostly Non-OECD countries. In 1973, the OECD accounted for about 50% of the world hard coal production. While OECD's production increased throughout the 70s and 80s, its share of world production declined to about 40% by 1990 and by 2008 was only about 26%.

Brown coal production showed a slight rise in the last 37 years. With an annual average growth rate of 0.65% in the last seven years, only reached to 1994 levels after a sharp decrease in the previous decade.

In contrast to hard coal, with a 64.9% share OECD was dominant in Brown coal production in 2008 and mostly concentrated in OECD Europe (71.5%).

As shown in Table 1.4, of the gross coal consumption, about 69% was consumed to produce electricity and heat in 2007 (about 65% of hard coal, mostly other bituminous coal, and more than 90% of brown coal). 11% of gross consumption was attributed to coke oven plants while the rest was consumed while the rest was consumed in the end use sectors (industry, transport, residential etc.).

Table 1.4 World Coal Balance (mtons)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-2007	1971-2007
Production	4,679	4,574	4,515	5,855	6,149	6,398	**2.14**	**1.86**
Gross Inland	**4,670**	**4,579**	**4,635**	**5,827**	**6,111**	**6,375**	**2.13**	**1.85**
Electricity and Heat	2,720	2,931	3,284	3,968	4,213	4,384	3.55	2.85
Coke Oven	508	519	464	624	683	734	1.02	2.19
TFC	**1,151**	**1,011**	**742**	**903**	**918**	**947**	**0.06**	**-1.14**
Industry	638	669	524	657	674	707	1.09	0.61
Residential	338	230	144	147	149	144	-2.03	-4.88
Transport	27	14	11	8	8	7	-6.14	-7.55
Agriculture/Fishing	30	26	21	28	26	26	0.14	-0.76
Non-Energy	37	26	19	37	36	38	5.47	0.06
Other	292	118	145	332	296	310	0.06	0.34

Source: IEA 2009

According to IEA statistics world global CO_2 (carbon dioxide) emissions were doubled with an annual average growth rate of 0.28% from 14 btons to 28 btons between 1971 and 2007. With an annual average growth rate of 3.10%, the second fastest after unallocated autoproducers, power and heat sector replaced the industry sector at the top after 80's.

About 69% of global coal consumption was by power sector in 2006 and 2007, holding 80% of coal sourced CO_2 emissions.

As for the emissions steming from burned natural gas, 33% was attributed to electricity and heat production while 22% was from manufacturing industries and construction. Other sector also includes 25% of total natural gas emissions and mostly coming from space heating.

1.2 Turkey Energy Outlook

Total primary energy production increased slightly with an average growth rate of 0.44% and reached 27.5 mtoe from 25.5 mtoe between 1990 and 2007. The average growth rate of 3.91% was the highest between 1980 and 1990 when comparing with the other decades. In contrast to other sources, share of lignite has increased continuously since 1970 and reached almost half of the total production in 2007. It was lowest in 2004 when the hydro was highest in the last decade.

Total Primary Energy Consumption increased by twice with a considerably fast pace of 4.3% per year between 1990 and 2007. It was in the range of 5.41-4.24% between 1970 and 2007. Coal, oil, gas and hydro main sources.

The rapid penetration of natural gas in life of the country is main reason of the decrease as in oil. Although hard coal showed a rise in consumption during the last decade, it is mostly coming from import. In 2007, coal, oil and natural gas constituted about 90%of all consumption.

Total Final Consumption increased from 41.6 mtoe in 1990 to 82.7 mtoe in 2007 with an average annual growth rate of 4.13% similar with that of TPES.

Although share of oil decreased slightly, it always protected its place at the top. As a consequence of energy policy on diversification of fuel mix, imported natural gas was introduced through the almost whole country and its share roared from 1.9% in 1990 to 19.1% in 2007. The rapid rise in share of electricity is also coming from rapid development of the country where electricity is driving force for the

development. Privatization in industry and development of the country also resulted in rapid penetration of imported hard coal to the country.

Residential sector had the highest share in 1990, but it was replaced by industry sector in 2007. The other sectors have almost retained their shares. The conversion sector including power plants , coke ovens and briquetting constitutes about 22% of total consumption.

Table 1.5 summarizes energy balance of Turkey and shows how the country has become more and more dependent on imported energy.

Table 1.5 Development of Energy in Turkey (ttoe**)**

	1990	**1995**	**2000**	**2005**	**2006**	**2007**
Production	25,478	26,719	26,047	24,549	26,580	27,453
Import	30,936	39,779	56,342	73,065	80,416	87,614
Export	2,104	1,947	1,584	5,171	6,572	6,926
Bunkers	355	464	467	628	588	92
Net Import	28,477	37,368	54,291	67,266	73,256	80,596
Gross Consumption	52,987	63,679	80,500	91,074	99,642	107,627
Production/Demand (%)	48.08	41.96	32.36	26.96	26.68	25.51

Source: MENR

Total installed capacity was only 2,235 MW in 1970 when electrification studies initiated yet. Seventies are remembered as “hard days” in history of economy, throughout world and also in Turkey. Oil shocks are of course main reason of the chaos in that years.

During the last two decade, electricity generation has more than tripled and reached 191,6 TWh in 2007. The average growth rate in the last 17 years was 7.33% which is considerably high and shows how fast Turkey has developed in spite of the economic crises the country faced with in 1991, 1994 and 2001 together with adverse effects of 1999 earthquake.

Table 1.6 is a summary of development of electricity in Turkey. When looking at the sectoral breakdowns of electricity consumption, it is seen that almost all the electricity has been consumed by industry and residential sector.

Table 1.6: Development of Electricity (GWh)

	1990	**1995**	**2000**	**2005**	**2006**	**2007**
Gross Generation	57,543	86,247	124,922	161,956	176,300	191,558
Own Use and Loses	-9,992	-18,158	-29,980	-30,531	-31,567	-34,865
Net Generation	47,551	68,090	94,942	131,425	144,733	156,693
Import	176	0	3,791	636	573	864
Export	907	696	437	1,798	2,236	2,422
Gross Consumption	**46,820**	**67,394**	**98,296**	**130,263**	**143,071**	**155,135**
Refineries	1,150	1,670	2,156	847	855	1,033
Net Consumption	45,670	65,724	96,140	129,416	142,216	154,102
Industry	28,062	36,337	46,686	58,721	67,172	73,795
Railways	345	490	720	749	790	936
Residential	16,688	27,384	45,664	65,833	69,813	74,391
Agriculture	575	1,513	3,070	4,113	4,441	4,981
Industry Growth Rate (%)	-2.8	1.7	-2.8	-6.0	4.1	1.4
Residential Growth Rate (%)	4.9	-2.7	2.4	6.2	-3.5	-1.7

Source: MENR/TEIAS

1.3 Turkey Coal Outlook

Hard coal is only found around Zonguldak Region located at the North Western Black Sea in Turkey. The region is within the Western Pondites tectonic province, and it is included in the Palezoic sequences cropping around Zonguldak. The sequence ranges from Upper Devonian to Upper Carboniferous.

Total hard coal reserves are about 1.3 billion tons of which 526 mtons is proved. Coals of Kozlu, Üzülmez and Karadon Basins can be cokeable while that of Armutçuk Basin are semicokeable and Amasra Basin are non-cokeable.

Lignite is spread widely through the country and can be found almost every region. Of the total reserves 4.3 mtons are situated in Afsin-Elbistan basin owned by Electricity Generation Corporation (EÜAŞ). Turkish Coal Enterprises (TKI) is the other state own producer. They have about 80% of the total reserves and exploitation licences. Most of lignite is used in power plants since considerably young reserves usually have low calorific value and high ash value.

After having peaked in 1974, hard coal production has been decreased continuously since 1970. Although gross coal consumption is declined by half and reached 25.4 mtons with a considerably high average growth rate of 6.9%, production, in contrast, slightly decreased from 2.7 mtons to 2.46 tons with an average rate of 0.64 in 2007. Tbale 1.7 summarizes hard coal balance.

Table 1.7 Hard Coal Balance (ttons)

	1990	**1995**	**2000**	**2005**	**2006**	**2007**
Production	2,745	2,248	2,392	2,170	2,319	2,462
Import	5,557	5,941	12,990	17,360	20,286	22,946
Gross Coal Consumption	8,191	8,548	15,525	19,421	22,798	25,388
Transformation Sector	5,444	5,508	6,282	9,517	10,262	10,539
Total Final Coal Consumption	2,747	3,040	9,244	9,904	12,536	14,849

Source: MENR

As shown in Table 1.8, between 1990 and 2007, lignite production was increased from 44.4 to 72.1 mtons with an average growth rate of 2.9%, lower than that of power plants.

Most of the lignite is consumed by power plants and therefore all the power plants are located near the lignite mines.

Table 1.8 Lignite Balance (ttons)

	1990	1995	2000	2005	2006	2007
Production	44,407	52,758	60,854	57,708	61,484	72,121
Import	15	10	11	0	29	0
Gross Lignite Supply	45,891	52,405	64,384	56,571	60,184	72,317
Transformation Sector	30,152	39,985	53,314	48,562	49,979	60,709
Total Final Lignite Consumption	15,739	12,420	11,070	8,009	10,205	11,608

Source: MENR

1.4 National Emissions

Turkey's total GHG emissions excluding Land Use, Land-Use Change and Forestry (LULUCF) rose from 170.1 mtons to 372.6 mtons CO_2 equivalent between 1990 and 2007. The average annual growth rate of 4.72% is in paralel with that of TPES and TFC. The main reason behind this increase is rapid industrialization and population growth rate as a developing country.

CO_2 is responsible for largest proportion of Turkey's total emissions followed by CH_4, N_2O and F gases respectively. About 80% of total GHG emissions are coming from CO_2. The share of CH_4 emissions decreased gradually from about 19% to 15% in the last years while that of N_2O emissions has almost doubled in the same period.

The SF6 and HFC emissions are coming from electricity generation and manufacturing sectors. SF6 emissions have been recorded since 1996 while HFCs first introduced to the industry in 2000, in order to replace CFCs which was controlled under the Montreal Protocol. Table 1.9 shows greenhouse gases by sources and sectors.

Table 1.9 Greenhouse Gases (ttons of CO_2 equivalent)

	1990	1995	2000	2005	2006	2007	1990-2007 Growth Rate (%)
CO_2 emissions excluding net CO_2 from LULUCF	139,594	171,854	223,806	256,434	273,705	304,475	4.69
CH_4 emissions excluding CH_4 from LULUCF	29,207	42,539	49,269	49,317	50,330	54,384	3.72
N_2O emissions excluding N_2O from LULUCF	1,257	6,327	5,740	3,432	4,594	9,652	12.74
HFCs	NA	NA	818	2,379	2,730	3,174	
PFCs	NA	NA	NA	NA,NE	405	C,NA,NE	
SF_6	NA,NE	NA,NE	323	859	911	952	
Total (including LULUCF)	**125,188**	**158,883**	**212,398**	**242,888**	**256,739**	**296,364**	**5.2**
Total (excluding LULUCF)	**170,059**	**220,719**	**279,956**	**312,420**	**332,675**	**372,638**	**4.72**

1.5 Recalculated National Emissions

In preparation of emission inventory, same activity data have to be used for all emittants in a specific year. However, the activity data used by TurkStat and EÜAŞ in calculation of emission was not same till 2004. The data on energy balance sheets was more aggregated in the previous years although separate data was available for each thermic power plant.

In addition, same emission factor have been used for all oil products, even though there are separate emission factors in the IPCC Inventory Guidebook.

Chapter 6 deals with those discrepancies and presents recalculated greenhouse emissions using plant data for each year.

The methodologies used in the calculation of emissions are based on the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines).

In the study, the data collected by MENR was main source of activity data used. The total amount of each fuel type burned in power plants was compared with that in balance sheets for consistency.

The total heat produced is calculated by using net calorific values (NCVs) of fuel burned.

The quantities were first converted to energy units using NCVs from tons to giga calories then expressed as gigajoule using the conversion factor of 4.1868 Gj/Gcal.

The following Table 1.10 presents IPCC default emission factors to be used used in calculations.

Table 1.10 IPCC Default (Uncontrolled) Emission Factors (kg/Tj)

	Hard Coal	**Lignite**	**F. Oil**	**D. Oil**	**LPG**	**Naphtha**	**Natural Gas**
Effective CO2 Emision Factor	25.80	27.60	21.10	20.20	17.20	20.00	15.30
Effective CH4 Emission Factor	1.00	1.00	3.00	3.00	3.00	3.00	1.00
Effective N2O Emission Factor	1.40	1.40	0.60	0.60	0.60	0.60	0.10
Effective NOx Emission Factor	300.00	300.00	200.00	200.00	200.00	200.00	150.00
Effective CO Emission Factor	20.00	20.00	15.00	10.00	10.00	10.00	20.00
Effective NMVOC Emission Factor	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Table 1.11 summarizes results of the study.

Table 1.11 Recalculated Direct and Indirect Greenhouse Gases (ttons)

	1990	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CO_2	29,450	41,189	72,501	74,781	69,325	69,340	70,816	83,993	85,590	101,073
CH4	0.439	0.638	1.223	1.254	1.204	1.192	1.175	1.304	1.298	1.546
N2O	0.335	0.461	0.711	0.717	0.624	0.603	0.620	0.751	0.770	0.903
CO	6.679	9.364	17.587	18.462	17.589	18.070	18.625	22.170	22.642	26.751
NMVOC	1.729	2.440	4.626	4.820	4.594	4.692	4.804	5.657	5.756	6.807

1.6 Evaluation of State Owned Coal Fired Plants

In Turkey, all domestic lignite fired power plants are being operated by EÜAŞ except Çayırhan which is privatized in 2000, regardless of small scale cogeneration units mostly having a capacity lower than 20 MW. Out of Afşin-Elbistan, Çayırhan and Kangal, all the lignite mines feeding those utilities are being operated by TKİ. Sugözü, Çolakoğlu, İçdaş and Kahraman Maraş Kağıt are the other coal fired power plants using imported coal. Çatalağzı, under portfolios of EÜAŞ, is the only domestic power plant burning hard coal and TTK is the only owner of coal basin.

In this study, after scrutinizing historical and current operation characteristics of indigenous coal fired power plants, first, their generations and fuel consumptions were forecasted then the results were evaluated together with coal reserves.

Table 1.12 presents total cumulative fuels consumed, total cumulative reserves exploited and remaining reserves after exploitation of those mines at the end of plants life.

Table 1.12 Remaining Reserves After Decommissioning of Current Power Plants

Public Coal Fields	**Total Cumulative Fuel Consumed (tons)**	**Total Cumulative Reserves Explored**	**Reserves at the end of 2008**	**Reserves at the end of Plant Life**
		(tons)	**(tons)**	**(tons)**
Zonguldak Basin	49,683,150	70,975,928	534,620,488	463,644,560
Elbistan Basin (Sector A and B)	955,439,546	1,061,599,496	1,381,000,000	319,400,504
Çan Basin	64,429,695	71,588,550	82,924,000	11,335,450
Kangal Basin	72,759,085	80,843,428	83,200,000	2,356,572
Orhaneli Basin	34,281,880	38,090,978	99,401,000	61,310,022
Seyitömer Basin	75,680,913	84,089,903	152,509,000	68,419,097
Soma Basin	258,921,181	369,887,401	666,083,000	296,195,599
Tunçbilek-Tavşanlı Basin	23,443,775	36,067,346	283,017,000	246,949,654
Milas and Yatağan Basin	287,310,123	319,233,469	438,495,000	119,261,531
Total	**1,821,949,346**	**2,132,376,498**	**3,721,249,488**	**1,588,872,990**

It can be seen easily that there would be still remaining reserves to be allocated for power plants except Kangal Basin. Reserves within the Kangal Basin would be almost exhausted at the end of plant life which is envisaged as 14 years.

The final step is allocation of the remaining reserves for new units. But, it is assumed that surface mining will be mostly replaced by underground mining at the end of plants lifes in Soma and Tunçbilek regions.

40 years of plant life is considered except Çan Basin where 30 years of a new unit is proposed.

The results of the new forcast study and proposals are presented in the following Table 1.13. In this table total cumulative fuel consumption includes, both thermic and ather consumptions together with mining losses.

Table 1.13 Proposed New Units

Public Coal Fields	**Installed Capacity (MW)**	**Generation (kWh)**		**Fuel Consumption (tons)**		**Total Cumulative Reserves Explored (tons)**	**Reserves at the beginning of Projections (tons)**	**Reserves at the end of Plant Life (tons)**
		Thermic Annual	**Thermic Cumulative**	**Thermic Annual**	**Total Cumulative**			
Zonguldak Basin	360	2,340,000	93,600,000	1,924,826	128,321,722	183,316,745	463,644,560	280,327,815
Elbistan Basin (Sector A and B)	460	2,990,000	119,600,000	6,408,588	284,826,139	316,473,488	319,400,504	2,927,017
Çan Basin	55	357,500	10,725,000	282,897	9,429,892	10,477,658	11,335,450	857,792
Orhaneli Basin	180	1,170,000	46,800,000	1,232,641	54,784,023	60,871,137	61,310,022	438,886
Seyitömer Basin	140	910,000	36,400,000	1,367,359	60,771,512	67,523,902	68,419,097	895,195
Soma Basin	140	910,000	36,400,000	1,336,920	76,395,413	117,531,404	296,195,599	178,664,195
Tunçbilek-Tavşanlı Basin	160	1,040,000	41,600,000	895,051	89,505,087	149,175,146	246,949,654	97,774,509
Milas and Yatağan Basin	210	1,365,000	54,600,000	1,876,767	83,411,877	119,159,824	119,261,531	101,706
Total	**1705**	**11,082,500**	**439,725,000**	**15,325,048**	**787,445,665**	**1,024,529,304**	**1,588,872,990**	**564,343,685**

The study shows that coal reserves in the Kangal Basin would be exploited totally after 14 years. However, first two units are almost 20 years old and the third one is 10 years old. This means that the units can work more than the reserve life. The fuel to be needed for the power plants have to be planned before exhausting the reserves.

The best way of forecasting Soma and Tunçbilek Basins is forming a detailed district plan and requires carrefully management of mining and well established coordination with power plant

Kışlaköy and Çöllolar Sections of Elbistan Basin have also large reserves being able to feed a power plant having a capacity of 460 MW for about 40 years. In reality, the borders of the sections have to be drawn accordingly with new founded reserves.

High amount of coal will also remain in Milas-Yatağan Basin. Since underground mining would be applied in the region, only a unit having 210 MW is considered.

New units of 180 MW and 55 MW are also forecasted for Seyitömer and Çan regions. The new unit proposed for Seyitömer can be higher when taking into account the two old units of Seyitömer

Elbistan, Çan, Orhaneli and Kangal regions the new units can be constructed before end of plant life, since it would be easier to increase production in open pit mines.

For the others a well designed district plans have to be applied in order to use reserves efficiently, especiaaly in forcasting new units.

CHAPTER 2

WORLD OUTLOOK

2.1 Production

The world total primary energy production increased slightly from 8.8 btoe (billion tons of oil equivalent) to 11.9 btoe with an average growth rate of 1.81% between 1990 and 2007. The relatively high growth rate in the last five years was replaced by a lower rate in 2007 mostly due to the recession the world faced with. The increase by 1.68% between 2006 and 2007 was mostly driven by coal and in 2007 the increase in Chinese coal production alone (+6%) contributed to almost 40% of the growth in the world total energy production (IEA 2009_a, p.1.55).

Table 2.1 World Gross Production (mtoe)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-2007	1990-2007
Coal and coal products	2,217	2,217	2,220	2,918	3,076	3,206	2.2	2.2
Peat	7	6	4	4	5	3	-4.4	-5.3
Oil	3,229	3,371	3,686	4,001	4,011	4,001	1.2	1.3
Natural gas	1,694	1,818	2,074	2,366	2,437	2,498	2.8	2.3
Nuclear	526	608	676	722	728	709	9.0	1.8
Hydro	184	213	225	251	261	265	2.6	2.1
Geothermal	34	37	47	46	47	49	6.9	2.2
Solar/wind/other	2	3	8	16	20	25	18.7	14.8
Combustible renewables	904	971	1,029	1,121	1,146	1,175	1.7	1.6
Heat	0,1	0,4	1	10	10	9		30.3
Total	**8,797**	**9,246**	**9,969**	**11,456**	**11,742**	**11,940**	**2.0**	**1.8**
Growth Rate (%)	**1.81**	**2.33**	**2.46**	**3.23**	**2.50**	**1.68**		

Source IEA 2009

OECD (Organization for Economic Co-operation and Development) countries were accounted for 32% of the global production. After the first oil shock in 1973, a special effort was made by most of the OECD countries to reduce their dependence on imported oil by various policies, including the development of alternative sources of energy, and for some of them, by exploiting their oil reserves. Within 15 years, the launch of large nuclear programmes in several countries and the exploitation of new open-sky mines in North America led to a dramatic increase of nuclear and coal production. In 1971, nuclear represented 27 mtoe whereas in 1990 it accounted for 450 mtoe. Similarly coal went up from 812 mtoe in 1971 to 1,061 mtoe in 1990. These increases, combined with the increase in oil production (especially in the Gulf of Mexico, Norway and the United Kingdom) from 686 to 922 mtoe, explain the relatively high growth in energy production observed in the first half of the 37-year period (IEA 2009$_b$, p.xi-xii).

As it can be seen from the Figure 2.1, general overview has not much changed since 1990. During the period fossil fuels have constituted about 80% of total production, having almost flat shares. A slight decrease in share of oil has been compensated by hard coal and natural gas.

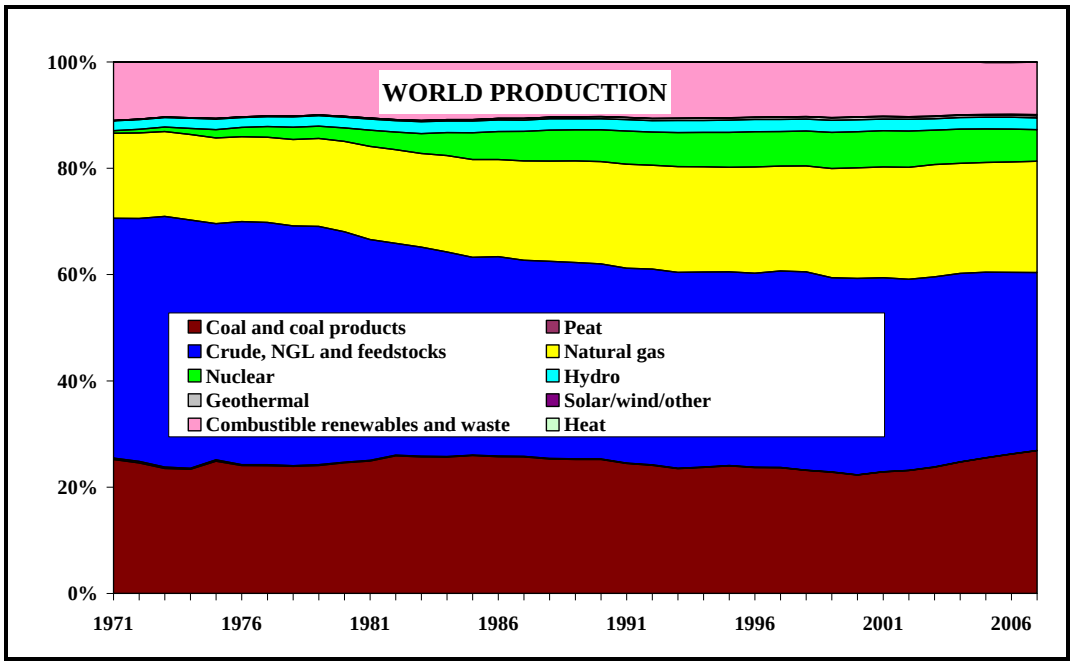

Figure 2.1 Share of Fuels in World Gross Production (IEA 2009)

Among non-fossil sources, nuclear decreased by 3% while hydro increased by 2% between 2006 and 2007. With a 3% increase, combustible renewables kept their 10% share in global production, but other renewable sources, despite representing just 1% of the total production, registered the most pronounced growth rates. In 2007, wind generation increased by 32%, solar thermal generation by 15% and solar photovoltaic by 48% (IEA 2009_a, p.1.55).

In 2007, decrease in production in Japan and United Kingdom by 11% and 6% orderly was compensated by increase by 5% and 1% in production in Australia and United States, keeping production of OECD countries almost flat. China and United States together produced almost 60% of the world total in 2007 although Saudi Arabia is prominent in the global production of oil and Russian Federation in the production of natural gas (IEA 2009_a, p.1.56).

2.2 Total Primary Energy Consumption

Total primary energy consumption (TPES), or in other words gross consumption – defined as production + imports – exports - international bunkers ± stock changes- increased more than twice with an average growth rate of 2.12 between 1970 and 2007.

Table 2.2 Growth Rates of Gross Consumption by Fuel Type (%)

	1971-2007	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2007**	**1990-2007**
Coal and coal products	2.17	2.20	2.17	*0.32*	4.82	2.15
Peat	1.41	2.46	0.36	*1.28*	1.62	1.42
Oil	2.84	3.26	3.08	*2.24*	2.75	2.45
Petroleum products	9.03	20.47	10.92	*2.54*	0.69	1.78
Natural gas	2.57	3.60	2.24	*2.03*	2.33	2.15
Nuclear	1.90	1.97	2.13	*1.45*	2.14	1.73
TPES	2.12	2.71	1.94	*1.35*	2.65	1.88

Source IEA 2009

Oil reduced in share from 44% to 37% in 1990 and 35% in 2007. In contrast, natural gas continuously increased from 16% to 19% and then 21% in the same period. Coal, hydro and renewables (including net electricity) have kept their shares at constant

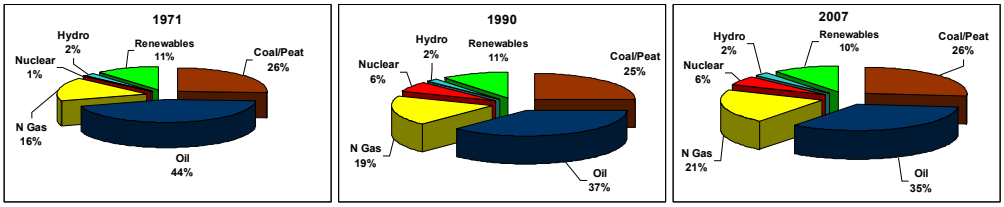

Figure 2.2 TPES by Fuel Type (IEA 2009)

The share of OECD decreased from 60% to 45%, in contrast Asia more than doubled its share from 13% to 28%. United States is leading country representing more than 40% of the OECD total and the increase in Asia is led by China. The other striking region is the Middle East with more then five times increase in share. Latin America and Africa has also showed gradual increases in shares.

Table 2.3 TPES- Top Ten Countries in 2007

Country	**TPES (mtoe)**	**Share in World TPES**
United States	2,340	19
People Of Rep. of China	1,956	16
Russian Federation	672	6
India	595	5
Japan	514	4
Germany	331	3
Canada	269	2
France	264	2
Brazil	236	2
Korea	222	2
Rest of the world	4,630	39
World Total	**12,029**	**100**

Source IEA 2009

In 2007, the top-five countries (Table 2.3) produced together half of the global GDP (in purchasing power parity), consumed 51% of total world energy and accounted for 46% of the total population (IEA 2009_a, p. 1.57).

2.3 Total Final Energy Consumption

The term final consumption (equal to the sum of the consumption in the end-use sectors) implies that energy used for transformation and for own use of the energy producing industries is excluded. Final consumption reflects for the most part deliveries to consumers (IEA 2009c, p.1.6).

Between 1990 and 2007, the World Total Final Consumption (TFC) increased with an average growth rate of 1.63% from 6.3 btoe to 8.3 btoe. Actually, the growth rate of last decade was about 45% higher than that of the previous one, since the first half of the 90s, consumption was almost steady. Asian Pacific region, especially China and India have played an important role in this consumption.

Table 2.4 World Total Final Consumption by Fuel Type (mtoe)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-2007	1990-2007
Coal and coal products	759	669	532	665	699	728	0.43	-0.24
Peat	3	1	1	1	1	1	-0.78	-8.95
Crude, NGL and	7	7	10	11	11	14	-0.36	4.53
Petroleum products	2,600	2,792	3,097	3,420	3,469	3,518	1.57	1.79
Natural gas	957	1,010	1,132	1,225	1,245	1,296	2.09	1.80
Geothermal	2	3	3	4	4	4	7.01	3.56
Solar/wind/other	2	2	5	7	8	9		9.63
Combustible renewables	797	853	924	986	1,008	1,029	1.49	1.51
Electricity	833	932	1,087	1,293	1,348	1,414	3.64	3.16
Heat	333	286	246	268	277	273	3.82	-1.16
Total	**6,293**	**6,555**	**7,037**	**7,878**	**8,068**	**8,286**	**1.82**	**1.63**
Growth Rate (%)	**1.96**	**2.37**	**2.17**	**2.21**	**2.42**	**2.70**		

Source IEA 2009

Oil always remains dominant in TFC although a slight decrease from 47% to 43% in its share has been observed between 1971 and 2007. Even though efforts have been made to reduce the use of oil in sectors where it can be substituted by other fuels, e.g. electricity production, the growing demand in "captive" sectors such as transport explains why the share of oil remains the highest amongst all energy sources (IEA 2009_b, p.xvi).

With an annual average growth rate of 1.8%, similar to that of TPES, natural gas protected its share around 15% in the same period. The increase in renewables has been mostly driven by solid biomass including wood, wood wastes and other solid wastes. Consumption of electricity has grown about two times more rapidly than that of TFC.

The adverse effects of the atmospheric GHGs (greenhouse gases) having been lived in last quarter of the previous century and global warming concerns have forced the world to search alternative sources, particularly renewables at the end of 80s. Together with the world efforts towards use of more renewables, especially after 90s, consumption of geothermal, solar and wind energy has accelerated much more rapidly, but their shares are still very small.

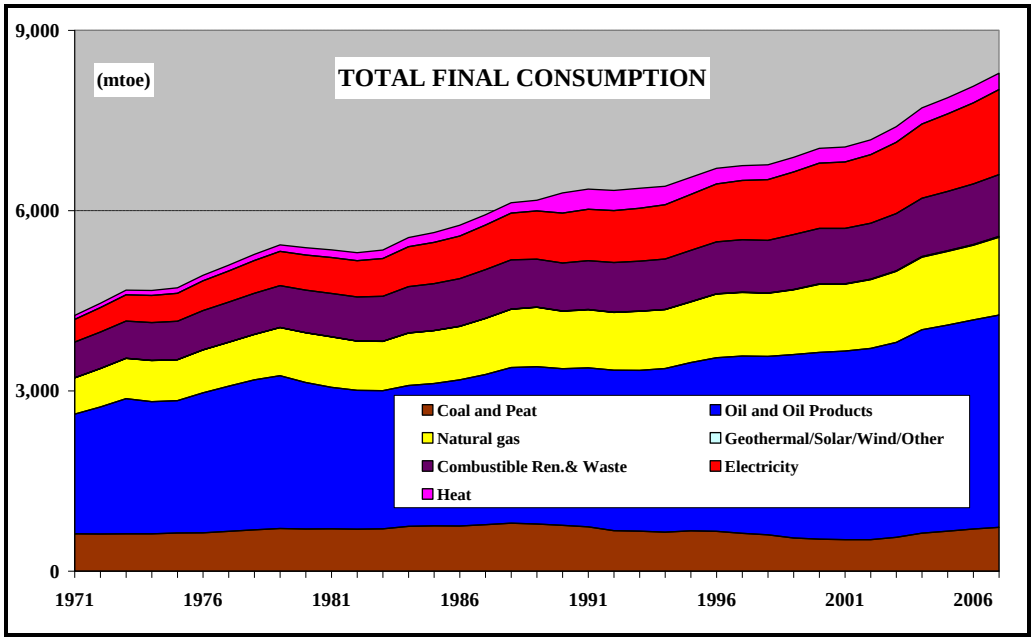

Figure 2.3 Share of Fuels in TFC (IEA 2009)

Since 1990, the share of consumption by industry sector in total has decreased gradually from 29% to 27% while that of transport sector rose from 25% to 28% replacing industry sector at top. In 70's, their shares were 33% and 23% respectively. The average growth rate of consumption in transport sector, a captive sector, was higher than that of the others. Despite the share consumption in residential sector showed a few percent increase in 90s, it dropped down to 1990 level of 25% in 2007 (Table 2.5).

Table 2.5 Sectoral Breakdown of World TFC (ttoe)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-2007	1990-2007
Industry sector	1,800	1,790	1,870	2,098	2,184	2,275	1.31	1.39
Transport sector	1,578	1,728	1,939	2,175	2,230	2,297	2.37	2.23
Residential	1,973	2,221	2,360	2,558	2,573	2,600	1.76	1.64
Agriculture/forestry	163	170	163	181	184	186	1.27	0.77
Non-energy use	779	647	706	867	898	929	2.28	1.04
TFC	6,293	6,555	7,037	7,878	8,068	8,286	1.82	1.63
Growth Rate (%)	**1.96**	**2.37**	**2.17**	**2.21**	**2.42**	**2.70**		

Source IEA 2009

Coal, oil, natural gas and electricity are main components of consumption in industry sector while iron-steel, chemical and petrochemical and non metallic mineral sectors are main consumers of those fuels. Consumption of transport sector is mostly driven by gasoline and diesel oil.

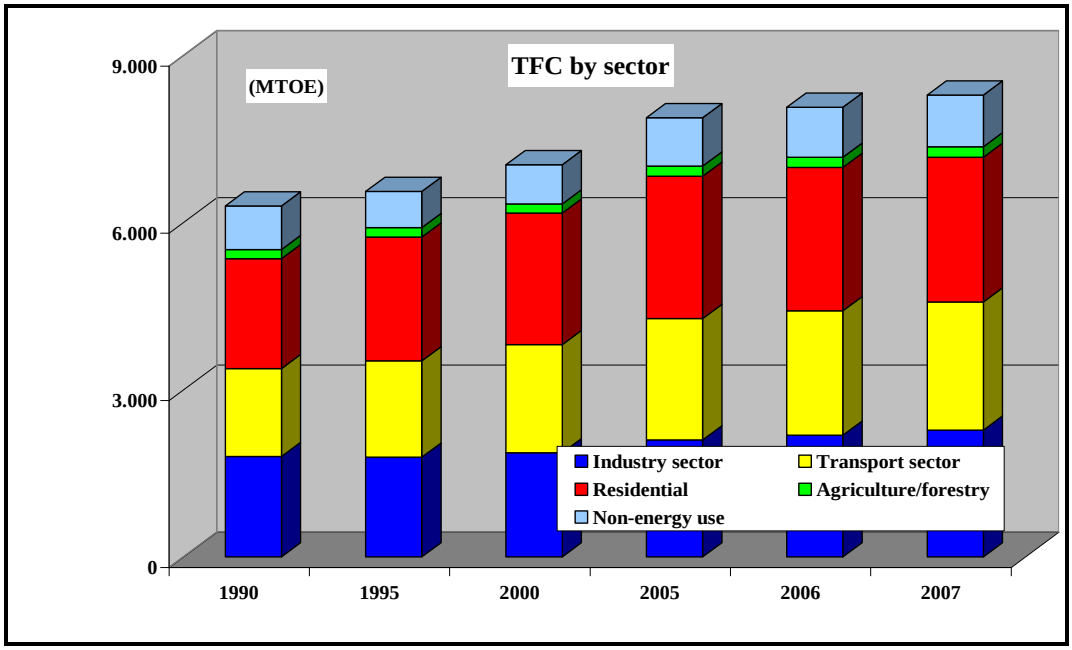

Figure 2.4 Sectoral Breakdown of World TFC (IEA 2009)

The following table summarizes world energy balance from production to final consumption by sectors.

Table 2.6 World Energy Balance (mtoe)

	1990	1995	2000	2005	2006	2007	Growth Rate	
							1971-2007	1990-2007
Production	8,797	9,246	9,969	11,456	11,742	11,940	2.0	1.8
Import	3,027	3,139	3,783	4,484	4,623	4,729	2.7	2.7
Export	-3,026	-3,164	-3,799	-4,494	-4,584	-4,645	2.5	2.6
TPES	8,762	9,227	10,019	11,425	11,720	12,029	2.1	1.9
TFC	6,293	6,555	7,037	7,878	8,068	8,286	1.8	1.6
Industry sector	1,800	1,790	1,870	2,098	2,184	2,275	1.3	1.4
Transport sector	1,578	1,728	1,939	2,175	2,230	2,297	2.4	2.2
Residential	1,973	2,221	2,360	2,558	2,573	2,600	1.8	1.6
Agriculture/forestry	163	170	163	181	184	186	1.3	0.8
Non-energy use	779	647	706	867	898	929	2.3	1.0

Source IEA 2009

2.4 Electricity

Electricity is driving force of industry. Its consumption is an indicator of development.

Table 2.6 summarizes world electricity balance. Between 1971 and 2007, world gross electricity production rose from 5,256 TWh to 19,855 TWh with an average annual growth rate of 3.08%. The annual average growth rate was higher than the previous decade (2.68% between 1990 and 2000 vs. 3,64% between 2000 and 2007).

Table 2.7 World Electricity Balance (TWh)

	1990	1995	2000	2005	2006	2007	Growth Rate	
							1971-2007	1990-2007
Gross Production	11,86	13,28	15,45	18,31	19,02	19,85	3.66	3.08
Distribution Losses	1,006	1,136	1,367	1,603	1,628	1,667	3.75	3.02
Total Consumption	9,690	10,84	12,64	15,03	15,67	16,44	3.64	3.16
Total Industry	4,411	4,644	5,294	6,183	6,525	6,940	2.95	2.70
Total Transport	244	213	219	258	261	270	2.39	0.59
Residential	4,545	5,454	6,574	7,772	8,025	8,305	4.49	3.61
Agriculture/ Forestry/ Fishery	351	372	350	386	410	426	3.66	1.14
Other	139	157	203	438	454	505	3.36	7.87
Production Growth Rate (%)	2.32	3.47	4.73	4.46	3.87	4.39		

Source:IEA 2009

The share of OECD countries was more than 70% in 70s, but realized as 54% in 2007, pointing out higher average growth rate in Non-OECD countries. Actually, according to IEA (International Energy Agency) statistics, the average annual growth rate of Non-OECD countries is 1.96 time higher than that of OECD countries in the last 34 years (5.1% vs. 2.6%).

Fossil fuel fired power plants were dominant in generation with a share of 67.8%, followed by hydro (15.9%), nuclear (13.7%) combustible renewable and waste (1.3%) and others power plants including geothermal solar and wind. In OECD countries, fossil fuel, nuclear and hydro plants generated 61,8%, 21.2% and 12,7% of gross electricity production orderly whereas fossil fuels plants, hydro and nuclear fired plants accounted for 74.1%, 20.1% and 4.9% of total Non-OECD respectively.

Total final electricity consumption increased from 4,380 TWh to 9,690 TWh in 1990 and 16,446 TWh in 2007 with an average annual growth rate of 3.64%. It was 2.69% between 1990 and 2000 and 3.83% between 2000 and 2007, mostly resulting from fast development of Asian countries, especially China and India.

Industry was replaced by residential sector having the highest share in 2007. About 54% of share in 1971 dropped down to first 45.5% in 1990 then 42.2% in 2007. In contrast, that of residential sector increased from 37.3 % to 46.9% and 50.5% respectively that was in line with welfare of the North. Increasing welfare made people desire more comfort in their house and resulted in more use of electrical appliances in houses that means naturally more use of electricity.

2.5 Coal

2.5.1 Production

World coal production and use is broadly grouped by the two main coal types – hard coal and brown coal. Hard coal with a higher thermal value (varying from coal to coal and depending on the degree of preparation) is economically suited to international trade, with characteristics making some coals suitable for metallurgical (coking) uses. Brown coal (lignite) has a much lower thermal value (the amount depending on the coal type and its water content) and is suitable largely for power generation locally or to a lesser extent for briquette manufacture. World hard coal production continued to show strong growth in 2008 despite the 4th quarter slowdown due to the global economic downturn. In fact it showed

stronger growth than the previous three years in a period encompassing seven years of record growth (IEA 2009_d, p.1.5).

Total world coal production about doubled in the last 37 years and reached 6,397.5 mtons in 2007 with an annual average growth rate of 2.14%. Production decreased slightly between 1990 and 2000 and but gained acceleration after 2001. The average annual growth rate was 5.1% between 200 and 2007 in contrast to -0.36% in the previous decade.

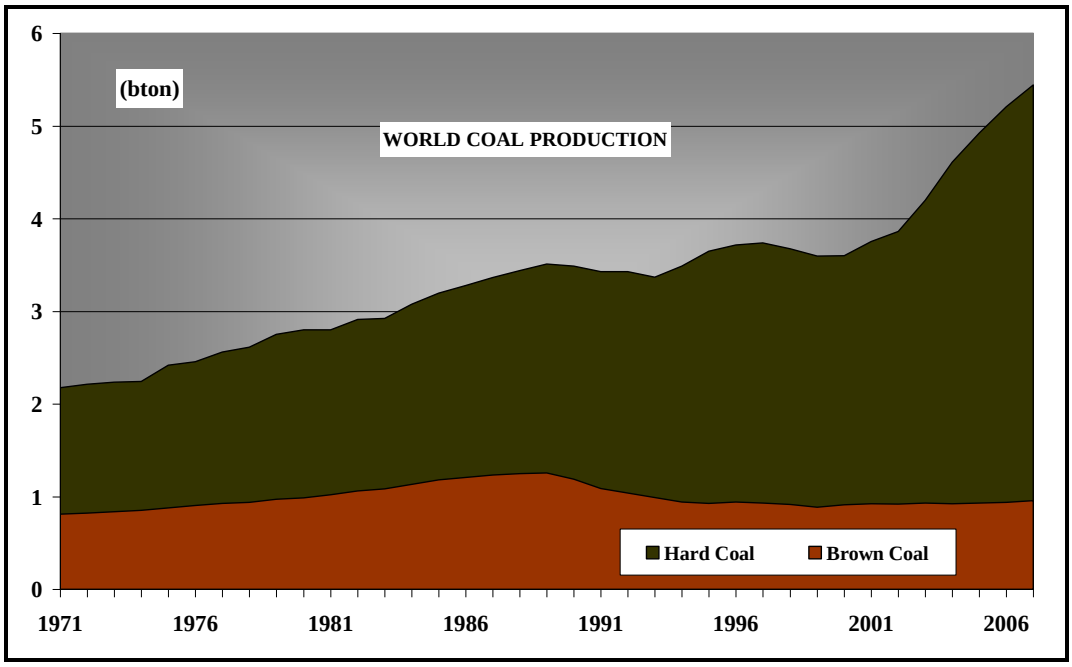

Figure 2.5 Global Coal Production

As shown in Figure 2.5, global production was mostly driven by hard coal which increased to 5,442 mtons in 2007 from 2,174 mtons in 1971. The average annual growth rate was about 6.0% in the last 7 years, compared with 0.3% in the previous decade. The production was driven by mostly Non-OECD countries. In 1973, the OECD accounted for about 50% of the world hard coal production. While OECD's production increased throughout the 70s and 80s, its share of world production declined to about 40% by 1990 and by 2008 was only about 26% (Table 2.8).

Table 2.8 Major Hard Coal Producers (mtons)

Production	1990	1995	2000	2005	2006	2007	2008	Growth Rate (%)			
								1990-2000	2000-2008	1990-2007	2007-1971
China	1,006	1,293	1,179	2,067	2,219	2,353	2,653	1.60	10.67	5.53	5.30
United States	854	859	894	950	978	968	993	0.46	1.32	0.84	1.87
India	205	262	305	399	422	448	483	4.03	5.93	4.87	5.33
Australia	159	191	239	300	300	324	325	4.21	3.91	4.07	5.55
Russia	238	162	153	209	210	218	247	-4.33	6.21	0.22	
Indonesia	7	36	63	144	196	230	246	24.87	18.62	22.05	21.24
South Africa	175	206	224	245	245	248	236	2.52	0.63	1.68	3.83
Kazakhstan	128	81	75	83	92	94	104	-5.22	4.24	-1.12	
Poland	147	136	102	97	94	87	84	-3.60	-2.47	-3.10	-1.48
Colombia	21	26	38	59	66	70	79	5.99	9.43	7.50	9.50
Ukraine	143	74	62	60	61	59	59	-8.11	-0.46	-4.79	
Vietnam	5	8	12	32	39	43	40	9.61	16.70	12.71	7.26
Canada	38	39	34	29	30	33	33	-1.08	-0.23	-0.70	3.38
Korea, DPR	36	24	23	27	27	24	29	-4.51	3.02	-1.23	0.65
Germany	77	59	37	28	24	24	19	-6.92	-8.02	-7.41	-4.80
Other								-6.46	-2.12	-4.56	-5.89
World	**3,435**	**3,587**	**3,540**	**4,812**	**5,087**	**5,306**	**5,715**	**0.30**	**6.17**	**2.87**	**2.65**
OECD Total	1,443	1,393	1,385	1,462	1,484	1,495	1,510	-0.41	1.09	0.25	0.83
OECD N. America	898	907	939	990	1,019	1,013	1,038	0.45	1.25	0.80	1.92
OECD Pacific	186	206	250	308	308	331	333	3.00	3.63	3.28	3.52
OECD Europe	359	280	196	165	157	150	140	-5.88	-4.13	-5.11	-3.42
Non-OECD Total	1.991	2.194	2.155	3.350	3.603	3.812	4.205	0.79	8.72	4.24	3.79

The largest OECD coal-producing region is OECD North America, with 69% of the OECD production. Nearly 22% of the OECD production is in the Pacific region and the remaining 9% is in the OECD-Europe region.

Over 99% of the non-OECD coal production is accounted for by ten producing countries. Among the non-OECD countries, China accounts for over 47% of world hard coal production and nearly 64% of non-OECD production. India is the second largest non-OECD hard coal producer and third in the world. South Africa accounts for 97% of Africa's hard coal production, which represents 4% of world production. Russia is by far the largest producer among FSU countries. Its production combined with Kazakhstan and Ukraine represents over 99% of total production from transition economies. Indonesia produces over 70% of the hard coal mined in South-East Asia annually and it remains the sixth largest hard coal producer in 2008. Indonesia is also the second largest coal exporter worldwide behind Australia and the largest exporter of steam coal since 2005. Australia. Kazakhstan is the second ranking among the Former Soviet Union Countries in terms of production (IEA 2009_d, p.1.6-1.7).

Brown coal production showed a slight rise in the last 37 years. With an annual average growth rate of 0.65% in the last seven years, only reached to 1994 levels after a sharp decrease in the previous decade.

Table 2.9 Major Brown Coal Producers (mtons)

	1990	1995	2000	2005	2006	2007	2008	Growth Rate (%)			
								1990-2000	2000-2008	1990-2007	2007-1971
Germany	357,5	192,8	167,7	177,9	176,3	180,4	175,3	-7.29	0.56	-3.88	-1.96
Russia	134,4	83,3	87,8	73,7	74,1	71,1	76,0	-4.17	-1.78	-3.11	
Turkey	**44,7**	**52,8**	**60,9**	**56,2**	**61,9**	**72,9**	**73,1**	**3.14**	**2.32**	**2.77**	**8.02**
Australia	46,0	50,8	67,3	67,2	67,7	65,6	72,4	3.88	0.92	2.55	3.13
United States	79,9	78,5	77,6	76,2	76,4	71,3	68,7	-0.29	-1.52	-0.84	6.02
Greece	51,9	57,7	63,9	69,4	64,8	66,3	65,7	2.10	0.35	1.32	4.94
Poland	67,6	63,5	59,5	61,6	60,8	57,5	59,6	-1.27	0.02	-0.70	1.49
Czech Republic	87,0	63,5	57,0	54,9	55,2	55,0	52,7	-4.13	-0.99	-2.75	-1.08
Indonesia	3,7	5,6	13,8	27,1	30,7	34,5	38,0	14.17	13.48	13.86	
Serbia	45,8	40,5	37,0	35,1	36,8	37,1	37,4	-2.11	0.15	-1.11	
Canada	30,7	36,4	35,4	36,3	36,1	35,6	34,9	1.44	-0.16	0.72	4.43
Romania	33,7	40,8	29,0	31,1	34,9	35,8	34,7	-1.50	2.28	0.16	2.52
India	14,1	22,1	24,2	30,2	31,3	34,0	32,2	5.59	3.63	4.71	6.01
Bulgaria	31,5	30,6	26,3	24,7	25,7	28,4	28,7	-1.79	1.11	-0.51	0.21
Thailand	12,4	18,4	17,7	20,9	19,0	18,2	17,6	3.61	-0.10	1.94	10.44
Other	148,6	88,8	88,4	87,6	88,3	91,8	84,3		-0.60	-3.10	-2.76
World	**1,189,4**	**926,2**	**913,5**	**930,0**	**940,1**	**955,7**	**951,4**	**-2.60**	**0.51**	**-1.23**	**0.43**
OECD Total	814,2	632,3	620,8	622,8	621,8	626,1	617,3	-2.68	-0.07	-1.53	0.20
OECD Europe	657,5	466,5	440,4	443,0	441,3	453,3	441,1	-3.93	0.02	-2.19	-0.52
OECD N. America	110,6	114,8	113,0	112,4	112,5	106,9	103,6	0.22	-1.08	-0.36	5.38
OECD Pacific	46,2	51,0	67,5	67,4	68,0	65,9	72,7	3.88	0.92	2.55	3.10
Non-OECD Total	375,1	293,8	292,7	307,1	318,3	329,6	334,1	-2.45	1.67	-0.64	0.92
Non-OECD Europe	145,1	125,8	111,8	111,5	118,7	123,1	120,1	-2.57	0.90	-1.04	1.42

In contrast to hard coal, with a 64.9% share OECD was dominant in brown coal production in 2008 and mostly concentrated in OECD Europe (71.5%). The global production showed a slight decline in 2008 when comparing in 2007. Of the eight countries in the region, Germany, Greece and Czech Republic recorded decrease in their productions while that in Turkey and Poland showed increase in 2008.

Russia is the largest Non-OECD brown coal producer followed by Serbia, Romania and Bulgaria (Table 2.9).

Ten countries- China, the United States, India, Japan, Russia, S. Africa, Germany, Korea, Poland and Australia- are accounted for 83% of global production and 84.4% of world total coal consumption (Table 2.10).

2.5.2 Consumption

Hard coal consumption covers coking coal and steam coal greater than 18,600 kJ/kg. Because of special coking qualities and their higher calorific value, and lower moisture and ash levels which minimise the transportation costs of the energy contained in these products, these coals comprise the vast majority of coal that moves in international trade, while brown coal is almost exclusively for domestic use.

The world hard coal consumption rose an estimated 7.4% in 2008 from 5,415.2 mtons to 5,814.1 mtons. The OECD consumption decreased by 1.8% from 1,734.9 mtons to 1,704.1 mtons, while the non-OECD consumption increased 11.7% from 3,680.3 mtons to 4,110.0 mtons.

Steam coal which comprises anthracite and other bituminous coal has three main end-uses:

- by far, most steam coal is an input in the power sector to produce electricity and heat (which is then sold to third parties, mostly as district heat);
- as a fuel in the final consumption sectors for the production of heat and/or steam (i.e. in the industry, residential, commercial and public services, agriculture and transport sectors);

Table 2.10 Total World Coal Consumption (mtce*)

	2006	2007	2008e	Growth Rate (%)	
				2006-2007	2007-2008
OECD Countries					
United States	783.4	790.7	788.1	0.93	-0.33
Japan	156.2	162.8	161.5	4.23	-0.80
Germany	114.7	119.8	114.0	4.45	-4.84
Korea	75.3	79.9	91.2	6.11	14.14
Poland	87.5	86.0	84.8	-1.71	-1.40
Australia	80.3	78.7	81.3	-1.99	3.30
United Kingdom	58.0	54.5	49.7	-6.03	-8.81
Turkey	37.3	41.5	39.1	11.26	-5.78
Canada	40.0	42.3	36.4	5.75	-13.95
Czech Republic	30.1	30.2	29.3	0.33	-2.98
Italy	23.4	23.7	24.1	1.28	1.69
Spain	26.5	29.4	20.2	10.94	-31.29
France	17.9	18.8	18.1	5.03	-3.72
Greece	12.0	15.4	15.0	28.33	-2.60
Netherlands	11.5	12.0	11.1	4.35	-7.50
Mexico	12.2	12.0	11.4	-1.64	-5.00
Denmark	7.8	6.6	5.9	-15.38	-10.61
Slovak Republic	6.1	5.8	5.8	-4.92	0.00
Belgium	6.8	6.2	5.4	-8.82	-12.90
Other OECD,	30.3	28.3	24.7	-6.60	-12.72
Non-OECD Countries					
PR of China	1740.3	1855.3	2098.6	6.61	13.11
India	313.8	342.4	377.1	9.11	10.13
Russia	153.7	148.7	177.5	-3.25	19.37
South Africa	133.7	138.7	133.2	3.74	-3.97
Chinese Taipei	56.6	59.2	61.9	4.59	4.56
Indonesia	41.7	52.5	58.2	25.90	10.86
Ukraine	56.6	56.8	54.2	0.35	-4.58
Kazakhstan	43.5	43.4	51.2	-0.23	17.97
DPR of Korea	26.7	21.7	28.5	-18.73	31.34
Brazil	16.9	18.0	20.8	6.51	15.56
Thailand	17.8	20.2	20.5	13.48	1.49
Vietnam	12.9	14.0	16.7	8.53	19.29
Malaysia	10.1	12.6	13.2	24.75	4.76
Romania	13.0	13.1	12.8	0.77	-2.29
Hong Kong (China)	10.0	10.8	11.9	8.00	10.19
Israel	11.7	12.0	11.8	2.56	-1.67
Bulgaria	9.8	10.9	11.1	11.22	1.83
Philippines	8.2	9.0	10.6	9.76	17.78
Serbia	10.3	10.4	10.2	0.97	-1.92
Other non-OECD	55.5	59.6	70.8	7.39	18.79
European Union	458.4	465.5	438.5	1.55	-5.80
Total IEA	1605.0	1632.5	1605.9	1.71	-1.63
Total OECD	**1617.3**	**1644.5**	**1615.4**	**1.68**	**-1.77**
Total non-OECD	**2742.8**	**2909.3**	**3248.1**	**6.07**	**11.65**
World	**4360.1**	**4553.8**	**4863.5**	**4.44**	**6.80**

* The term total coal refers to the sum of hard coal and brown coal after conversion to a common energy unit (tonne of coal equivalent - tce). The conversion is done by multiplying the calorific value of the coal in question by the total volume of hard coal and brown coal used, measured in physical units, i.e. in tonnes. The energy content of one tonne of coal equivalent is 29.3 Gigajoules (GJ) or 7000 kcal and corresponds to 0.7 tonnes of oil equivalent (toe). (IEA 2009_d, p.1.12)

- small amounts are being used as PCI coal (pulverised coal injection) in blast furnaces and as well as for blending with coking coal.

World steam coal consumption was up 7.0% in 2008, from 4,671.0 mtons to 5,000.3 mtons. Steam coal consumption in the OECD countries decreased by 1.8% in 2008, from 1,536.6 mtons to 1,509.1 mtons. Viewed on a regional basis, steam coal consumption decreased by 1.1% in OECD-North America, a whopping 9.8% in OECD-Europe, and increased by 4.7% in OECD Pacific, led by Korea. Non-OECD steam coal consumption was up sharply by 11.4% from 3,134.4 mtons to 3,491.2 mtons. Steam coal consumption increased in almost all of the major consumer countries with the exception of South Africa which decreased 8.1 mtons or 4.5%. It was up 12.2% in China from 2,073.2 mtons to 2,326.6 mtons, it increased by 8.3% (or 37.6 mtons) in India from 454.1 mtons to 491.7 mtons, and it was up 26.4 mtons in Russia reaching levels not seen since 1994 (IEA 2009_d, p.1.13).

It should be noted that, of the gross coal consumption about 69% was consumed to produce electricity and heat in 2007 (about 65% of hard coal, mostly other bituminous coal, and more than 90% of brown coal). 11% of gross consumption was attributed to coke oven plants while the rest was consumed in the end use sectors (industry, transport, residential etc.).

The following Table 2.11 summarizes world coal balance. In this table, hard coal is the sum of coking coal, anthracite and other bituminous coal while brown coal represents the sum of sub-bituminous coal and lignite.

Table 2.11 World Coal Balance (mtons)

	1990	1995	2000	2005	2006	2007	Growth Rate (%)	
							1971-	1971-
Production	4,679	4,574	4,515	5,855	6,149	6,398	**2.14**	**1.86**
Hard Coal	3,489	3,647	3,601	4,925	5,209	5,442	2.58	2.65
Brown Coal	1,189	927	914	930	940	956	0.45	-1.28
Gross Inland Consumption	**4,670**	**4,579**	**4,635**	**5,827**	**6,111**	**6,375**	**2.13**	**1.85**
Hard Coal	3,461	3,646	3,705	4,886	5,168	5,415	2.58	.67
Brown Coal	1,209	934	930	941	943	960	0.44	-1.35
Electricity and Heat	2,720	2,931	3,284	3,968	4,213	4,384	3.55	2.85
Hard Coal	1,806	2,113	2,435	3,106	3,355	3,506	4.38	3.98
Brown Coal	914	818	849	861	859	878	1.59	-0.23
Coke Oven	508	519	464	624	683	734	1.02	2.19
Hard Coal	507	518	464	624	683	734	1.02	2.20
Brown Coal	0,2	0,2	0,1	0,2	0,2	0,2		-0.55
TFC	**1,151**	**1,011**	**742**	**903**	**918**	**947**	**0.06**	**-1.14**
Hard Coal	1,007	945	689	855	868	897	0.36	-0.68
Brown Coal	144	66	53	49	50	50	-2.79	-6.01
Industry	638	669	524	657	674	707	1.09	0.61
Hard Coal	564	631	490	625	642	674	1.52	1.06
Brown Coal	74	39	34	32	32	33	-2.71	-4.68
Residential	338	230	144	147	149	144	-2.03	-4.88
Hard Coal	289	212	132	135	137	131	-1.96	-4.52
Brown Coal	49	19	13	11	13	13	-2.70	-7.60
Transport	27	14	11	8	8	7	-6.14	-7.55
Hard Coal	26	13	11	8	7	7	-6.06	-7.64
Brown Coal	0,2	0,1	0,1	0,1	0,2	0,2	-8.33	0.00
Agriculture/Fishing	30	26	21	28	26	26	0.14	-0.76
Hard Coal	27	25	20	28	25	26	0.36	-0.38
Brown Coal	2	1	1	0	1	0	-4.70	-9.88
Non-Energy	37	26	19	37	36	38	5.47	0.06
Hard Coal	37	26	19	37	36	37	5.78	0.11
Brown Coal	1	0,2	1	0,3	0,2	0,4	-1.44	-3.71
Other	292	118	145	332	296	310	0.06	0.34
Hard Coal	141	68	117	301	262	279	2.35	4.08
Brown Coal	151	50	28	31	34	31	-4.80	-8.89

Source: IEA 2009

2.6 CO_2 Emissions

According to IEA statistics world global CO_2 (carbon dioxide) emissions were doubled with an annual average growth rate of 0.28% from 14 btons to 28 btons between 1971 and 2007. With an annual average growth rate of 3.10%, the second fastest after unallocated autoproducers, power and heat sector replaced the industry sector at the top after 80's. Although average annual growth rate of CO2 emissions arising from manufacturing industries and construction was about three times more in the last 6 years when comparing to that in the last 35 years (3.38% vs. 1.04%), its share decreased by 7% in the same period. The share of transport sector emissions increased slightly from 20% to 23%.

Table 2.12 World CO_2 Emissions by Sectors (mtons)

							Growth Rate (%)			
CO_2 Sectoral Approach	**1971**	**1990**	**1995**	**2000**	**2005**	**2006**	**1990 - 2000**	**2000 - 2006**	**1990 - 2006**	**1971 - 2006**
Main Activity Electricity and Heat Production	3,568	6,942	7,021	8,115	9,954	10,400	1.57	4.22	2.56	3.10
Unallocated Autoproducers	170	574	1,021	1,003	1,077	1,109	5.73	1.69	4.20	5.50
Other Energy Industries	760	1,012	1,115	1,203	1,304	1,338	1.74	1.79	1.76	1.63
Manufacturing Industries and Construction	3,815	4,535	4,512	4,487	5,230	5,477	-0.11	3.38	1.19	1.04
Transport	2,855	4,580	5,013	5,645	6,309	6,453	2.11	2.26	2.17	2.36
Other Sectors	2,927	3,344	3,147	3,056	3,271	3,226	-0.89	0.90	-0.22	0.28
Total	**14,095**	**20,988**	**21,829**	**23,509**	**27,146**	**28,003**	**1.14**	**2.96**	**1.82**	**1.98**

Source IEA 2009

In 1971, global CO_2 emissions coming from oil and oil products was 46% of total but it decreased by 10% in 35 years though it has still the highest share. This decrease was mostly compensated by coal and natural gas with 6% and 4% increase in their shares respectively.

Table 2.13 World CO_2 Emissions by Fuel Source (mtons)

							Growth Rate (%)			
CO_2 Sectoral Approach	**1971**	**1990**	**1995**	**2000**	**2005**	**2006**	**1990-2000**	**2000-2006**	**1990-2006**	**2006-1971**
Coal	4,047	6,954	7,302	7,638	9,215	9,743	0,94	4,14	2,13	2,54
Oil and Oil Prd.	6,531	8,366	8,627	9,338	10,130	10,211	1,11	1,50	1,25	1,28
N. Gas	2,059	3,812	4,113	4,716	5,335	5,445	2,15	2,42	2,25	2,82
Other	1,458	1,855	1,787	1,816	2,466	2,604	-0,21	6,19	2,14	1,67
Total	**14,095**	**20,988**	**21,829**	**23,509**	**27,146**	**28,003**	**1,14**	**2,96**	**1,82**	**1,98**

Source IEA 2009

As mentioned in the Section 2.5, about 69% of global coal consumption was by power sector in 2006 and 2007, holding 80% of coal sourced CO_2 emissions.

As for the emissions stemming from burned natural gas, 33% was attributed to electricity and heat production while 22% was from manufacturing industries and construction. Other sector also includes 25% of total natural gas emissions and mostly coming from space heating.

CHAPTER 3

TURKEY ENERGY OUTLOOK

3.1 Production and Consumption

Total primary energy production increased slightly with an average growth rate of 0.44% and reached 27.5 mtoe from 25.5 mtoe between 1990 and 2007. The average growth rate of 3.91% was the highest between 1980-1990 when comparing with the other decades. In contrast to other sources, share of lignite has increased continuously since 1970 and reached almost half of the total production in 2007. It was lowest in 2004 when the hydro was highest in the last decade.

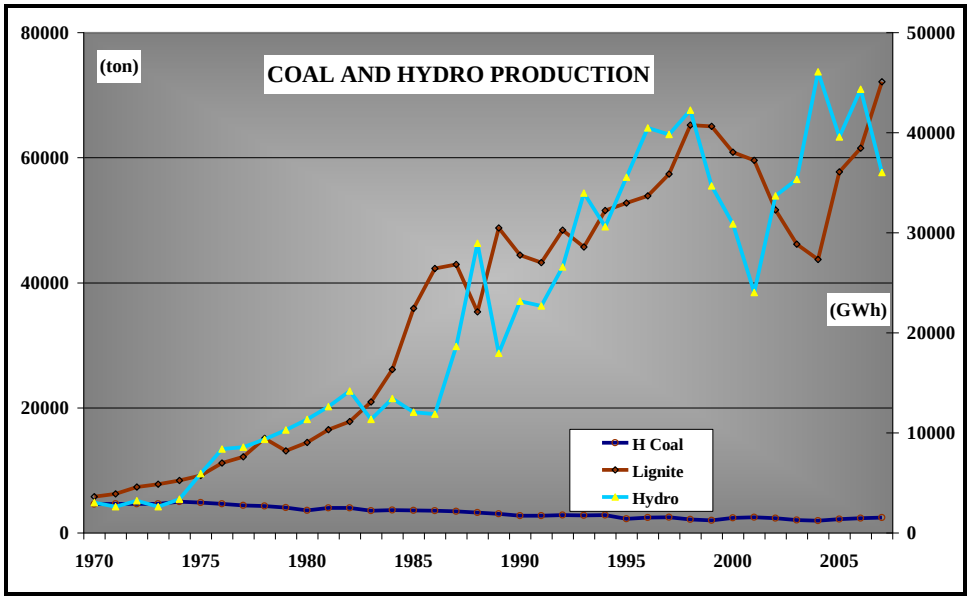

Figure 3.1 Coal vs. Hydro Production (MENR)

The decrease in production of hard coal especially gained acceleration after the end of 1980s when TTK (Turkish Hard Coal Enterprises) went to restructuring. It can be shown from Figure 3.1 that during the last decade the decrease in hydro resources has been compensated by lignite production. Drought season the country faced with in 2007 resulted in decrease in production from hydro sources significantly back to 2003 values.

Table 3.1 Total Primary Energy Production

		1990	**1995**	**2000**	**2005**	**2006**	**2007**
Hard Coal	(tton)	2,745	2,248	2,392	2,170	2,319	2,462
Lignite	(tton)	44,407	52,758	60,854	57,708	61,484	72,121
Asphaltite	(tton)	276	67	22	888	452	782
Oil	(tton)	17,870	18,374	16,938	13,819	13,411	12,932
Natural Gas	(10^6 m^3)	212	182	639	897	907	893
Hydro	(GWh)	23,148	35,541	30,879	39,561	44,338	36,007
Geoth. Electricity	(GWh)	80	86	76	94	0	0
Geoth. Heat	(ttoe)	364	437	648	926	898	914
Wind	(GWh)			33	59	127	355
Solar	(ttoe)	28	143	262	385	403	420
Wood	(tton)	8,030	6,765	5,981	5,127	4,984	4,850
Waste	(tton)	3,717	3,516	2,749	2,281	2,176	2,134
Biofuels	(tton)					2	14
Total	**(ttoe)**	**25,478**	**26,719**	**26,047**	**24,549**	**26,580**	**27,454**
Growth Rate	**(%)**	**-1.07**	**0.784**	**-5.83**	**0.89**	**8.27**	**3.29**

Sources: MENR

Total Primary Energy Consumption increased by twice with a considerably fast pace at 4.3% per year between 1990 and 2007. It was in the range of 5.41-4.24% between 1970 and 2007. Coal, oil, gas and hydro main sources. Table 3.1 shows that there is striking decrease in share of oil while a sharp increase in that of natural gas. There is also a fast decrease in share of wood and waste which is used for heating purposes in the residential sector, especially in the last decade.

The rapid penetration of natural gas in life of the country is main reason of the decrease as in oil. Although hard coal showed a rise in consumption during the last decade, it is mostly coming from import. In 2007, coal, oil and natural gas constituted about 90%of all consumption. The use of bio fuels in transportation sector was started in 2006.

Table 3.2 Total Primary Energy Consumption by Sources

		1990	**1995**	**2000**	**2005**	**2006**	**2007**
Hard Coal	(tton)	8,191	8,548	15,525	19,421	22,798	25,388
Lignite	(tton)	45,891	52,405	64,384	56,571	60,184	72,317
Asphaltite	(tton)	287	66	22	738	602	632
Oil	(tton)	22,700	27,918	31,072	31,062	31,395	32,143
Natural Gas	(10^6m^3)	3,418	6,937	15,086	27,171	31,187	36,682
Hydro &Geo. Elec.	(GWh))	23,228	35,627	30,954	39,655	44,338	36,007
Geothermal Heat	(ttoe)	364	437	648	926	898	914
Wind	(GWh)			33	59	127	355
Solar	(ttoe)	28	143	262	385	403	420
Wood	(tton)	17,870	18,374	16,938	13,819	13,411	12,932
Waste	(tton)	8,030	6,765	5,981	5,127	4,984	4,850
Biomass	(tton)					2	14
Net Electricity Import	(GWh)	-731	-696	3,354	-1,162	-1,663	-1,558
Coke, P Coke & Briq.	(tton)	459	1,025	2,184	2,604	2,417	2,358
TPES	**(ttoe)**	**52,987**	**63,679**	**80,500**	**91,074**	**99,642**	**107,627**
Growth Rate	**(%)**	**4.5**	**7.7**	**8.4**	**3.7**	**9.4**	**8.0**

Sources MENR

3.2 Total Final Energy Consumption

TPES minus own use and loses minus the energy consumed by conversion sectors such as refineries, coke ovens gives Total Final Consumption.

TFC increased from 41.6 mtoe in 1990 to 82.7 mtoe in 2007 with an average annual growth rate of 4.13% similar with that of TPES. The average growth rate is 4.4% between 1970 and 2007.

Table 3.3 presents TFC by fuel type while Figure 3.2 shows their shares. Although share of oil decreased slightly, it always protected its place at the top. As a consequence of energy policy on diversification of fuel mix, imported natural gas was introduced through the almost whole country and its share roared from 1.9% in 1990 to 19.1% in 2007. The rapid rise in share of electricity is also coming from rapid development of the country where electricity is driving force for the development. Privatization in industry and development of the country also resulted in rapid penetration of imported hard coal to the country.

Table 3.3 Total Final Consumption by Sources

		1990	**1995**	**2000**	**2005**	**2006**	**2007**
Hard Coal	(ttons)	2,747	3,040	9,244	9,904	12,536	14,849
Lignite	(ttons)	15,739	12,420	11,070	8,009	10,205	11,608
Asphaltite	(ttons)	285	66	18	738	602	632
Oil	(ttons)	19,380	24,193	24,751	26,333	27,215	28,411
Natural Gas	(ttons)	862	3,335	5,201	11,409	14,326	16,029
Electricity	(ttons)	45,670	65,724	96,140	129,416	142,216	154,102
Geothermal Heat	(ttoe)	364	437	2,564	3,153	1,856	1,946
Solar	(ttoe)	28	143	262	385	403	420
Wood	(ttons)	17,870	18,374	16,938	13,819	13,268	12,739
Dung	(ttons)	8,030	6,765	5,981	5,127	4,984	4,850
Coke, Pcoke and Briquet	(ttons)	3,644	4,158	5,111	5,716	5,784	5,755
TFC	**(ttoe)**	**41,611**	**49,976**	**61,556**	**71,510**	**77,440**	**82,748**
Growth Rate	**(%)**	**3.01**	**10.22**	**11.91**	**3.63**	**8.29**	**6.85**

Sources: MENR

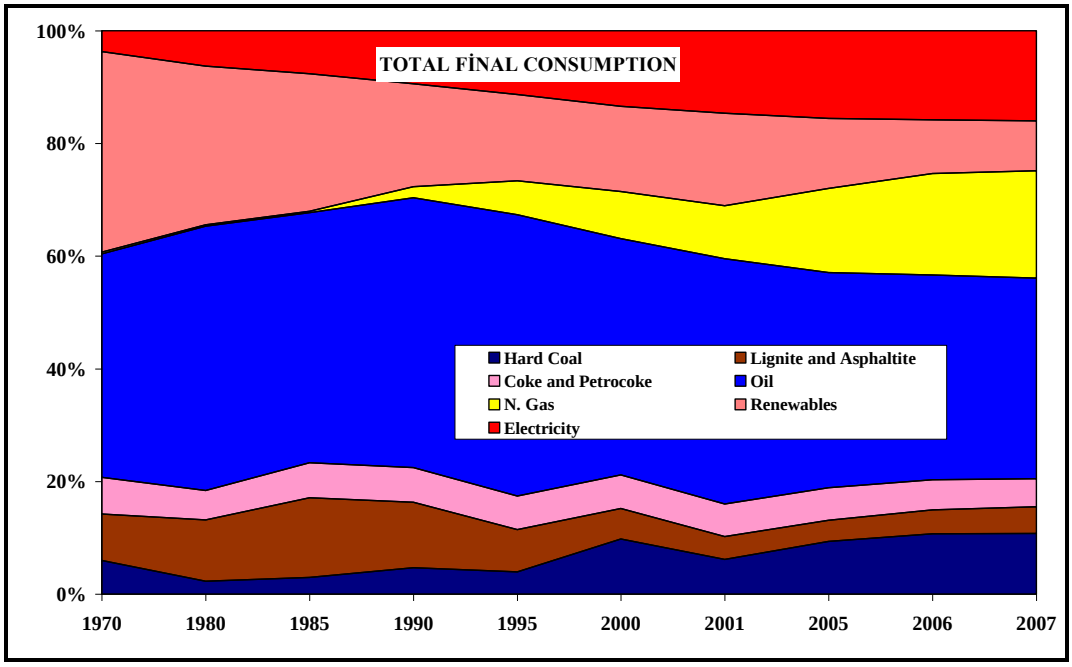

Figure 3.2 Shares of Fuels in Total Final Consumption (MENR)

Table 3.4 gives sectoral breakdown of TFC and their shares. Although residential sector had the highest share in 1990, it was replaced by industry sector in 2007. The other sectors have almost retained their shares. The table also shows that conversion sector including power plants , coke ovens and briquetting constitutes about 22% of total consumption.

Table 3.4 Sectoral breakdowns and shares in TFC (ttoe)

	1990	**(%)**	**1995**	**(%)**	**2000**	**(%)**	**2005**	**(%)**	**2006**	**(%)**	**2007**	**(%)**
Industry	14,543	35	17,372	35	24,501	40	28,084	39	30,996	40	32,466	39
Transport	8,723	21	11,066	22	12,008	20	13,849	19	14,994	19	17,284	21
Residential	15,358	37	17,596	35	20,058	33	22,923	32	23,677	31	24,623	30
Agriculture	1,956	5	2,556	5	3,073	5	3,359	5	3,610	5	3,945	5
Non Energy	1,031	2	1,386	3	1,915	3	3,296	5	4,163	5	4,430	5
TFC	**41,611**	**100**	**49,976**	**100**	**61,556**	**100**	**71,510**	**100**	**77,440**	**100**	**82,748**	**100**
Conversion	11,377	21	13,703	22	18,945	24	19,564	39	22,201	40	24,879	39
TPES	**52,987**	**100**	**63,679**	**35**	**80,500**	**40**	**91,074**	**19**	**99,642**	**19**	**107,627**	**21**

Sources: MENR

Energy consumption of household and services grew by 2.8% between 1990 and 2007. Since very fast increase in use of natural gas for heating purposes instead of other sources, its share reached 31.1% in 2007 when comparing with 0.4% in 1990. The shares of electricity also increased quickly from 9.3% to 26% within this period. Fast penetration of natural gas resulted in sharp decrease in use of wood and waste.

With a slight rise from 35% to 37% between 1990 and 2007, industry has the highest share in TFC in 2007. The significant decrease in share of oil has been compensated by natural gas and import coal.

Share of the transportation sector has remained around 22% in the period of 1990-2007. Total energy consumption of transportation sector realized as 17 mtoe in 2007.

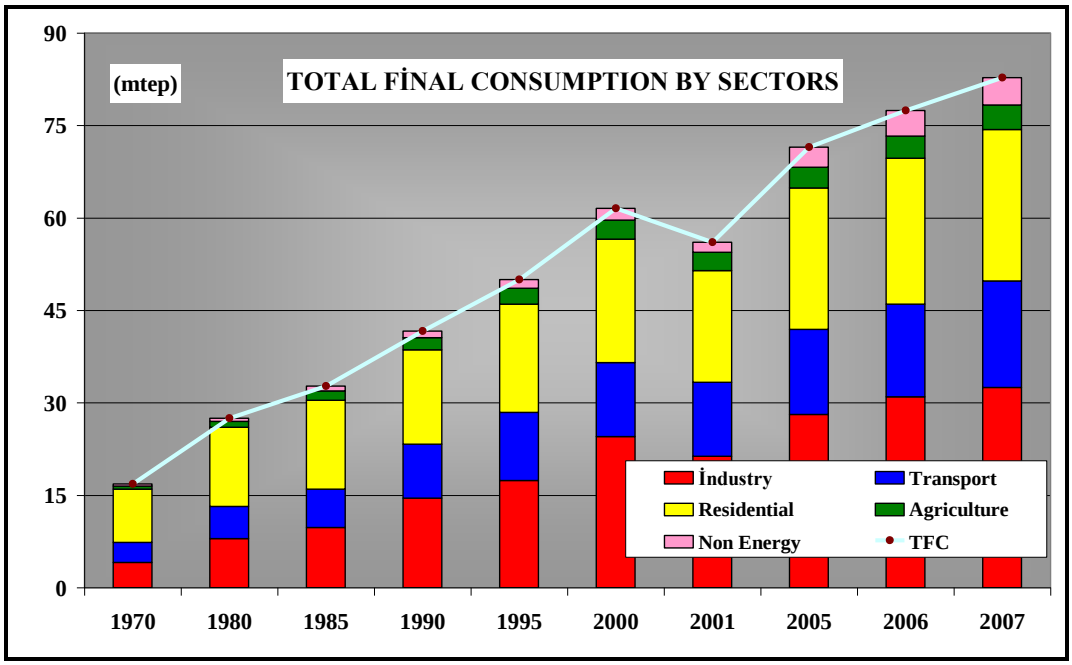

Figure 3.3 Energy Consumption by Sectors (MENR)

The following table summarizes energy development in Turkey between 1970 and 2007. Although the dynamics of each decades were not same during the period, it is clear that there has been a continuous increase in demand for energy which means that the country has becoming more and more energy dependent.

Table 3.5 Summary of Growth Rates Between 1970-2007

	1970-2007	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2007**	**1990-2007**
Indigenous Production	1.74	1.80	3.91	0.22	0.75	0.44
Import	8.26	12.47	7.49	6.18	6.51	6.31
TPES	4.82	5.41	5.18	4.27	4.24	4.26
Conversion Sector	7.01	8.20	9.80	5.23	3.97	4.71
TFC	4.40	5.03	4.23	3.99	4.32	4.13

Source: MENR

3.3 Energy Import and Export

Rapid development together with an almost stationary production has resulted in meeting the increasing demand with outside sources. Therefore, import dependency of Turkey was increased from 52% to 75% between 1990 and 2007.

Table 3.6 and Figure 3.4 summarize the country's energy balance and show how the country has become more and more dependent on imported energy.

Table 3.6 Development of Energy Demand-Production Import and Export (ttoe**)**

	1990	**1995**	**2000**	**2005**	**2006**	**2007**
Production	25,478	26,719	26,047	24,549	26,580	27,453
Import	30,936	39,779	56,342	73,065	80,416	87,614
Export	2,104	1,947	1,584	5,171	6,572	6,926
Bunkers	355	464	467	628	588	92
Net Import	28,477	37,368	54,291	67,266	73,256	80,596
Gross Consumption	52,987	63,679	80,500	91,074	99,642	107,627
Production/Demand (%)	48.08	41.96	32.36	26.96	26.68	25.51

Source: MENR

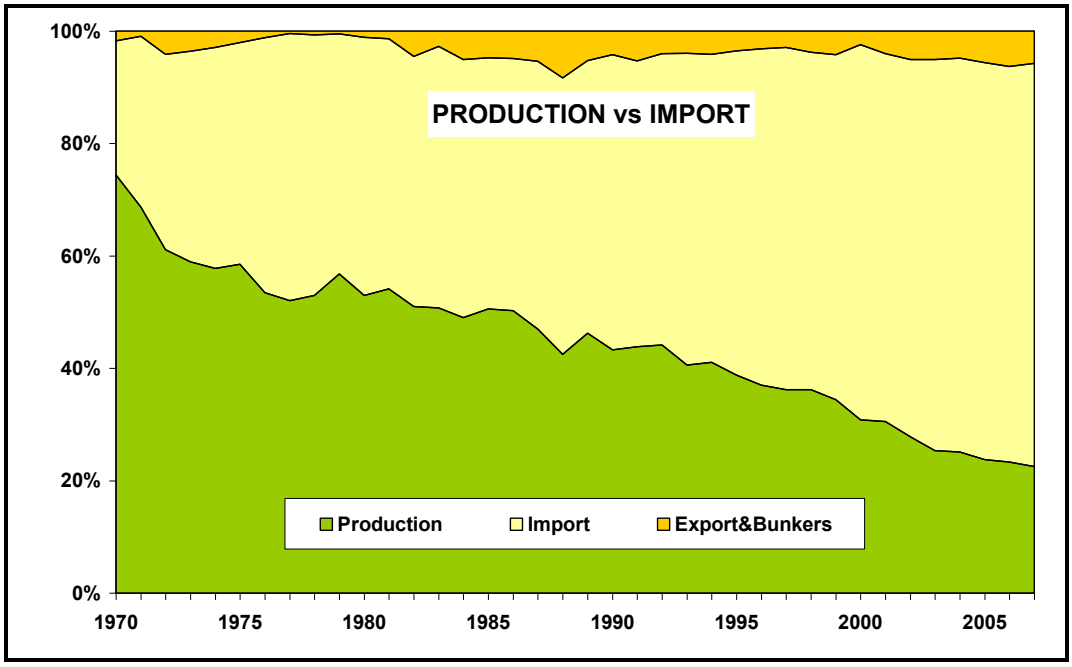

Figure 3.4: Production vs. Import (MENR)

3.4 Electricity

Electricity is a key element and indicator of development. Increasing income together with welfare means much more need for electricity especially for developing countries but also means, on the other side, need for more investment in that sector.

Total installed capacity was only 2,235 MW in 1970 when electrification studies initiated yet. Seventies are remembered as “hard days” in history of economy, throughout world and also in Turkey. Oil shocks are of course main reason of the chaos in that years (Yücel, 1997, p.10).

Turkey’s electrification story is a very successful and interesting example to the countries in poverty. Turkey in such poverty wrote a great epic in 20 years. Fuel supply of oil fired power plants generating 35% of total production was one of the main problems in electricity sector of Turkey in that years. Non-commissioning of planned power plants in time due to different factors was another problem making trouble in the sector. In addition to these the drought seasons Turkey faced with

starting from the year 1971 made the situation worse. Together with those troubles, programmed blackouts were started on 17 October 1973 (Yücel, 1997, p.12-13).

First Energy Consultative Congress realized in 1953 was a mile stone for electrification of villages. The output of the Congress was a report named Electrification of Our Villages and Organisation for This Objective. F. Behçet Yücel summarizes the electrification process as following (Yücel, 1997, p.39):

- Preliminary Process
- the objective of electrification of 1000 village per year was overcome
- the objective of electrification of 1000 village per year was overcome
- 18,000 village (2000 village per year)

Table 3.7 Electrification of Villages in Turkey

Years	At the beginning of the year	At the end of the year	Share of electrified village (%)		Years	At the beginning of the year	At the end of the year	Share of electrified village (%)
1963	-	0.5	0.7		1976	1695	9157	31.0
1964	40	250	0.7		1977	2049	11206	36.0
1965	125	375	1.0		1978	1788	12994	42.7
1966	202	577	1.6		1979	2466	15460	50.7
1967	157	734	2.0		1980	2885	18345	54.8
1968	363	1097	3.0		1981	1466	19811	61.0
1969	512	1609	4.5		1982	2221	22032	67.5
1970	762	2371	6.5		1983	2404	24436	73.3
1971	601	2972	8.2		1984	2079	26515	84.6
1972	934	3906	10.8		1985	4076	30591	93.7
1973	977	4883	16.5		1986	3294	33885	98.7
1974	1113	5986	20.5		1987	1516	34773	99.2
1975	1476	7462	25.3		1988	331	35871	

Source Yüksek Gerilimli Yıllar

Installed capacity reached 40.8 TW in 2007 from 16.3 TW in 1990 (Table 3.8). Although hydro peaked its share in the beginning of 80s and half of 90s and

doubled its capacity in the same period, thermal has always been dominant, also before 1990. Hard coal capacity increased 6 times when comparing to 1990, but its share decreased three times. The increase is coming from imported coal since there has been no public investment in generation of hard coal after Çatalağzı Power Plant.

Table 3.8 Installed Capacity by Fuel (MW)

	1990	**1995**	**2000**	**2005**	**2006**	**2007**
H. Coal	332	326	480	1,986	1,986	1,986
Lignite	4,874	6,048	6,509	7,131	8,211	8,211
F. Oil	2,120	1,761	1,996	2,961	2,868	2,471
Natural Gas	2,210	2,925	7,044	13,790	14,315	14,560
Renewable	18	31	60	70	123	212
Hydro	6,764	9,863	11,175	12,906	13,063	13,395
Gross Total	**16,318**	**20,954**	**27,264**	**38,844**	**40,565**	**40,836**
Growth Rate	**3.22**	**0.45**	**4.38**	**5.48**	**4.43**	**0.67**

Source MENR

Lignite is an indigenous source that Turkey could decrease her dependency to outside sources with correct and careful planning. However, share of its capacity decreased sharply from 34% to 20% with a slight capacity increase of 1.8 TW in 2007. The most striking development is roaring of natural gas starting from 90s. It doubled its share during two decade and reached 14.6 TW, in other words 36% of total installed capacity. The following Figure 3.5 is another indicator of Turkey's dependence on import, especially natural gas. Hard coal, renewables jumped from 18 to 212 MW but their share is still very low.

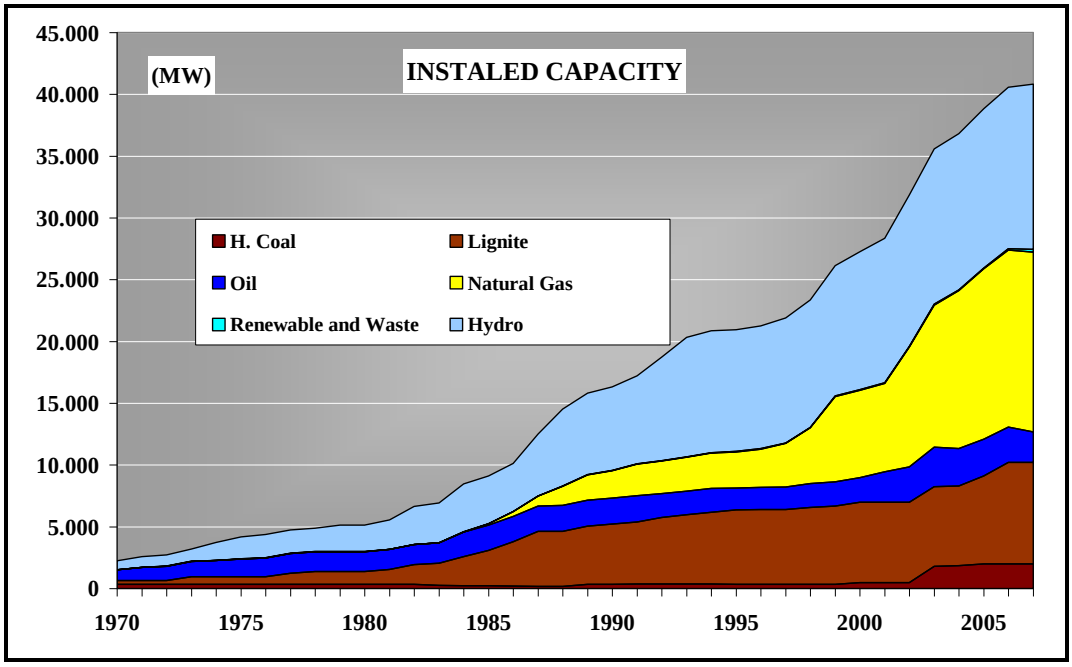

Figure 3.5 Installed Capacity by Fuel Type (MENR)

During the last two decade, electricity generation has more than tripled and reached 191,6 TWh in 2007. The average growth rate in the last 17 years was 7.33% which is considerably high and shows how fast Turkey has developed in spite of the economic crises the country faced with in 1991, 1994 and 2001 together with adverse effects of 1999 earthquake.

As it can be seen from Table 3.9, electricity generation and so demand for electricity has been growing very rapidly. The average growth rate was 8.74% between 1970-2009 and 7.33 between 1990-2007.

Generation by lignite increased about twice but its share in total dropped 1.7 times. Hydro reached in 2004 a production peak of 46 TWh, 31% of total, but adversely affected from drought and fell back to 95 values in 2007 with 18% share (Figure 3.6).

Table 3.9 Generation by Fuel Type (GWh)

	1990	1995	2000	2005	2006	2007
H. Coal	621	2,232	3,819	13,246	14,217	15,136
Lignite	19,561	25,815	34,367	29,946	32,433	38,295
Oil	3,942	5,772	9,311	5,483	4,340	6,527
Natural Gas	10,192	16,579	46,217	73,445	80,691	95,025
Hydro	23,148	35,541	30,879	39,561	44,244	35,851
Renewable	80	308	329	276	375	725
Gross Generation	57,543	86,247	124,922	161,956	176,300	191,558
Growth Rate	10,57	10,12	7,28	7,47	8,86	8,65

Source: TEIAS

Total generation has more than tripled since 1990 while generation form natural gas increased nine times and constituted half of the total generation in 2007. This is very high for a developing country. Renewables also rise nine times, but their shares are still negligible.

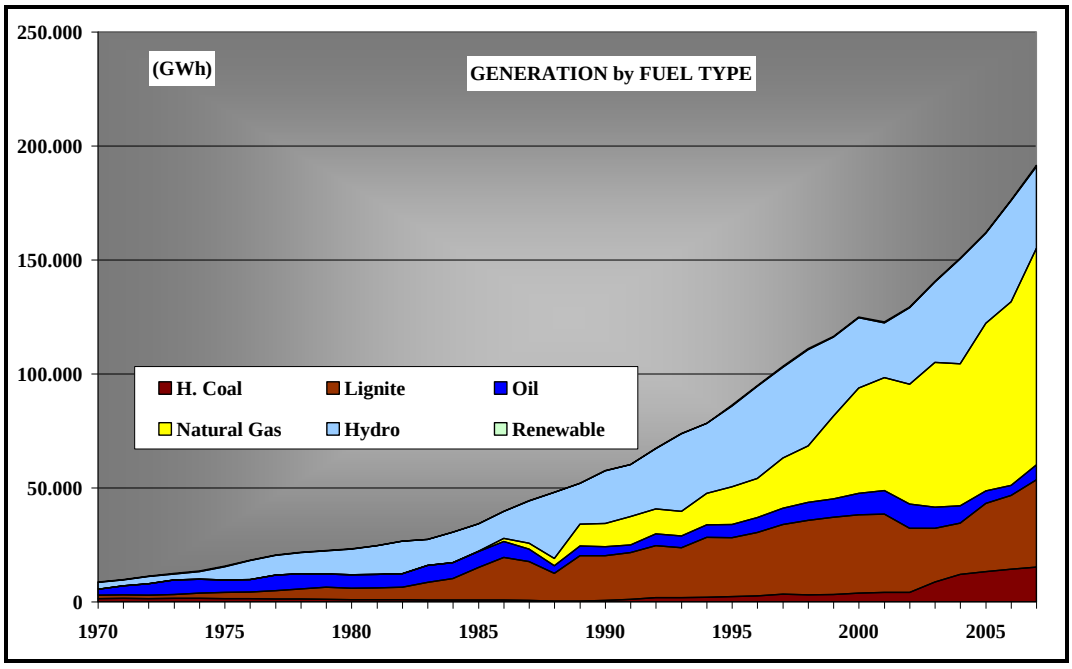

Figure 3.6 Generation by Fuel Type (MENR)

Table 3.10 shows how fast the installed capacity and generation have developed in Turkey. The difference in the last two decade that generation increased with a considerably higher growth rate when comparing to installed capacity is coming from rehabilitations of public power plants and working of private sector power plants with a higher capacity rate (WEC TNC 2008, p.77).

Table 3.10: Growing Rates of Installed Capacity and Generation (%)

	1970-2007	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2007**	**1990-2007**
Electricity Generation	8.74	10.44	9.47	8.06	6.30	7.33
Installed Capacity	8.17	8.64	12.29	5.27	5.94	5.54

Source MENR

Table 3.11 gives a summary of development of electricity sector in Turkey. When looking at the sectoral breakdowns of electricity consumption, it is seen that almost all the electricity has been consumed by industry and residential sector. Electricity consumption of industry has risen 2.6 times since 1990 and, with an average growth rate of 5.85%, reached 73.8 TWh in 2007. That of residential sector is much higher and it increased 74.4 TWh with an average growth rate of 13.54% in 2007, 4.5 times higher than 1990 level. In 1990 the share of industry sector and residential sectors were 61% and 31% orderly while both of shares were 48% in 2007.

This also means that the high growth rate of electricity consumption has mostly driven by residential sector. Increasing living standards, efficiency increase in industry and a shift to service sectors from industry are a few reasons of the difference in growth rates.

Table 3.11: Development of Electricity (GWh)

	1990	1995	2000	2005	2006	2007
Gross Generation	57,543	86,247	124,922	161,956	176,300	191,558
Own Use and Loses	-9,992	-18,158	-29,980	-30,531	-31,567	-34,865
Net Generation	47,551	68,090	94,942	131,425	144,733	156,693
Import	176	0	3,791	636	573	864
Export	907	696	437	1,798	2,236	2,422
Gross Consumption	**46,820**	**67,394**	**98,296**	**130,263**	**143,071**	**155,135**
Refineries	1,150	1,670	2,156	847	855	1,033
Net Consumption	45,670	65,724	96,140	129,416	142,216	154,102
Industry	28,062	36,337	46,686	58,721	67,172	73,795
Iron-Steel	4,839	6,955	8,395	11,661	13,398	15,477
Chemistry-P.	4,042	4,377	6,381	4,913	4,108	4,595
Fertilizer	1,153	380	500	508	511	195
Cement	3,992	2,883	3,998	4,323	4,595	5,475
Sugar	380	357				
Non-Iron	2,553	2,162		2,485	2,785	3,036
Other Industry	11,103	19,223	27,412	34,831	41,775	44,924
Railways	345	490	720	749	790	936
Residential	16,688	27,384	45,664	65,833	69,813	74,391
Agriculture	575	1,513	3,070	4,113	4,441	4,981
Industry Growth Rate (%)	-2.8	1.7	-2.8	-6.0	4.1	1.4
Residential Growth Rate	**4.9**	**-2.7**	**2.4**	**6.2**	**-3.5**	**-1.7**

Source: MENR/TEIAS

CHAPTER 4

TURKEY COAL OUTLOOK

4.1 Defining Coal

Coal is an organic matter and is a product of sedimentary environments. The most favourable areas of coal-forming flora are the shallow-swampy environments which are developed in various parts of sedimentary basins occurring along seashores, deltas and lakes (Korkmaz, 1994).

Coal is a combustible, brown to black sedimentary rock composed of heterogeneous components which are different physical and chemical properties. It consists of an aggregate of variable materials mainly composed of organic constituents called macerals or litho-types, such as vitrain, durain, fusain and clarain which are associated with minor or moderate amounts of mineral matter that yield ash after the complete burning of coal at high temperatures (Korkmaz, 1994).

Classification systems for coal are broadly of two types: scientific and commercial. Scientific classifications broadly describe origin, composition and structure, the fundamental properties of coal. Commercial classification is more concerned with the market value, utilization and technological properties of coals.

Coal scientists and important coal buyers generally are concerned with two major classification systems. One is American system (ASTM), the other is the agency of the United Nations Economic Commission for Europe (ECE). There are other coal classifications, like the Japanese and British. The Japanese generally refer to ASTM, but also have their own industrial standards (JIS) (Karayiğit, 1994).

4.2 Hard Coal

4.2.1 Petrography of the Western Black Sea Region

Cengiz Calışkan and A. Sami Derman from TPAO (Turkish Petroleum Corporation) studied continental sediments of Çakraz Group covering a large area between Amasra and Cide towns. They also studied continental sediments exposed in and Around Çamdağ, Adapazarı. According to the study, the area shows three distinct facies types and lithologic characters each of which reflects different environmental conditions. From top the bottom, these are as followings:

1-Red colored, lensoif sandstones and conglomerates enclosed in red colored mudstones representing fluvial channel and arid floodplan deposits,

2- Red to orange colored, large scale, high angle parallel cross laminated quartz sandstones representing colian sand deposits and

3- Gray to white, pink to green varicolored clay, marl, and argillaceous limestone representing lake deposits. These lake deposits grade into red colored mudstones laterally and vertically.

They found from distribution and relations of Triassic and Permian sediments that Western Black Sea, between Gebze and Cide, was a high area subjected to erosion and continental sedimentation during late Permian and late Triassic. They also concluded that the Çamdağ formation has been considered to be late Permian whereas the Çakraz group is Triassic in age and the Başköy formations of Late Triassic Age (Çalışkan, 1995).

4.2.2 Zonguldak Region

Hard coal is only found around Zonguldak Region located at the North Western Black Sea in Turkey. The region is within the Western Pondites tectonic province, and it is included in the Palezoic sequences cropping around Zonguldak. The sequence ranges from Upper Devonian to Upper Carboniferous.

Upper Devonian is represented by the Göktepe Formation that mainly consists of marine shales and limestones. The unit starts with conglomerates at the base, continues with sandy limestone, followed by limestone-shale alternations.

Lower Carboniferous (Tournasian-Visean) is represented by the Gökgöl Formation that mainly consists of well bedded dolomitic limestones.

The Alacaağzı Formation of Namurian age consist of thin bedded shale-arkosic sandstone alterations. The shales are dominant in the lower parts with thin coal seams. In the upper part of the formation, sandstones are more abundant, compared to lower parts, and rarely include conglomerates; coal seams of mineable thicknesses are observed in some regions.

The Kozlu formation of Westphalian-A age dominantly consists of conglomerates and sandstones. The formation also includes shales and coal seams. The Kozlu formation is divided into two members as the Kılıç member at the base and the Dilaver Member at the top. The Kılıç member is observed as beds steeply (almost vertically) dipping northwards. The Dilaver Member crops out as folds with E-W axes. The formation contains about 50 seams; of these 20 are in the Lower Kılıç Member, and 30 are in the upper Dilaver Member.

Westphalian B-D is represented by the Karadon Formation that starts with coarse grained conglomerates at the base and continues with sandstone-shale alterations with occasional conglomerate intercalations. The Formation contains about 20 coal seams.

The Mesozoic rocks around Zonguldak were folded into a system of very large scaled folds, whose exes generally trend E-W. The Carboniferous rocks are exposed along the core of anticline. Due to multi-stage folding, they display folds with shorter spans. The principal folds within the Zonguldak Carboniferous inlier are the Gelik anticline and the Üzülmez syncline, both with approximately E-W axes (Dirik, 1995).

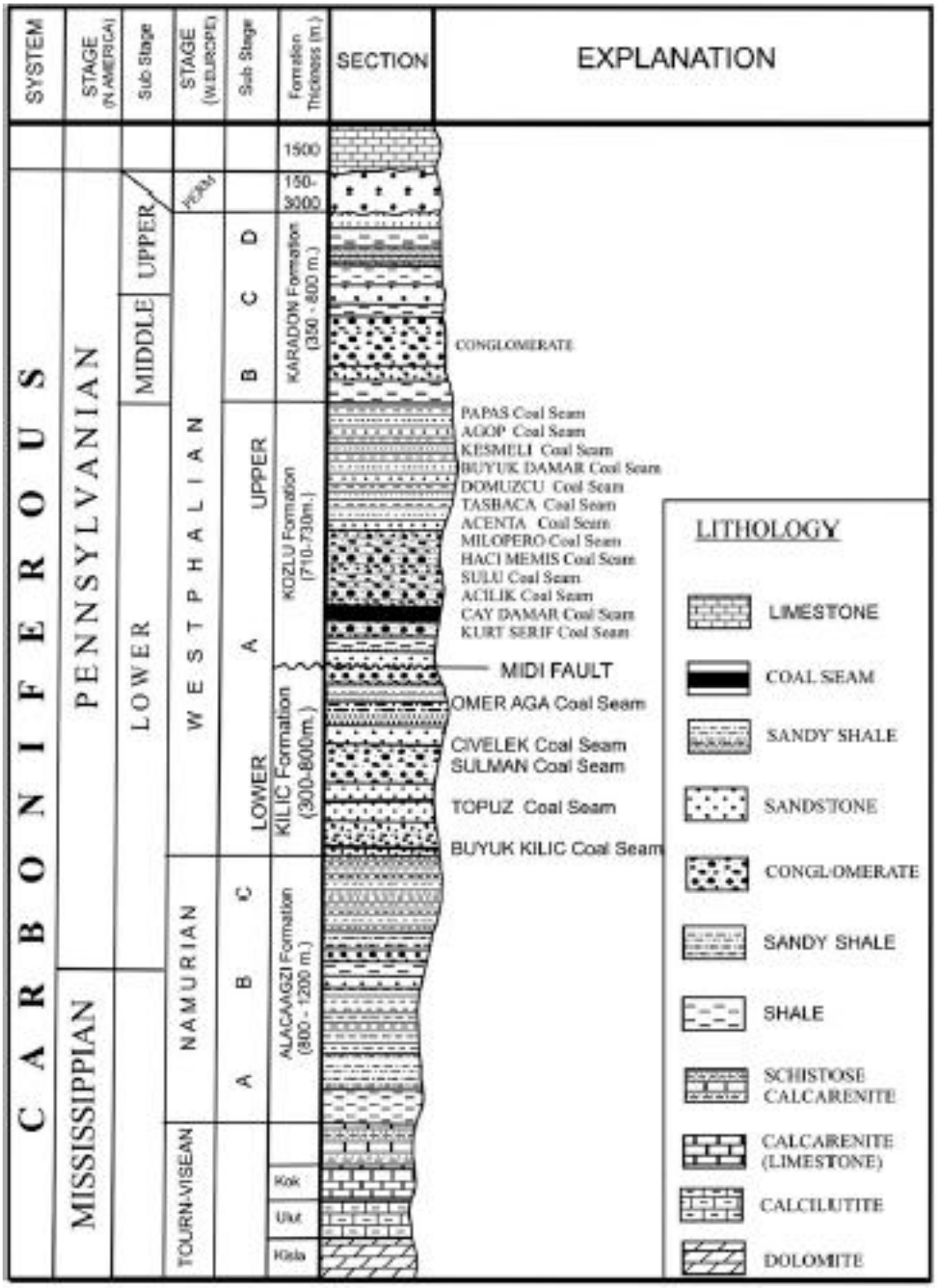

Figure 4.1 Lithology in Zonguldak Coal Basin

4.2.3 Hard Coal Reserves

Total hard coal reserves are about 1.3 billion tons of which 526 mtons is proved. Coals of Kozlu, Üzülmez and Karadon Basins can be cokeable while that of Armutçuk Basin are semicokeable and Amasra Basin are non-cokeable.

Table 4.1 Hard Coal Reserves (tons)

	Ready	Proved	Possible	Probable	Total
Armutçuk Basin	7.888.164	15.859.636	9.169.250	1.339.515	34.251.565
Kozlu Basin	2.933.854	68.486.178	40.539.000	47.975.000	159.934.032
Üzülmez Basin	1.471.820	137.369.240	94.342.000	74.020.000	307.203.060
Karadon Basin	6.511.825	132.502.731	159.162.000	117.034.000	415.210.556
Amasra Basin	170.480	171.704.914	115.052.000	121.535.000	408.462.394
Total	18.971.143	525.922.699	418.264.250	361.903.515	1.325.061.607

Source: TTK

4.3 Lignite

4.3.1 Coal Formation in Turkey

The first paleogeographic atlas of Turkey was prepared by Luttig et al. in 1976. The second paleogeographic study was a joint study having done by TÜBİTAK (The Scientific and Technological Research Coincil of Turkey)-Global Tectonic Research Unit, Mine and Geology Departments of Istanbul Technical University and MTA (General Directorate of Mineral Research and Exploration). As output of the study, the Triassic-Miocene Paleogeographic Atlas of Turkey prepared by Görür et al. and was published in 1998. A 1/2,00,000 scaled geological map of Turkey, prepared by Bingöl (1998) was taken as basis in the construction of paleogeographic maps.

Table 4.2 Geological age, coal type and environment of important lignite deposits

System	Series	Time (Ma)	Coal Type	Environment	Coal Type	Environment	Coal Type
			Sub bituminous		Lignite		Peat
Quaternary	Holocene	Recent			Konya-Argıthanı-Dursunluk	Peat swamp	Hakkari (Yüksekova) Bolu (Yenicağa and others)
	Pleistocene	1.7					
NEOGENE	PLIOCENE	(3.7) 5.4	Bursa-Keles-Harmanalan, Konya-Seydişehir Bayavşar	Limnic-fluvial with volcanogenic inter-calations	Adana-Tufanbeyli, Adıyaman-Gölbaşı, Afşin-Elbistan, Erzurum-Horasan-Aliçeyrek, Erzurum-İspir, Sivas-Kangal	Limnic-fluvial with volcanogenic inter-calations	
	MIOCENE	(17.6) 23.0	Aydın-Sahinali, Aydın-Söke, Balıkesir-Dursunbey-Odaköy, Bolu-Göynük-Himmetoğlu, Bursa-Orhaneli-Burmu, Çanakkale-Yenice-Çırpılar, Corum-Alpagut-Dodurga, Denizli-Kale-Kurbanlık, Erzurum-Aşkale-Kükürtlü, Erzurum-Oltu-Balkaya and Sütkans, Eskişehir-Mihalıçık-Koyunağlı, İçel-Namrun-Çamlıyayla, Karaman-Ermenek, Konya-Ilgın-Haremiköy, Kütahya-Seyitömer-Tunçbilek, Manisa-Soma (Eynez, Darkale, Işıklardere, Deniş, Manisa-Gördes-Çıtak, Muğla-Milas (Alakilise,Çakıralan)	Limnic-fluvial with volcanogenic inter-calations	Balıkesir-Dursunbey-Hamzacık-Çakırca, Muğla-Milas (Ekizköy, Sekköy, Hüsamlar) Muğla-Yatağan (Tınaz-Bağyaka-Eskihisar-Bayır	Limnic-fluvial with volcanogenic inter-calations	
PALEOGENE	OLIGOCENE	(14.0) 37.0	Edirne-Uzunköprü-Harmanlı, Tekirdag-Saray-Edirköy	Limnic-fluvial with volcanogenic inter-calations	Tekirdağ-Malkara-Ahmetpaşa, Tekirdağ-Hasköy-İbrice	Limnic-fluvial	
	EOCENE	(18.0) 55.0	Bolu-Mengen-Salıpazarı, Yozgat-Sorgun, Amasya-Çeltek	Limnic-fluvial			

Source: Chemical and Technological Properties of Turkish Coal Tertiary Coals, MTA, 2002.

4.3.2 Lignite Reserves

Lignite is spread widely through the country and can be found almost every region. Of the total reserves 4.4 mtons are situated in Afşin-Elbistan basin owned by Electricity Generation Corporation (EÜAŞ). TKİ (Turkish Coal Enterprises) is the other state own producer. They have about 80% of the total reserves and exploitation licences.

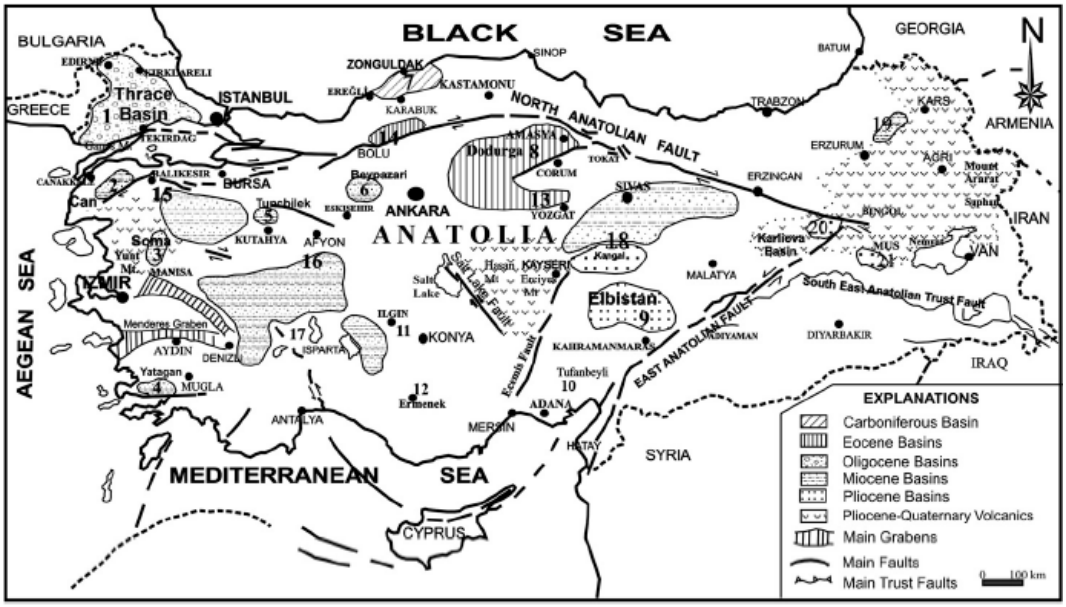

Figure 4.2 Lignite Reserves in Turkey

Most of lignite is used in power plants since considerably young reserves usually have low calorific value and high ash value. The following figure shows that about 70% of our lignites have low calorific value and most of this share is constituted by state owned Afsin-Elbistan lignites with an average calorific value of 1100 kcal/kg (WEC TNC 2007, p.19).

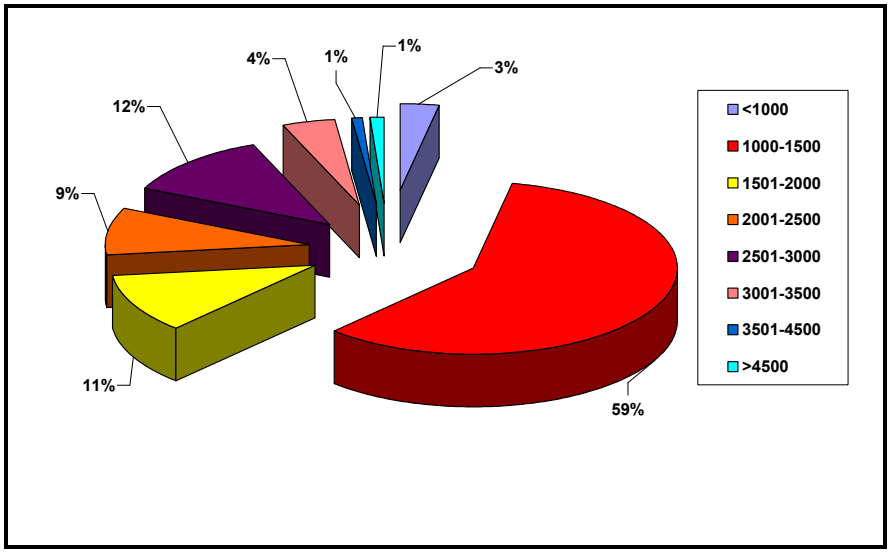

Figure 4.3 Calorific Breakdown of Turkish Lignites (Source: WEC-TNC, 2007)

4.4 Hard Coal Production and Consumption

After having peaked in 1974, hard coal production has been decreased continuously since 1970. Especially after the Great Strike in 1989, TTK was restructured starting with retiring of all workers having over 25 years of work life. The number was over 40,000 before 1990.

Table 4.3 Number of Workers by Years

Years	In Production	Underground	Surface	Total
1995	4.486	13.348	8.172	21.520
1996	4.193	13.028	7.375	20.403
1997	3.770	12.277	6.397	18.674
1998	3.490	11.684	5.722	17.406
1999	3.042	10.898	5.282	16.180
2000	6.022	14.588	4.563	19.151
2001	4.953	13.472	4.617	18.089
2002	4.579	11.765	4.027	15.792
2003	4.279	10.339	3.723	14.062
2004	3.861	8.932	3.329	12.261
2005	3.277	8.200	3.049	11.249
2006	2.936	7.669	2.942	10.611
2007	2.971	7.983	2.582	10.565
2008	2.308	7.392	2.305	9.697

Source: TTK

It can be concluded from the above table that; underground/surface worker ratio is low comparing with the world, number of workers working in direct production is also very low in total and total number of workers have fallen down by half since 1995, i.e. workforce was decreased by half.

Table 4.4 Hard Coal Balance (ttons)

	1990	**1995**	**2000**	**2005**	**2006**	**2007**
Production	2,745	2,248	2,392	2,170	2,319	2,462
Import	5,557	5,941	12,990	17,360	20,286	22,946
Gross Coal Consumption	8,191	8,548	15,525	19,421	22,798	25,388
Transformation Sector	5,444	5,508	6,282	9,517	10,262	10,539
Power Plants	474	1,246	2,034	5,259	5,477	5,912
Coke Ovens	4,723	4,182	4,191	4,218	4,745	4,443
Total Final Coal Consumption	2,747	3,040	9,244	9,904	12,536	14,849
Industry	1,459	1,803	8,529	8,970	11,671	13,984
Cement	946	1,137	1,236	1,982	2,215	2,666
Other Industry	513	666	7,293	6,988	9,455	11,318
Railways	13	4	1	0	0	0
Residential	1,275	1,233	714	935	865	865

Source: MENR

Table 4.4 gives the balance of coal from production to end users. Although gross coal consumption is declined by half and reached 25.4 mtons with a considerably high average growth rate of 6.9%, production, in contrast, slightly decreased from 2.7 mtons to 2.46 tons with an average rate of 0.64 in 2007. To increase production, a royalty system was put into practice in 2004. The following table gives private sector and TTK's productions by years.

Table 4.5 Public and Private Sector Productions (ttons)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
TTK	2,257	2,357	2,244	2,011	1,881	1,659	1,523	1,645
Private Sector	135	137	75	48	65	511	796	817

Source TTK

However, royalty system did not solve the supply problem. So, the remaining demand was met by imports. After first imported in 1973, it was increased by about six times between 1980 and 1990 and more than doubled between 1990 and 2000.

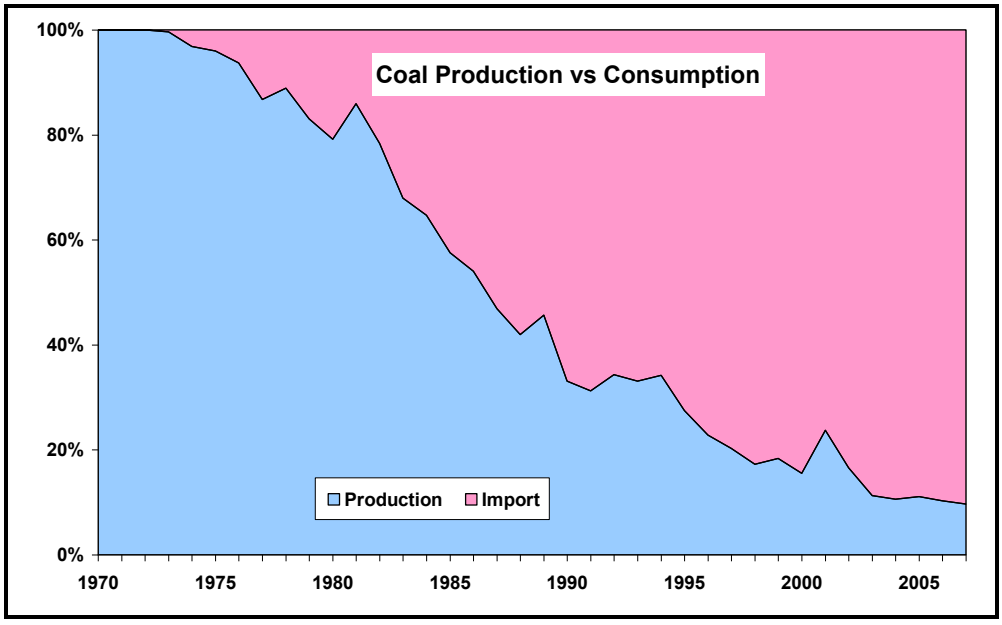

Figure 4.4 Coal Production vs. Consumption (Source MENR)

Çatalağzı Thermic Power Plant is the only one using indigenous hard coal. There was the Zonguldak Coal Washery Plant washing Kozlu and Üzülmez coals to produce high quality coal for iron-steel and residential sectors. Due to depletion of economic life it was demounted in 2006 and instead two new but small washery units constructed in two districts by private sector. It has been aimed that slugs of the first and then next two washery plants together with non-cokeable and semi-coakeble coals could feed the power plant. Nevertheless, in the last decade, the power plant has been fed by coked coal having a calorific value of more than 4500 kcal/kg and to balance the boiler design, it had to buy shale and uncalorific matters.

Between 1965 and 1989 sells of TTK to iron-steel industry was around 1,5 to 2 million tons. Unfortunately, due to capacity increase realized after 1982 and increase of demand for coakeble coal, total production has not enough to meet the

need of total integrated steel industry of which Erdemir and Karabük iron-steel plants are located west and east of Zonguldak. So, the industry started to import hard coal. The sales fell down to 189 ttons in 1998 but, especially due to rising demand of Karabük, they rose to 400 ttons in 2007. Cheaper coal around the world is also the other reason for the preference. In the last years, Erdemir has started to use pulverized coal injection methodology using mixture of some semi-coked Armutçuk coal and imported coal. İsdemir also begin to use this technology in 2008.

The coal used for heating purposes is also decreased from 1.3 mtons to 0.9 mtons with an average rate of 2.2% although the population increased. The main reason is widening of natural gas throughout Turkey. Nearly 80% of the coal consumed is coming from import in the last years. Indigenous hard coal is only consumed around Zonguldak region. Table 4.6 shows average growth rate of hard coal for the last five decades.

Table 4.6 Hard Coal Growth Rates for Ten Years Period

	1970-2007	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2007**	**1990-2007**
Production	-1,66	-2,37	-2,67	-1,37	0,42	-0,64
Gross Coal Consumption	4,65	-0,21	5,87	6,60	7,28	6,88
Power Plants	5,04	-2,23	-4,67	15,68	16,46	16,00
Coke Ovens	2,40	3,55	6,07	-1,19	0,84	-0,36
Total Final Coal Consumption	6,11	-4,71	10,41	12,90	7,01	10,44
Industry	9,80	2,91	9,55	19,31	7,32	14,22
Cement	11,94	10,47	23,90	2,71	11,61	6,29
Other Industry	9,46	1,76	0,77	30,40	6,48	19,96
Residential	2,21	-6,79	20,91	-5,63	2,78	-2,26

Source: MENR

4.5 Lignite Production and Consumption

In contrast to hard coal lignite is widely spread through the country. After peaking in1989, lignite production did not show such a high rate of increase up to 2005. In 1988 the production was decreased by 17.6 % which was the lowest rate of decrease since 1970. But right after 1988 the production increased from 35.3 mtons to 48.7 mtons or by 40%, the highest increase rate since 1970. After 1999 it also started to decrease continuously and faced with the second lowest decrease rate in 2002 and the fourth (the third one was in 1979) in 2003 with 13.28% and 13.63 decrease rates orderly. In 2005 it increased by 32 % which is also a very high growth rate after 1985 (37.35%9 and 1989 (37.89%) and continued to increase with lower rates. In summary production was increased from44.4 to 72.1 mtons with an average growth rate of 2.9%, lower than that of power plants.

Most of the lignite is consumed by power plants and therefore all the power plants are located near the lignite mines. (Figure 4.5) The reason of sharp decrease between 2000 and 2004, specially after 2002, is the İzmit Earthquake and economic recession together with giving priority to gas fired power plants due to buy or pay agreements. After 2005, Çan Thermic Power Plant and Afşin Elbistan B Power plant were put into operation to meet increasing high demand. The drought seasons between 2006 and 2007 in addition to fast growing rate, resulted in running all lignite power plants with their possible maximum loads.

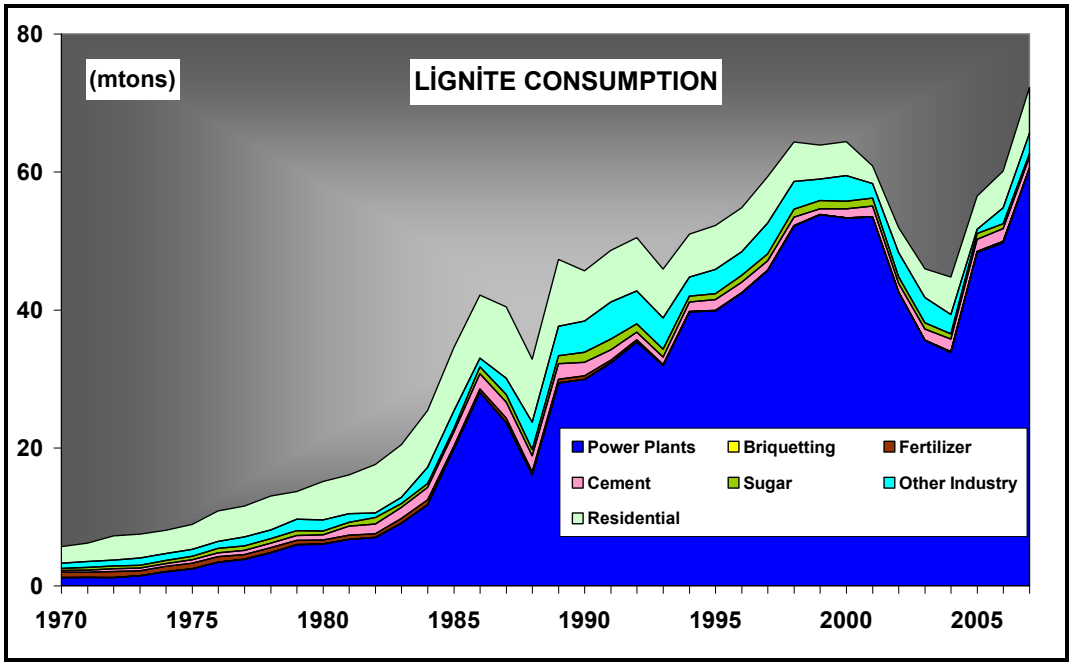

Figure 4.5: Lignite Consumption by Sectors (Source MENR)

Table 4.8 shows lignite balance of Turkey from production to final consumption. Cement and sugar sectors are main consumers. Although fertilizer sector used lignite, after 1990s, its consumption decreased rapidly and become zero after 2004. These sectors mostly tended to use imported coal more and more. In reality, some of the imported hard coal used in these sectors has been recorded as lignite since the importing firms are likely selling the coal as lignite in the inner market.

The Poor Fund is buying lignite and distributing freely to poor regions in several years, which contributed to increase in lignite consumption for space heating although there is a slight decrease from 7.2 mtons to 6.6 mtons which was 4.9 mtons and 4.8 mtons in 1995 and 2000. The main reason of 3.8% average decrease between 1990 and 2000 was more and more use of natural gas by years and the main reason of increase except recession in 2001 was the poor fund between 2000 and 2007.

Table 4.7 Lignite Balance (ttons)

	1990	1995	2000	2005	2006	2007
Production	44,407	52,758	60,854	57,708	61,484	72,121
Import	15	10	11	0	29	0
Gross Lignite Supply	45,891	52,405	64,384	56,571	60,184	72,317
Transformation Sector	30,152	39,985	53,314	48,562	49,979	60,709
Power Plants	29,884	39,815	53,312	48,319	49,709	60,536
Briquetting	35	2	2	160	190	52
Total Final Lignite Consumption	15,739	12,420	11,070	8,009	10,205	11,608
Industry	8,470	6,013	6,144	3,202	4,896	5,006
Fertilizer	509	124	40	0	0	0
Cement	1,980	1,549	1,283	1,747	1,876	1,513
Sugar	1,425	835	1,113	872	722	547
Other Industry	4,556	3,505	3,708	584	2,298	2,945
Residential	7,247	6,407	4,926	4,807	5,309	6,602

Source: MENR

The following table summarizes average growth rates for lignite produced and consumed in the last five decades.

Table 4.8: Lignite Growth Rates for Ten Years of Period

	1970-2007	1970-1980	1980-1990	1990-2000	2000-2007	1990-2007
Production	7,06	9,61	11,87	*3,20*	2,46	2,89
Power Plants	11,36	18,23	17,35	*5,96*	1,83	4,24
Briquetting	-1,05	-12,61	5,76	*-24,89*	59,31	2,37
Total Final Lignite Consumption	2,55	7,25	5,53	*-3,46*	0,68	-1,78
Industry	2,43	5,40	9,29	*-3,16*	-2,88	-3,05
Cement	4,90	11,58	9,88	*-4,25*	2,39	-1,57
Sugar	1,61	6,10	10,03	*-2,44*	-9,64	-5,47
Other Industry	3,82	7,94	11,15	*-2,04*	-3,24	-2,53
Residential	2,76	8,76	2,65	*-3,79*	4,27	-0,55

Source: MENR

CHAPTER 5

EMISSIONS in TURKEY

5.1 UNFCCC and TURKEY

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted on 9 May 1992 by the Intergovernmental Negotiating Committee established for its negotiation. In June 1992, the UNFCCC was opened for signature. It entered into force on 21 March 1994.

The ultimate objective of the Convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. (UNEP, 2009)

The Convention divides countries into three main groups according to differing commitments:

- **Annex I** Parties include the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

- **Annex II** Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change.

- **Non-Annex I** Parties are mostly developing countries ($UNFCCC_a$).

Turkey was a member of the OECD when the UNFCCC was adopted in 1992, and was therefore included among the Annex I and the Annex II countries. Through this inclusion in both annexes, Turkey was considered among industrialized countries, and thus, it was obliged to fulfil all the commitments of industrialized countries. However in comparison to the other countries included in the annexes, Turkey was at a relatively early stage of industrialization and had a lower level of economic development as well as a lower means to assist developing countries (IEA, 2005, p.39).

At 6^{th} Conference of Parties (COP 6-The Hague Conference), the Minister of Environment and Forestry of Turkey made a new proposal, whereby the name of Turkey would be deleted from Annex II, but would remain in Annex I, with an accompanying footnote indicating that Turkey should enjoy favourable conditions within "common but differentiated responsibilities", taking into consideration its early stage of industrialization ($UNFCCC_b$).

An important decision, which was taken at the 7^{th} Conference of Parties (COP7) in Marrakech in 2001, has had an impact on Turkey. This was deletion of the name of Turkey from the list in Annex II to the Convention and invitation of the parties to recognize special circumstances of Turkey, which place Turkey, after becoming a Party, in a situation different from other parties included in Annex I to the Convention on the basis of the “common but differentiated responsibilities” principle of the Convention. After that, the “Law No: 4990 concerning the accession of Turkey to the UNFCCC was promulgated in the Official Gazette on 16 October 2003. The Convention came into force for Turkey on May 2004 (MoEF, 2007).

Article 12 of the Convention requires all Parties to report on the steps they are taking to implement the Convention. In accordance with this article, Turkey submitted the First National Communication Report on 20 February 2007 to the UNFCCC. Turkey also prepared its first National Inventory Report (NIR) and CRF (Common Reporting Format) tables for the period 1990-2004 and submitted to UNFCCC in 2006. Turkey has, now, prepared its fifth NIR for the year 2008.

5.2 Total Greenhouse Gas Emissions (GHGs)

Turkey's total GHG emissions excluding Land Use, Land-Use Change and Forestry (LULUCF) rose from 170.1 mtons to 372.6 mtons CO_2 equivalent between 1990 and 2007 (Figure 5.1). The average annual growth rate of 4.72% is in parallel with that of TPES and TFC. The main reason behind this increase is rapid industrialization and population growth rate as a developing country.

CO_2 is responsible for largest proportion of Turkey's total emissions followed by CH_4 (Methane), N_2O (Nitrous Oxide) and F (Fluorinated Greenhouse Gases) gases respectively. About 80% of total GHG emissions are coming from CO_2. The share of CH_4 emissions decreased gradually from about 19% to 15% in the last years while that of N_2O emissions has almost doubled in the same period.

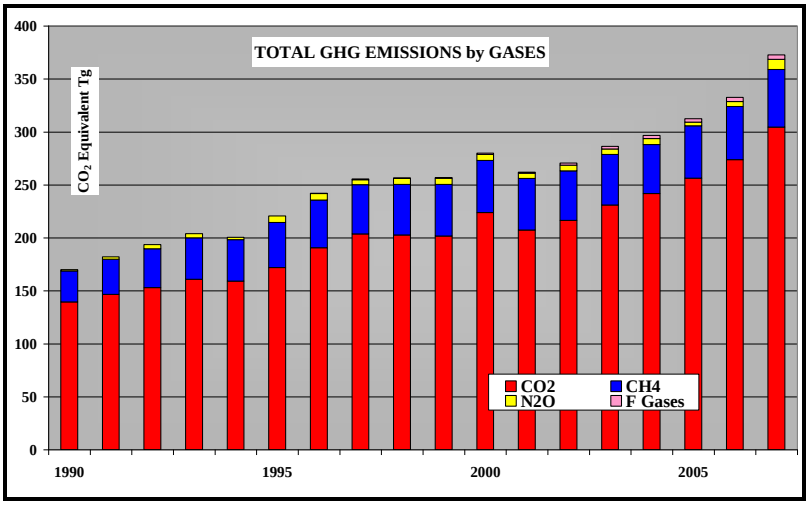

Figure 5.1 Greenhouse Gas Emissions by Gases

The SF6 (Sulphur hexafluoride) and HFCs (Hydrofluorocarbons) emissions are coming from electricity generation and manufacturing sectors. SF_6 (Sulphur Hexafluoride) emissions have been recorded since 1996 while HFCs first introduced to the industry in 2000, in order to replace CFCs (Chlorofluorocarbons) which was controlled under the Montreal Protocol. The emissions of HFCs are limited to use of HFC134a in certain manufacturing sectors producing refrigerators and air conditioners and constitute about 75% of total F gases (MoEF, 2007).

The Table 5.1 shows greenhouse gases by sources and sectors excluding LULUCF and total with LULUCF

Table 5.1 Greenhouse Gase Emissions (ttons of CO_2 equivalent)

	1990	**1995**	**2000**	**2005**	**2006**	**2007**	**1990-2007 Growth Rate (%)**
CO_2 emissions excluding net CO_2 from LULUCF	139,594	171,854	223,806	256,434	273,705	304,475	4.69
CH_4 emissions excluding CH_4 from LULUCF	29,207	42,539	49,269	49,317	50,330	54,384	3.72
N_2O emissions excluding N_2O from LULUCF	1,257	6,327	5,740	3,432	4,594	9,652	12.74
HFCs	NA	NA	818	2,379	2,730	3,174	
PFCs	NA	NA	NA	NA	405	NAE	
SF_6	NA	NA	323	859	911	952	
Total (including LULUCF)	**125,188**	**158,883**	**212,398**	**242,888**	**256,739**	**296,364**	**5.2**
Total (excluding LULUCF)	**170,059**	**220,719**	**279,956**	**312,420**	**332,675**	**372,638**	**4.72**

NA: Not Available

Over the period, GHGs from the energy sector constitutes the highest share with around 77%. The share of industry sector which was the second pollutant at the beginning of the period was replaced by the waste disposal starting from the year 1996. In 2007 the shares of energy, industry, waste disposal and agriculture sectors were 77.4%, 7.0%, 7.1% and 8.5% respectively.

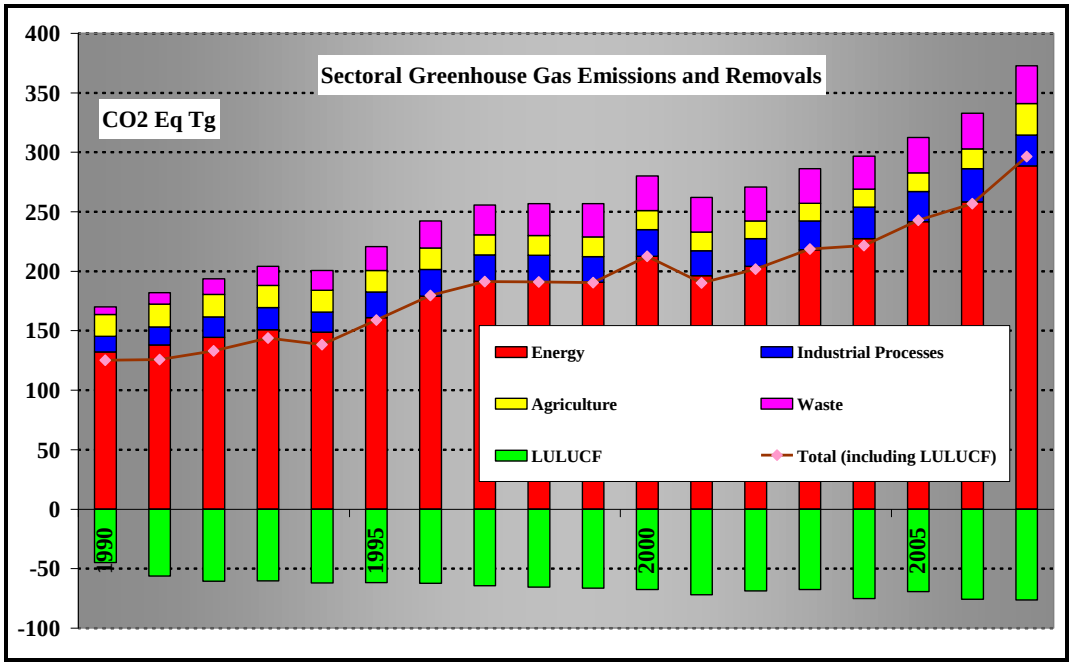

Figure 5.2 Greenhouse Gas Emissions and Removals by Sector

5.3 CO_2 Emissions

Having the responsibility of 60% of total world GHG emissions, CO_2 is the most important greenhouse gas. More than 90% of total CO_2 emissions are arising from fuel combustion, i.e. energy sector. Total CO_2 emissions excluding LULUCF increased with an annual average growth rate of 4.83% from139.6 mtons to 304.5 mtons between 1990 and 2007. The following table is a summary of CO_2 emissions from CRF Tables submitted to the UNFCCC.

As shown in Table 5.2 and Figure 5.3, total CO_2 emissions from the fuel combustion, excluding LULUCF, increased with an average growth rate of 5.03% from 126.7 mtons to 282.5 mtons between 1990 and 2007. Except a few years including the base year 1990, emissions arising from energy industries, sum of electricity and heat generation and refining) has the highest share followed by that from industry transport, residential sectors and agriculture sectors.

Table 5.2 Total CO_2 Emissions (ttons)

	1990	1995	2000	2005	2006	2007	1990-2000	2000-2007	1990-2007
							(%)	(%)	(%)
Energy	126,701	155,347	207,054	236,051	252,794	282,472	5.03	4.54	4.83
A. Fuel Combustion	126,701	155,347	207,054	236,051	252,794	282,472	5.03	4.54	4.83
1. Energy Industries	34,015	47,314	76,780	88,557	90,602	106,603	8.48	4.80	6.95
a. Public Electricity and Heat Production	30,325	43,750	72,089	83,680	85,312	100,662	9.05	4.88	7.31
b. Petroleum Refining	3,689	3,564	4,690	4,877	5,290	5,941	2.43	3.44	2.84
2. Manufacturing Industries and Construction	37,531	41,982	59,875	67,102	76,876	80,012	4.78	4.23	4.55
a. Iron and Steel	9,402	9,652	10,088	9,325	9,029	9,975	0.71	-0.16	0.35
b. Non-Ferrous Metals	1,011	1,663	1,954	2,369	2,728	9,957	6.81	26.19	14.40
c. Chemicals	2,514	2,768	3,152	4,352	4,433	2,411	2.29	-3.76	-0.25
f. Other	24,604	27,899	44,681	51,056	60,685	57,668	6.15	3.71	5.14
3. Transport	25,955	32,830	34,969	40,526	43,738	51,011	3.03	5.54	4.05
a. Civil Aviation	905	2,710	3,058	4,054	4,534	6,064	12.95	10.27	11.84
b. Road Transportation	24,036	28,792	30,822	34,517	37,082	42,934	2.52	4.85	3.47
c. Railways	517	618	478	677	682	424	-0.78	-1.69	-1.15
d. Navigation	497	710	611	1,277	1,440	1,589	2.07	14.64	7.07
4. Other Sectors	29,201	33,220	35,431	39,866	41,577	44,846	1.95	3.42	2.56
b. Residential	23,406	25,848	26,892	30,639	31,667	34,051	1.40	3.43	2.23
c.Agriculture/Forestry/ Fisheries	5,795	7,372	8,539	9,227	9,910	10,795	3.95	3.41	3.73
B. Fugitive Emissions from Fuels									
Industrial Processes	12,893	16,507	16,752	20,382	20,911	22,003	2.65	3.97	3.19
Land Use, Land-Use Change and Forestry[(2)]	-44,871	-61,836	-67,558	-69,533	-75,935	-76,274	4.18	1.75	3.17
Total CO_2 emissions including net CO_2 from LULUCF	94,724	110,018	156,248	186,901	197,769	228,201	5.13	5.56	5.31
Total CO_2 emissions excluding net CO_2 from LULUCF	139,594	171,854	223,806	256,434	273,705	304,475	4.83	4.50	4.69

Between 1990 and 2007, CO_2 emissions arising from electricity and heat production increased with a considerably high annual average growth rate of 7.31%, almost similar as that of electricity generation, and reached 100.7 mtons in 2007.

Cement production is main source of total CO_2 emissions from industry sector which is rose from 37.5 mtons to 80 mtons with an annual average growth rate of 4.55%. in parallel with that of energy consumption. However share of emissions decreased from 30% to 28 %.

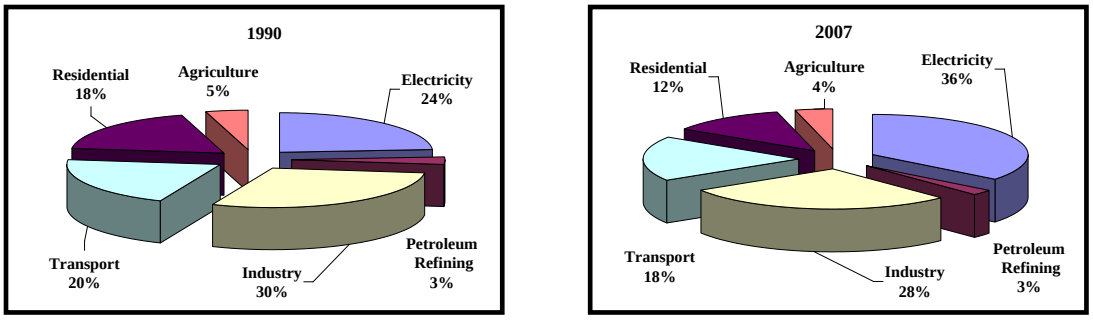

Figure 5.3 CO_2 Emissions from Fuel Combustion

Road vehicles are responsible for about 84% of total CO_2 emissions in transport sector in 2008. The share was about 90% in 1990. As in the electricity generation and industry sectors, the average annual growth rate of 4.05% in the same period is in line with that of consumption in the sector. 2% decrease is also observed in its share in total.

Emissions from agriculture, forestry and fisheries retained their shares in total in the period of 1990-2007. The same trend can be seen in that coming from petroleum refining.

5.4 CH_4 Emissions

Between 1990 and 2007, total methane emissions increased from 1,391 ttons to 2,590 ttons with an average rate of 3.72 which was considerably high in the first decade and low in the second half. Shifting from coal and other conventional biomass resources to natural gas, especially in the second half of the period, was the main reason of such difference. As can be seen from the following table, solid waste disposal on the land area and agriculture are main sources of methane.

CH_4 emission from fuel combustion was decreased about 19% considerably during the time. The main reason behind this is fuel switching from coal and conventional biomass to natural gas. Especially after the second half of the 90's, use of natural gas widened rapidly, resulting in considerable decrease.

In Turkey, the main fugitive emissions were the CH_4 from the coal mining, especially the lignite and hard coal mining from underground and surface mines Figure 5.4). The emissions have been changed accordingly with production. During the 17 years of period emissions rose from 68.1 ttons to 87.5 ttons.

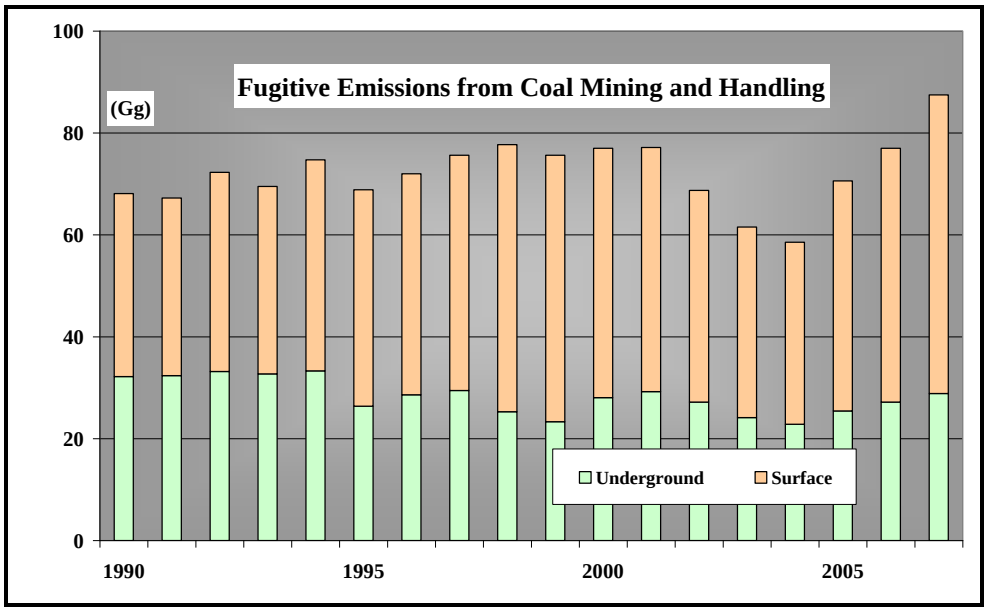

Figure 5.4 Fugitive Emissions From Coal Mining

Table 5.3 Total CH_4 Emissions (ttons)

	1990	1995	2000	2005	2006	2007	1990-2000	2000-2007	1990-2007
							(%)	(%)	(%)
Energy	211.1	206.1	199.5	185.0	190.3	203.4	-0.57	0.28	-0.22
Fuel Combustion	143.0	137.3	122.5	114.4	113.3	115.9	-1.54	-0.79	-1.23
Public Electricity and Heat Production	0.5	0.7	1.2	1.3	1.3	1.5	10.42	3.37	7.46
Petroleum Refining	0.2	0.1	0.2	0.2	0.2	0.2	2.43	1.12	1.89
Manufacturing Industries and Construction	3.0	3.3	5.4	6.1	7.2	7.8	5.92	5.47	5.74
Transport	3.4	5.6	6.5	5.8	5.9	6.1	6.74	-0.94	3.51
Residential	135.6	127.0	108.6	100.3	98.0	99.5	-2.20	-1.24	-1.80
Agriculture/Forestry/Fisheries	0.4	0.5	0.6	0.6	0.7	0.7	3.95	3.26	3.67
Fugitive Emissions (Coal Mining and Handling)	68.1	68.8	77.0	70.6	77.0	87.5	1.23	1.84	1.48
Underground Mining	32.2	26.4	28.1	25.4	27.2	28.9	-1.37	0.41	-0.64
Surface Mining	35.9	42.5	48.9	45.2	49.8	58.6	3.14	2.61	2.92
Industrial Processes	2.4	2.3	2.3	0.7	2.5	2.6	-0.42	1.81	0.49
Agriculture	873.2	849.9	761.5	746.0	772.2	867.2	-1.36	1.87	-0.04
Enteric Fermentation	811.8	784.2	692.5	664.3	686.2	744.4	-1.58	1.04	-0.51
Manure Management	29.2	35.5	34.4	39.7	42.6	84.2	1.64	13.65	6.42
Rice Cultivation	10.6	10.0	11.6	17.0	19.8	18.8	0.91	7.13	3.42
Field Burning of Agricultural Residues	21.6	20.1	23.0	24.9	23.7	19.8	0.61	-2.10	-0.51
Waste (Solid Waste Disposal on Land)	304.1	967.3	1,383.0	1,416.8	1,431.7	1,516.7	16.35	1.33	9.91
Total CH_4 emissions	1,390.8	2,025.7	2,346.1	2,348.4	2,396.7	2,589.7	5.37	1.42	3.72

As can be seen from Table 5.3, enteric fermentation is main reason of non-energy methane emissions. Although burning the agricultural residue is forbidden in the country, due to lack of data the residue of the agricultural crops has still assumed to be burned.

The disposed of solid waste emits methane as a result of anaerobic and aerobic decomposition of organic mater contained in the waste.

5.3 N_2O Emissions

Total N_2O emissions increased from 4.06 ttons to 31.14 ttons in the period of 1990 and 2007 (Table 5.4).

Table 5.4 Total N_2O Emissions (ttons)

	1990	1995	2000	2005	2006	2007	1990-2000 (%)	2000-2007 (%)	1990-2007 (%)
Energy	3.21	3.59	4.20	4.88	4.57	5.12	2.75	2.84	2.79
Public Electricity and Heat Production	0.34	0.49	0.71	0.75	0.77	0.90	7.59	3.46	5.87
Petroleum Refining	0.03	0.03	0.04	0.04	0.04	0.04	2.43	0.30	1.55
Manufacturing Industries and Construction	0.45	0.47	0.75	0.76	0.88	0.91	5.19	2.80	4.20
Transport	0.84	1.08	1.33	2.12	1.71	2.10	4.63	6.82	5.53
Residential	1.49	1.46	1.31	1.13	1.08	1.07	-1.30	-2.83	-1.93
Agriculture/Forestry/Fisheries	0.05	0.06	0.07	0.08	0.08	0.09	3.95	3.26	3.67
Industrial Processes	0.41	16.41	13.85	5.68	9.77	C,NA	42.08		
Agriculture	0.44	0.41	0.47	0.51	0.48	26.02	0.60	77.70	27.16
Total N_2O emissions	4.06	20.41	18.52	11.07	14.82	31.14	16.40	7.71	12.74

Emissions from fuel combustion rose with an annual average rate of 2.79% from 3.21 ttons to 5.12 ttons (Figure 5.5). On a sectoral basis, transport and electricity and heat generation are main drivers of this rise. Their shares in total have more

than doubled during the period. The only decrease in growth rate has been observed in residential sector, mostly due to shift to natural gas.

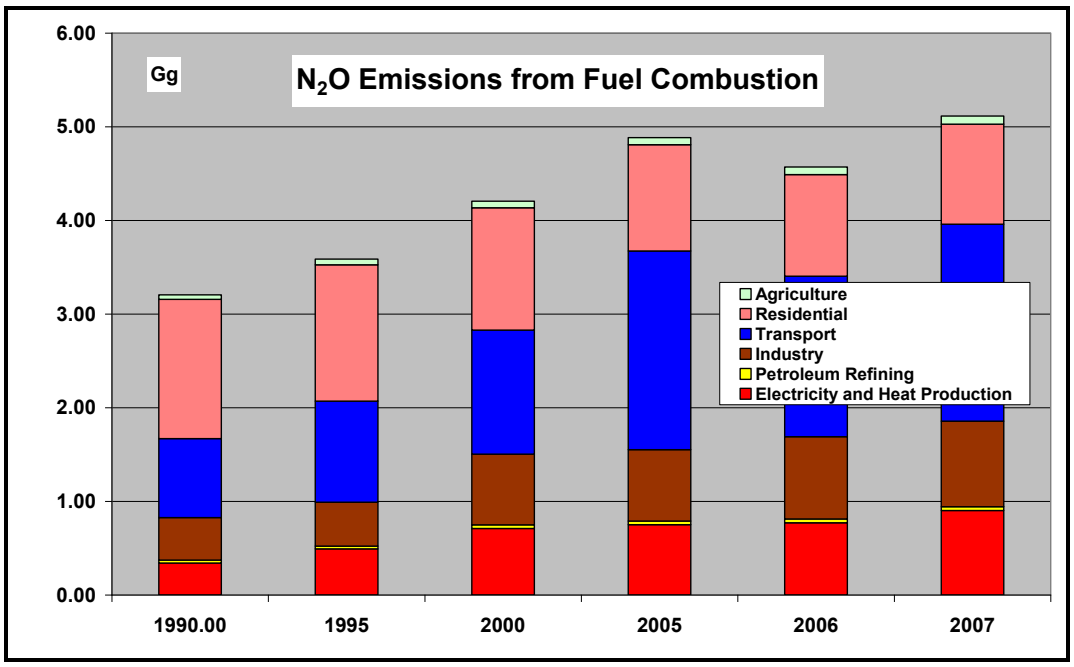

Figure 5.5 N_2O Emissions from Fuel Combustion

The source of non-energy N_2O emission from industrial processes was the chemical industry, especially the nitric acid production. Between the years 1990 and 2006, the N O emission trend shows a great variety and fluctuations. The main reason was the nitric acid demands changes in domestic markets.

5.4 Total CO Emissions

Total CO emissions showed an increase from 3.9 mton to 4.6 mton between 1990 and 2000, peaking in 1997 and then started to decrease down to 3.5 mton (Table 5.5). About 88% of total emissions are arising from fuel combustion. Transport and residential sectors are main drivers of these emissions.

Burning of agricultural residuals is main reason of CO emissions in the agriculture sector while metal production and chemical industry are main sources of Co emissions in the industry sector.

Table 5.5 Total CO Emissions (ttons)

	1990	1995	2000	2005	2006	2007	1990-2000 (%)	2000-2007 (%)	1990-2007 (%)
Total National Emissions and Removals	**3,917.00**	**4,932.93**	**4,587.68**	**3,612.84**	**3,652.23**	**3,514.75**	**1.59**	**-3.73**	**-0.64**
Energy	**3445.45**	**4,491.64**	**4,090.47**	**3,036.11**	**3,141.82**	**3,093.49**	**1.73**	**-3.91**	**-0.63**
Public Electricity and Heat Production	7.00	10.08	17.76	22.16	22.64	26.73	9.77	6.01	8.21
Petroleum Refining	0.76	0.74	0.97	0.98	1.09	1.39	2.43	5.34	3.62
Manufacturing Industries and Construction	40.68	41.62	73.44	78.04	93.18	100.33	6.09	4.56	5.45
Transport	1,513.51	2,610.13	2,350.43	1,473.43	1,591.85	1,532.09	4.50	-5.93	0.07
Residential	1,803.68	1,727.53	1,530.24	1,335.68	1,297.92	1,285.71	-1.63	-2.46	-1.97
Agriculture/Forestry /Fisheries	79.83	101.55	117.62	125.83	135.15	147.22	3.95	3.26	3.67
Industrial Processes	**16.46**	**17.78**	**13.37**	**14.79**	**13.17**	**4.37**	**-2.06**	**-4.78**	**-7.51**
Agriculture	**455.08**	**423.50**	**483.81**	**561.94**	**497.23**	**416.87**			
Land Use, Land-Use Change and Forestry	**0.01**	**0.01**	**0.03**	**0.00**	**0.01**	**0.02**	**6.73**	**-4.85**	**1.80**

5.6 Total NMVOC Emissions

Fuel combustion in transport and residential sectors followed by agriculture, fishery and forestry are main sources of NMVOC (Non-Methane Volatile Organic Compounds) emissions (Table 5.6).

The main sources of NMVOC emissions were road paving with asphalt, asphalt roofing, ammonia production, other chemical productions, iron and steel production, petroleum industry, pulp and paper, food and drink. The highest NMVOC emission was coming from the food and drink industries. The emission trend involves fluctuations throughout the years.

Table 5.6 Total NMVOC Emissions (ttons)

	1990	1995	2000	2005	2006	2007	1990-2000 (%)	2000-2007 (%)	1990-2007 (%)
Total National Emissions and Removals	**485.74**	**963.11**	**1,044.83**	**1,068.60**	**1,251.99**	**1,268.96**	**7.96**	**2.82**	**5.81**
Energy	**445.99**	**610.59**	**588.01**	**459.78**	**485.26**	**489.98**	**2.80**	**-2.57**	**0.55**
Public Electricity and Heat Production	1.81	2.61	4.63	5.66	5.76	6.77	9.86	5.58	8.08
Petroleum Refining	0.25	0.25	0.32	0.33	0.36	0.43	2.43	4.04	3.09
Manufacturing Industries and Construction	6.04	6.33	10.48	11.17	13.15	13.98	5.67	4.21	5.07
Transport	211.00	378.26	368.53	261.22	287.46	289.89	5.74	-3.37	1.89
Residential	210.92	202.84	180.52	156.23	151.51	149.46	-1.54	-2.66	-2.01
Agriculture/Forestry /Fisheries	15.97	20.31	23.52	25.17	27.03	29.44	3.95	3.26	3.67
Industrial Processes	**39.76**	**352.52**	**456.82**	**608.82**	**766.73**	**778.98**	**27.65**	**7.92**	**19.13**

5.7 Total SO_2 Emissions

Total SO2 emissions rose about 1.7 times with a considerably high annual growth rate of 5.7% between 1990 and 2000 but. Then, started to decrease with almost same annual growth rate in the second half (Table 5.7).

Table 5.7 Total SO_2 Emissions (ttons)

	1990	1995	2000	2005	2006	2007	1990-2000 (%)	2000-2007 (%)	1990-2007 (%)
Total National Emissions and Removals	**835.23**	**1,091.37**	**1,452.88**	**878.65**	**974.27**	**1004.27**	**5.69**	**-5.14**	**1.09**
Energy	810.80	1,059.65	1,421.91	860.57	954.30	973.17	5.78	-5.27	1.08
Public Electricity and Heat Production	789.56	1,034.23	1,398.99	831.14	922.25	936.51	5.89	-5.57	1.01
Transport	21.24	25.42	22.92	29.43	32.05	36.66	0.76	6.94	3.26
Industrial Processes	24.43	31.72	30.97	18.08	19.98	31.11	2.40	0.06	1.43

Fuel combustion from electricity and heat generation is responsible for about98% of total emissions. The reason of increase and decrease in emissions can be expressed with generation of electricity.

The following Figure 5.6 shows that emissions were rising when generation from fossil fuels increases in drought seasons while they were going down when hydro generation rise.

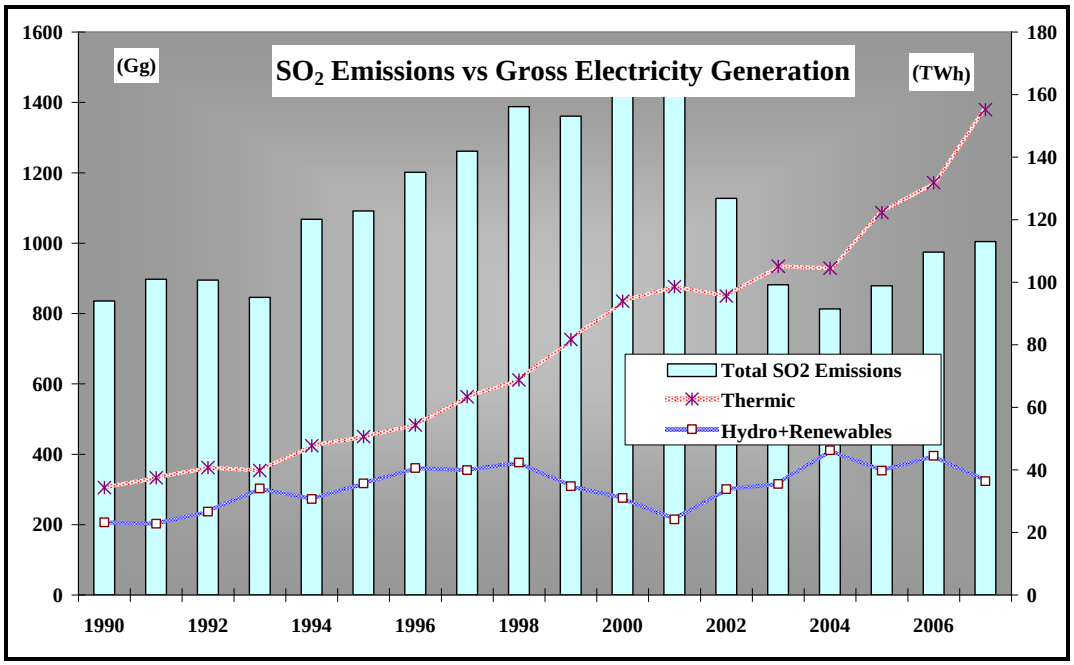

Figure 5.6 SO_2 Emissions from Fuel Combustion vs. Generation

CHAPTER 6

A DIFFERENT APPROACH IN CALCULATION OF EMISSIONS FROM FUEL COMBUSTION IN ELECTRICITY AND HEAT GENERATION

Chapter 5 deals with total greenhouse gas emissions and local pollutants officially submitted to UNFCC periodically.

TurkStat (Turkish Statistics Authority) is responsible for calculating and submitting greenhouse gas emissions coming from fuel combustion in energy sector. However, emission inventory of electricity and heat generation were prepared by the Electricity Generation Corporation between 2005 and 2007. Since 2008, the Directorate of General Energy Affairs (EİGM) related to the Ministry of Energy and Natural Resources (MENR) is the responsible body.

In calculations, TurkStat used energy balance sheets prepared by MENR while data from all thermic power plants having a capacity more than 50 MW have been used by EÜAŞ and EİGM. Tier 1 approach in The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories has been used although revised 2006 version was published since the later one is not advised by the secretary at present.

EÜAŞ was also responsible body in calculating and reporting local emissions of SO_2, NOx and particulate matters emitted due to fuel combustion up to the year 2007. Since 2007, the Directorate of General Energy Affairs has taken over. Country specific emission factors derived from coal analyses and data of emission measure equipments are being used in calculations.

In preparation of emission inventory, same activity data have to be used for all emittants in a specific year. However, the activity data used by TurkStat and EÜAŞ in calculation of emission was not same till 2004. The data on energy balance sheets was more aggregated in the previous years although separate data was available for each thermic power plant.

In addition, same carbon dioxide emission factor have been used for all oil products, even though there are separate emission factors in the IPCC Inventory Guidebook.

This chapter deals with those discrepancies and presents recalculated greenhouse emissions using plant data for each year.

6.1 Methodology

The methodologies used in the calculation of emissions are based on the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines).

The general method for estimating emissions can be described as following equation:

$$\textbf{Emissions} = \sum(\textbf{EF}_{ab} \times \textbf{Activity}_{ab}) \qquad \textit{(6.1)}$$

where:

EF = Emission Factor (kg/TJ);

Activity = Energy Input (TJ);

a = Fuel type; and

b = Sector-activity (Utility)

Emissions are calculated for each public and private power plant having a capacity over 50 MW.

6.1.1 Activity Data

In the study, the data collected by MENR was main source of activity data used. The total amount of each fuel type burned in power plants was compared with that in balance sheets for consistency. Table 6.1 presents the fuel used to produce electricity and heat in thermal power plants.

Table 6.1 Fuel Combusted in Electricity and Heat Plants (tons)

	Hard Coal	Lignite	Fuel Oil	Diesel Oil	LPG	Naphtha	Natural Gas
1990	30.357.818	29.883.584	1.133.804	21.430			2.555.583
1991	33.075.163	32.292.672	909.834	14.884			2.876.851
1992	36.656.650	35.317.534	1.525.179	13.506			2.616.944
1993	33.214.997	31.917.466	1.644.582	12.582			2.586.420
1994	41.141.204	39.700.538	1.716.673	12.490			2.927.147
1995	41.061.104	39.814.831	1.786.466	84.823			3.601.798
1996	43.917.030	42.440.748	1.844.298	106.878			3.791.404
1997	47.522.075	45.694.379	1.912.062	188.689			4.569.254
1998	53.999.337	52.114.989	2.117.739	262.719			5.157.015
1999	55.508.896	53.779.961	1.861.997	486.692			7.575.187
2000	55.087.370	53.311.900	2.870.216	549.848	86.750	135.841	9.885.117
2001	55.191.526	53.435.041	3.155.647	253.498	43.566	116.410	10.937.692
2002	44.117.358	42.576.239	3.180.701	98.374	9.521	219.122	11.556.750
2003	37.097.056	35.556.028	2.864.392	14.123	759	264.371	12.590.947
2004	35.104.263	33.776.660	2.403.338	29.141	12.673	208.749	13.325.721
2005	50.021.371	48.319.143	2.005.899	28.442	12.908	84.481	15.756.764
2006	52.275.102	50.583.810	1.746.370	61.501	33	13.453	17.034.548
2007	63.048.552	61.223.821	2.250.686	50.233		11.441	20.457.792

The total heat produced is calculated by using net calorific values (NCVs) of fuel burned. Table 6.2 summarizes annual weighted average NCVs for fuels. Due to that balance sheets consider a more aggregated value for net calorific values instead of weighted averages there are discrepancies between two data.

The quantities were first converted to energy units using NCVs from tons to giga calories then expressed as gigajoule using the conversion factor of 4.1868 Gj/Gcal.

Table 6.2 Net Calorific Values of Fuels by Year (kg/kcal-Sm^3/kcal)

	Hard Coal	**Lignite**	**Fuel Oil**	**(Diesel Oil)**	**LPG**	**Naphtha**	**Natural Gas**
1990	5.404	1.642	9.605	10.118	0	0	8.070
1991	4.722	1.609	9.605	10.285	0	0	8.062
1992	4.728	1.618	9.580	10.404	0	0	8.044
1993	4.870	1.735	9.588	10.300	0	0	8.076
1994	4.846	1.666	9.610	10.300	0	0	8.106
1995	4.719	1.634	9.575	10.300	0	0	8.237
1996	4.707	1.632	9.594	10.300	0	0	8.208
1997	4.754	1.704	9.577	10.300	0	0	8.282
1998	4.691	1.625	9.594	10.600	0	0	8.264
1999	4.958	1.583	9.594	10.569	0	0	8.293
2000	5.281	1.726	9.565	10.412	11.020	10.895	8.647
2001	5.164	1.714	9.612	10.316	10.949	10.738	8.667
2002	5.401	1.787	9.611	10.236	11.028	10.738	8.713
2003	5.215	1.778	9.566	10.293	10.540	10.566	8.881
2004	5.633	1.817	9.539	10.133	10.968	10.525	8.815
2005	5.228	1.675	9.604	10.299	10.540	10.594	8.907
2006	5.450	1.661	9.602	10.195	10.540	10.481	8.446
2007	5.395	1.639	9.523	10.299	10.540	10.310	8.329

6.1.2 Emission Factors

The following IPCC default emission factors were used in calculations (Table 6.4).

Table 6.4 IPCC Default (Uncontrolled) Emission Factors (kg/Tj)

	Hard Coal	**Lignite**	**F. Oil**	**D. Oil**	**LPG**	**Naphtha**	**Natural Gas**
CO_2	25.80	27.60	21.10	20.20	17.20	20.00	15.30
CH_4	1.00	1.00	3.00	3.00	3.00	3.00	1.00
N_2O	1.40	1.40	0.60	0.60	0.60	0.60	0.10
NOx r	300.00	300.00	200.00	200.00	200.00	200.00	150.00
CO	20.00	20.00	15.00	10.00	10.00	10.00	20.00
NMVOC	5.00	5.00	5.00	5.00	5.00	5.00	5.00

The amount of carbon that may remain unoxidized from combustion activities can vary for many reasons, including type of fuel consumed, type of combustion technology, age of equipment and operation and maintenance practices. 2 per cent of carbon in fuel consumed in unoxidized for coal, 1 per cent for oil-derived fuels and 0.5 per cent for natural gas used for electricity generation (IPCC 1996).

The following Table 6.5 gives the fraction of carbon oxidized having been used in the calculations.

Table 6.5 Fraction of Carbon Oxidised

Coal	0.98
Oil and Oil Products	0.99
Gas	0.995

Then the Equation 6.2 for calculating carbon emissions can be expressed as following:

$$\textbf{Emissions} = \sum(\ \textbf{Activity}_{ab}\ \textbf{x}\ \textbf{EF}_{ab}\ \textbf{x fraction oxidised}) \qquad \textit{(6.2)}$$

where:

Activity = Energy Input (TJ);

EF = Emission Factor (kg/TJ);

a = Fuel type; and

b = Sector-activity (Utility)

6.2 Recalculated Emissions

Using the above explained formulas emissions were recalculated and reported in Table 6.6. It can be shown that the difference were high between 1990 and 2000, especially due to difference in calorific values. Using different emission factors for oil products also resulted in small differences and can be observed from the tables after 2000.

Turkey is being forced to use higher approaches (Tier 2-3) and to produce its country specific emission factor for CO_2 emissions. In order to achieve this objective successfully, periodic ultimate and proximate fuel analysis have to be done and presented to the national team.

The team responsible for calculating emissions should be reinforced and the capacity must be increased via educational and training programs.

Table 6.6 Recalculated Direct and Indirect Greenhouse Gases and Difference Between that in CRF Tables (ttons)

	1990	1995	1999	2000	2003	2004	2005	2006	2007
CO_2 Emissions									
Hard Coal	692	1,492	2,265	3,053	7,270	9,738	11,009	11,456	12,466
Lignite	20,378	27,010	35,356	38,212	26,253	25,478	33,608	34,896	41,661
Oil	3,559	5,753	7,308	11,261	9,683	8,147	6,575	5,613	7,068
Natural Gas	4,820	6,934	14,682	19,975	26,133	27,452	32,800	33,625	39,878
Total	**29,450**	**41,189**	**59,610**	**72,501**	**69,340**	**70,816**	**83,993**	**85,590**	**101,073**
Total in CRF Tables	30,325	43,750	64,543	72,089	68,973	70,499	83,680	85,312	100,662
Difference	-876	-2,561	-4,933	411	366	316	313	278	411
CH_4 Emissions									
Hard Coal	0.007	0.016	0.024	0.033	0.078	0.105	0.119	0.124	0.134
Lignite	0.205	0.272	0.356	0.385	0.265	0.257	0.339	0.352	0.420
Oil	0.140	0.226	0.289	0.447	0.381	0.321	0.259	0.220	0.277
Natural Gas	0.086	0.124	0.263	0.358	0.468	0.492	0.588	0.602	0.714
Total	**0.439**	**0.638**	**0.933**	**1.223**	**1.192**	**1.175**	**1.304**	**1.298**	**1.546**
Total in CRF Tables	0.454	0.674	0.998	1.224	1.195	1.177	1.304	1.299	1.544
Difference	-0.016	-0.035	-0.065	-0.001	-0.003	-0.003	0.000	-0.001	0.002
N_2O Emissions									
Hard Coal	0.010	0.023	0.034	0.046	0.110	0.147	0.166	0.173	0.188
Lignite	0.288	0.381	0.499	0.539	0.371	0.360	0.474	0.493	0.588
Oil	0.028	0.045	0.058	0.089	0.076	0.064	0.052	0.044	0.055
Natural Gas	0.009	0.012	0.026	0.036	0.047	0.049	0.059	0.060	0.071
Total	**0.335**	**0.461**	**0.617**	**0.711**	**0.603**	**0.620**	**0.751**	**0.770**	**0.903**
Total in CRF Tables	0.342	0.493	0.675	0.711	0.604	0.621	0.750	0.770	0.902
Difference	-0.008	-0.032	-0.057	0.000	0.000	-0.001	0.001	-0.001	0.001
CO Emissions									
Hard Coal	0.149	0.322	0.489	0.659	1.568	2.101	2.375	2.471	2.689
Lignite	4.110	5.447	7.130	7.706	5.294	5.138	6.777	7.037	8.401
Oil	0.693	1.111	1.337	2.066	1.844	1.550	1.265	1.085	1.373
Natural Gas	1.727	2.484	5.260	7.157	9.364	9.836	11.752	12.048	14.288
Total	**6.679**	**9.364**	**14.216**	**17.587**	**18.070**	**18.625**	**22.170**	**22.642**	**26.751**
Total in CRF Tables	6.996	10.081	15.617	17.763	18.158	18.693	22.160	22.642	26.733
Difference	-0.317	-0.717	-1.401	-0.176	-0.087	-0.068	0.010	0.000	0.019
NMVOC									
Hard Coal	0.037	0.080	0.122	0.165	0.392	0.525	0.594	0.618	0.672
Lignite	1.027	1.362	1.782	1.926	1.324	1.285	1.694	1.759	2.100
Oil	0.233	0.376	0.482	0.746	0.635	0.535	0.431	0.367	0.462
Natural Gas	0.432	0.621	1.315	1.789	2.341	2.459	2.938	3.012	3.572
Total	**1.729**	**2.440**	**3.701**	**4.626**	**4.692**	**4.804**	**5.657**	**5.756**	**6.807**
Total in CRF Tables	1.807	2.615	4.025	4.628	4.699	4.808	5.655	5.756	6.768
Difference	-0.078	-0.175	-0.323	-0.002	-0.007	-0.004	0.002	0.000	0.039

CHAPTER 7

EVALUATION OF STATE OWNED COAL FIRED POWER PLANTS CONSIDERING COAL RESERVES

7.1 Reserves of Public Owned Coal Fields Allocated for Power Plants

As underlined in Chapter 4, all hard coal reserves are owned by TTK. Following the 2004 Mining Law, TTK is also able to transfer its rights to private undertakings, and some mines have been transferred to private undertakings under a royalty payment arrangement.

According to the Directorate of Mining Affairs (MİGEM), there are totally 449 licences for lignite fields. The Directorates of TKİ, EÜAŞ and Eti Maden, state owned companies, have 45, 3 and 1 operation licences respectively. Head of Private Administration has two and municipalities have 7 licences while the rest 391 licences are owned by private sector (Table 7.1).

Table 7.1 Number of Operation Licences by Owners

	TKİ	**EÜAŞ**	**Eti Maden**	**Private Administration**	**Municipalities**	**Private Sector**
Number of Licences	45	3	1	2	7	391

Source: MİGEM

According to the Figure 7.1, of the total 11,67 billion tons, EÜAŞ, TKİ and MTA have 4.85, 2.45 and 3,1 btons orderly. Though private sector has 87% of total licences, it corresponds only 10.6 % of total reserves.

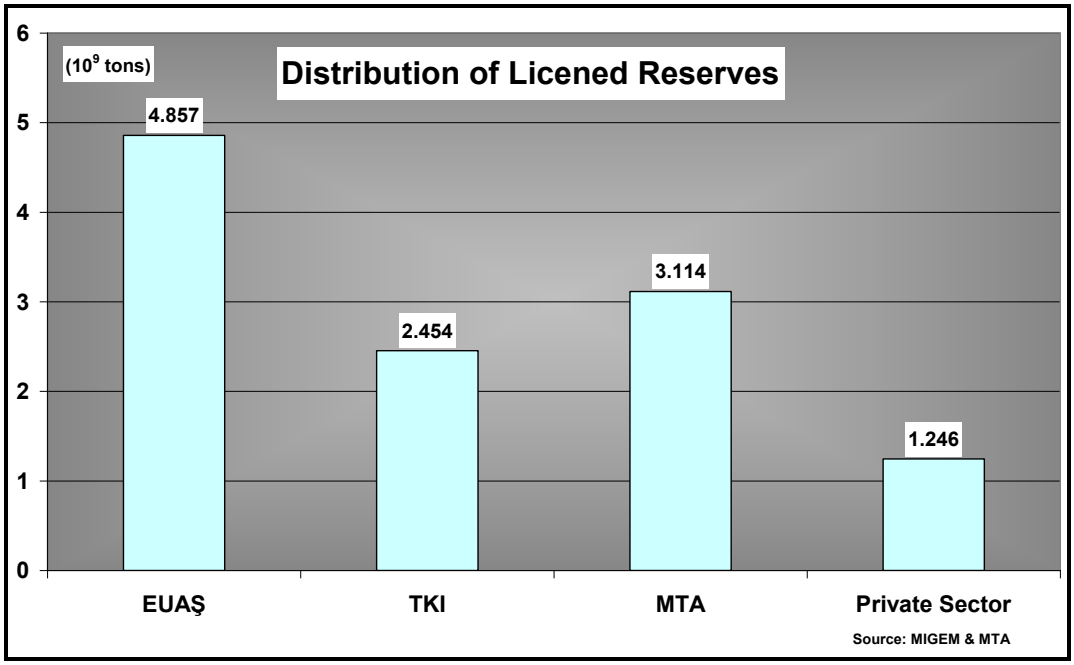

Figure7.1 Distribution of Licensed Lignite Fields (Source MİGEM)

A study within the Project named as the Development of Existing Mineral and Geothermal Reserves and Exploration of New Deposits was initiated by MTA in 2005. The main aim of the Project was to explore new lignite deposits within 20 districts including research and prospecting studies across 30,000 km^2 area together with 170,500 m of drilling from 2005 to 2010. The scope of the Project was then expanded and renamed as the Development of Mine and Geothermal Spring Reserves and Determination of New Deposits. After the studies a total of 4.138 btons of new reserves have been added to the total, 1.9 btons in Afsin-Elbistan basin, 1.28 btons in Karapınar-Konya basin, 170 mtons in Eynez-Soma-Manisa basin and 275 mtons in Alpu-Eskişehir basin. Studies are undergoing to classify the reserves.

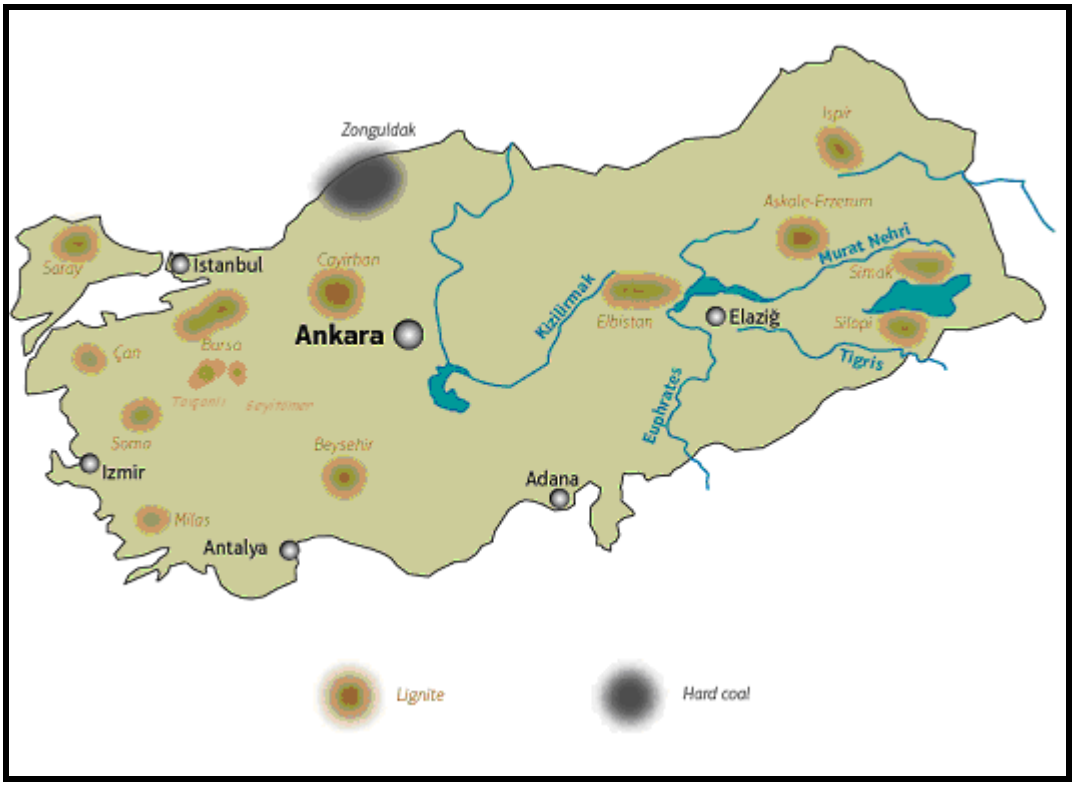

Figure 7.2 Coal Fields in Turkey

As mentioned in the Chapter 4 the biggest lignite reserves are found in Afsin-Elbistan basin (Figure 7.2). The coal field being operated by EÜAŞ is divided into 6 sectors and each of which allocated for a power plant.

Kışlaköy Sector is feeding Afsin-Elbistan A Thermic Power Plant while Çöllolar Sector is providing coal to Afşin-Elbistan B Thermic Power Plant which is constructed over Çoğulhan Sector.

In March 2007, the Elbistan-Çöllolar lignite deposit was tendered to the private sector by EÜAŞ to supply coal for Afşin Elbistan B Power Station. Kangal basin has also been operated by private sector via royalty. Çayırhan basin was privatized together with power plant excluding Koyunağlı field via Transfer of Operating Rights in 2000.

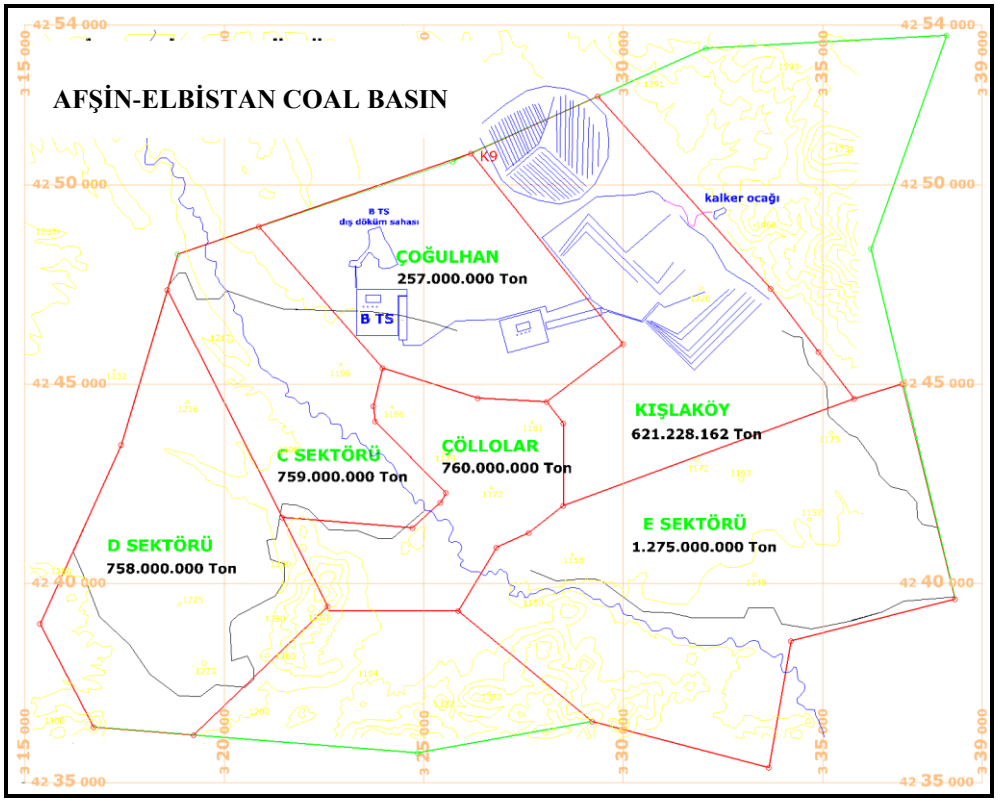

Figure 7.3 Afşin-Elbistan Coal Basin

Table 7.2 presents reserves and characteristics of lignite fields allocated for power plants. According to the table more than 70% of lignite reserves allocated for a power plant have a calorific value of lower than 1500 kcal/kg and higher high moisture of about 50%. This, in other words, creates environmental and operational problems. When considering non-uniform characteristics of coal, in order to operate a power plant effectively, good management of stock fields gains importance.

Even though all coal field feeding power plants are operated by TKİ excluding Afşin-Elbistan and Kangal basins most of the stock field have been operated by EÜAŞ, owner of public power plants. However, past trend shows that EÜAŞ has not been managing stock fields successfully. Lack of Mining engineers in power plant is one of main reasons. At present, it is planning to turn over management of all the stock field to TKİ.

Table 7.2 Reserves and Characteristics of Lignite Fields Feeding Power Plants

LOCATION	RESERVES (Million Tons)				CHEMICAL PROPERTIES				
	Proved	Possible	Probable	Total	Moisture	Ash	Sulphur	Volatile Matter	Net Calorific Value
					(%)	(%)	(%)	(%)	(kcal/kg)
K. Maraş-Elbistan Basin	**4,430**			**4,430**	**50.2**	**19.5**	**2.1**	**19-21**	**1145**
Kışlaköy (Sector A)	621			621	53.2	19.9	2.5		1031
Çöllolar (Sector B)	760			760	50.3	22.4	2.0		1156
Sector C	759			759	53.6	19.2	2.1		1114
Sector D	758			758	52.6	19.2	2.2		1201
Sector E	1,275			1,275	52.3	17.4	1.9		1176
Çoğulhan	257			257	50.3	22.4	2.0		1156
Sivas-Kangal Basin	**83.2**	**-**	**-**	**83.2**	**48-52**	**19-21**	**2.8**	**18-20**	**1282**
Kalburçayırı	53.3			53.3	50.0	21.0	2.0		1300
Etyemez	0.6			0.6	49.8	19.0	3.6		1494
Hamal	29.3			29.3	52.1	20.0	2.7		1207
Çayırhan Basin	**240**	**105**		**345**	**27.8**	**30.4**	**3.0**	**20-25**	**2592**
Field 1	154	19		173	22.2	35.0	3.7		2399
Field 2	58	74		132	26.4	25.4	2.8		2839
Koyunağlı Field	28	12		40	25.8	30.9	2.5		2539
TOTAL EÜAŞ	**4,753**	**105**		**4,858**					
Manisa-Soma	608	58		666	14.6	35.4	1.2	25.0	2827
Kütahya-Tavşanlı	283			283	15.0	41.0	1.6	25.0	2560
Muğla-Milas	278			278	30.1	24.9	3.1	26.7	2167
Muğla-Yatagan	161			161	30.6	25.6	2.7	27.4	2442
Kütahya-Seyitömer	153			153	32.6	42.4	1.2	22.1	2058
Konya-Ilgın	101	1		102	45.4	23.8	1.6	21.7	1340
Bursa-Orhaneli	78	20	2	99	29.5	25.3	2.8	17.9	2279
Çanakkale-Çan	83			83	23.0	25.0	4.2	30.0	3000
Others	507	141	0	648	40.5	24.8	1.7	21.9	1623
TOTAL TKİ	**2,251**	**219**	**2**	**2,472**	**27.5**	**30.6**	**1.9**	**24.1**	**2257**

Source: MENR

Within the TKİ's policy offering loss-making small mines and leasing currently unexploited reserves suitable for electricity generation to the private sector, production at eight small TKİ mines was stopped and they were leased to the private sector between 2002 and 2006.

The Çankırı-Orta Field was sold to the private sector while Bolu-Göynük, Tekirdağ-Saray and Bursa-Davutlar fields were leased to the private sector to produce coal for electricity generation.

Bolu-Göynük was awarded a generation licence from the Energy Market Regulatory Board and Environmental Impact Assessment (EIA) approved for power generation, but Bursa-Davutlar and Tekirdag-Saray failed to secure approval of an Environmental Impact Evaluation.

The following Table 7.4 presents candidate power plants awarded by TKİ. After realization of those projects, an additional 1685 MW capacity would be added to the present capacity. In other word about 11 TWh additional generation would result in decrease in import dependency.

Therefore awards for the failure ones have to be renewed as soon as possible.

Table 7.4 Candidate Power Plants awarded by TKİ

LOCATION	RESERVE (MTONS)	CAPACITY (MW)	LEGAL STATUS	BID YEAR	LEGAL STATUS
Tekirdağ-Saray	129	300	Royalty	2006	Licence for two units (2X150 MW) was obtained from EMRA. EIA process is failed.
Bolu-Göynük	39	270	Royalty	2006	For two units (2X135 MW), licence from EMRA and EIA from MoEF were obtained. Expropriation is underway. Construction agreement was signed but construction has not started.
Çankırı-Orta	51	170	Transfer of Rights of Licence	2005	Licence from EMRA and EIA from MoEF were obtained. Under award.
Koyunağlı-Mihalıççık-Eskişehir	41	270	Royalty	2007	For two units (2X135 MW), licence from EMRA and EIA from MoEF were obtained. Turn key agreement was signed and construction was started.
SİLOPİ (Harbul)	30	3X135	Royalty	2003	First unit commissioned in the first quarter of 2009. Licences for the other two were obtained from EMRA and turn key construction agreements were signed
ŞIRNAK	28	270	Royalty	2008	Licence and EIA applications for two units were done.
Total	**318**	**1685**			

Source: TKİ

At the beginning of 2008, TKİ had 15 active, 10 leased and 18 inactive mines with operating licences. The policy of leasing unexploited deposits to the private sector, or transferring the licences back to the government office if not successfully tendered, continues. In this frame, as given in Table 7.5, TKİ is conducting studies for the following possible projects.

Table 7.5 Possible Projects Towards Power Plant

Location	**Reserve (mtons)**	**Planned Minimum Capacity (MW)**	**Proposed Legal Status**	**Explanation**
Tufanbeyli-Adana	323	450	Royalty	Drillings were completed. Studies are going on
Karlıova-Bingol	88	75	Royalty	After bidding, no one gave order, so under re-evaluation
Kütahya-Seyitömer	50	175	Royalty	Negotiations are undergoing
Silopi (Üçkardeş.)	22	135	Royalty	Under project

Source: TKİ

According to EÜAŞ, the following projects, as shown in Table 7.6, would be realized as well and studies are undergoing to develop those projects.

Table 7.6 Possible lignite field owned by EÜAŞ

Location	**Additional Capacity Planned (MW)**
ÇATES	300
Çayırhan B	2X160
Orhaneli-Bursa	210
Seyitömer	150
Tuncbilek	300
Afsin-Elbistan C	4X350
Afsin-Elbistan D	4X350

Source: EÜAŞ

With the realization of possible projects import dependency of the country will decrease seriously and this would contribute to energy security as well.

7.2 Design Characteristics of State Owned Coal Fired Plants

It should be underlined once more that, in Turkey, all domestic lignite fired power plants are being operated by EÜAŞ except Çayırhan which is privatized in 2000, regardless of small scale cogeneration units mostly having a capacity lower than 20 MW. Out of Afşin-Elbistan, Çayırhan and Kangal, all the lignite mines feeding those utilities are being operated by TKİ. Sugözü, Çolakoğlu, İçdaş and Kahraman Maraş Kağıt are the other coal fired power plants using imported coal. Çatalağzı, under portfolios of EÜAŞ, is the only domestic power plant burning hard coal and TTK is the only owner of coal basin. Figure 7.4 shows the location of power plants in Turkey.

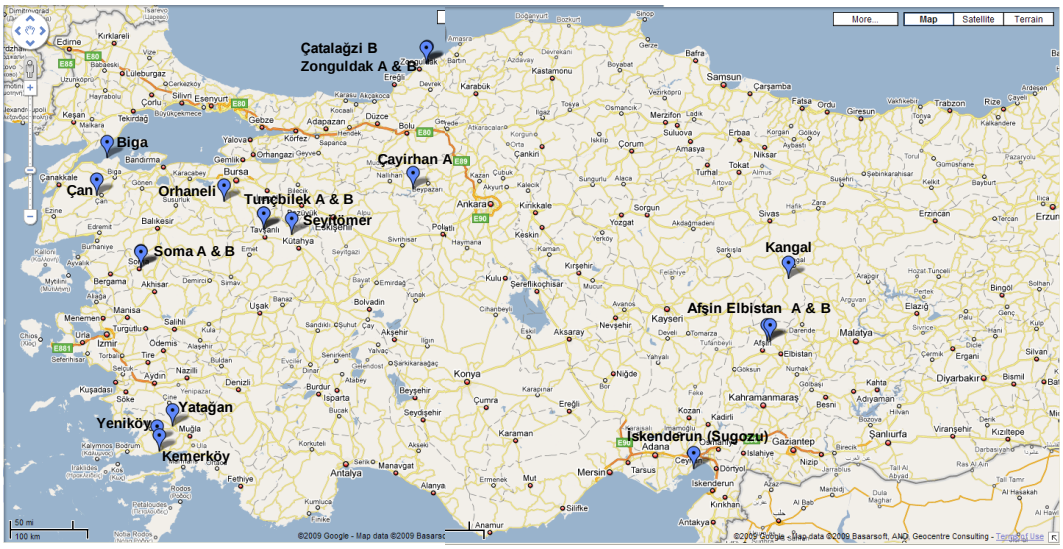

Figure 7.4 Location of Coal Fired Power Plans

Table 7.7 gives design characteristics of domestic coal fired power plants. It is important to point out that restructuring of electricity market did not only brought on splitting of TEAŞ into TEİAŞ, EÜAŞ and TEDAŞ in 2001 but also forced retirements and resignations of experienced persons from those companies and so caused loss of institutional memory. Therefore, there can be found different characteristic values for the same data.

Although life of power plants is usually designed as 30 years, they, in reality, operate more than 30 years due to some investments for wearing parts and for environmental concerns. For this reason, all the power plants are assumed to operate about 40 years and the rest of operating years after 2009 are estimated accordingly. In this frame, it can be seen from the following table that most of the coal fired power plants in Turkey are old.

This, in other word, means increasing need for investment in order to maintain higher efficiencies.

The third unit of Tuncbilek A, which is a very small scale plant, has already completed its life though it is still working. The other two units were run out and decommissioned in 2005. Like Tuncbilek A, two small scale units of Soma A are 52 years old, but still operating.

Even though the first three units of Seyitömer are almost completing their lives, due to new investments they will assumed to go longer.

Degrading of calorific value of coal in Kangal Basin resulted in modification of boilers .

Çan Thermic Power Plant is the only state owned utility having circulating fluidized bed, however private sector usually prefers such technology.

Table 7.7 Design Characteristics of Indigenous Lignite Fired Power Plants

Name of Utility	Installed Capacity (MW)	Date of Commissioning	Operating Years	Assumed Rest of Plant Life	Specific Heat Content (kcal/kWh)	Net Calorific Value (kcal/kg)	Electricity Generation	Fuel Consumption (gr/kWh)
Çatalağzı B	150	26.07.1989	20	20			975,000	
	150	05.02.1991	18	22			975,000	
	300			20	2652	2970	1,950,000	800
Afşin Elbistan A	340	07.07.1989	20	20			2,210,000	
	340	23.05.1984	25	15			2,210,000	
	340	25.01.1986	23	17			2,210,000	
	335	21.11.1987	22	18			2,177,500	
	1355			**18**	**2750**	**950-1300**	**8,807,500**	**2500**
Afşin Elbistan B	340	15.02.2005	4	36			2,210,000	
	340	15.02.2005	4	36			2,210,000	
	340	15.02.2005	4	36			2,210,000	
	340	15.02.2005	4	36			2,210,000	
	1360			**36**	**2208**	**950-1500**	**8,840,000**	**2000**
Çan	160	15.02.2005	4	36			1,040,000	
	160	15.02.2005	4	36			1,040,000	
	320			**39**	**2048**	**2600**	**2,080,000**	**850**
Kangal	150	22.12.1989	20	20	2364	1300	975,000	
	150	20.12.1990	19	21	2364	1300	975,000	
	157	09.06.2000	9	31			1,020,500	
	457			**30**	**2749**	**1300(±100)**	**2,970,500**	**2749**
Kemerköy	210	16.12.1993	20	20			1,365,000	
	210	31.05.1994	15	25			1,365,000	
	210	27.01.1995	14	26			1,365,000	
	630			25	2484	1750(±200)	4,095,000	1462
Orhaneli	210	05.01.1992	17	23	2750	2560(±100)	1,365,000	1300
			17	**23**				
Seyitömer 1-4	150	25.07.1973	36	4	2710	1750	975,000	1561
	150	06.03.1973	36	4	2710	1750	975,000	1561
	150	08.11.1977	32	8	2710	1750	975,000	1561
	150	16.02.1989	20	20	2320	1600	975,000	1478
	600			**20**	**2640**	**1,714**	**3,900,000**	**1540**
Soma A	22	26.06.1957	52	1			143,000	
	22	20.12.1958	52	1			143,000	
	44				**2866**	**3325**	**286,000**	**827**
Soma B	165	29.09.1981	28	12	2983	2400	1,072,500	1386
	165	02.08.1982	27	13	2983	2400	1,072,500	1386
	165	30.05.1985	24	16	2983	2400	1,072,500	1386
	165	20.02.1986	23	17	2983	2400	1,072,500	1386
	165	02.08.1991	18	22	2390	1550	1,072,500	1477
	165	25.03.1992	17	23	2390	1550	1,072,500	1477
	990			**25**	**2785**	**1967**	**6,435,000**	**1416**

7.3 Current Operating Characteristics of Indigenous Coal Fired Plants

Table 7.8 presents weighted average and/or sum data for the past performance of public owned coal fired plants. The power plants included are Çatalağzı, Afşin-Elbistan A, Afşin-Elbistan B, Çan, Kangal, Kemerköy, Orhaneli, Soma, Tunçbilek, Yatağan and Yeniköy thermic power plants.

Table7.8 Operating Characteristics of EÜAŞ Power Plants

	Gross Electricity Production (GWh)	Fuel Burned (ttons)	Operating Period (hr/year)	Load (MW)	Net Calorific Value (kcal/kg)	Specific Fuel Consumption (g/kWh)	Specific Heat Content (kcal/kWh)	Capacity Utilization Factor (%)	Time Utilization Factor (%)
2000	32,226	48,992	213,932	5220	1717	1520	2610	47.40	62.62
2001	31,754	49,552	207,605	5284	1684	1561	2628	46.71	60.77
2002	25,389	38,566	180,265	4946	1750	1519	2658	37.34	52.76
2003	20,710	31,527	144,725	4917	1723	1522	2623	30.46	42.36
2004	19,713	29,913	128,641	4880	1748	1517	2652	28.99	37.65
2005	27,390	44,352	154,875	4814	1627	1619	2634	40.29	45.33
2006	29,818	46,697	181,139	7345	1644	1566	2575	43.86	53.02
2007	35,811	56,939	229,602	6317	1612	1590	2562	52.67	67.21
2008	39,118	61,922	241,473	6398	1609	1583	2547	57.54	70.68
Design Values	**50,447**	**86,878**	**260,000**	**7761**	**1574**	**1722**	**2966**		
Theoric Values	**67,986**	**117,084**	**341,640**	**7761**	**1574**	**1722**	**2966**		

In the above table, data for total generation, fuel consumption and operating period are found by summing up power plant's data for each year. Net calorific value, i.e. lower calorific values on original basis, is the amount of heat released during the combustion of 1 kg of solid fuel at ^{0}C under the pressure of 760 Torr. It is calculated as weighted averages for each year using the following Equation 7.1:

$$NCV_{wa} = \frac{\sum (NCV \times F)_i}{Total\ Fuel\ Burned} \qquad (7.1)$$

Where NCV is net calorific value of a power plant *i* by any given year (kcal/kg),

F is fuel burned by power plant *i* (kg),

NCV_{wa} is weighted average of net calorific value for all power plants (kcal/kg) and

i is power plant

Specific heat content (SHC) is the ratio of the energy content of the fuel used to the electrical energy produced for a given period and formulated for each year as in the following Equation 7.2:

$$SHC = \frac{NCV_{wa} \times Total\ Fuel\ Burned}{Total\ Generation} \qquad (7.2)$$

Load is the ratio of generation by operating time in a year to that period and shows performance of a power plants.

Specific fuel consumption is the ratio of total fuel consumption within a year to total generation in that year.

Capacity utilization factor is the ratio of generation within a year to reference generation reflecting maximum generation within the same period. It is calculated dividing cumulative generation by theoric generation on the basis that a power plant can work theoretically 8760 hours per year.

Time utilization factor is the ratio of operating time to the reference time and calculated on the same basis as well.

There is a direct relation between utilization of state owned coal fired power plants and climatic conditions. As shown in Figure 7.2, in drought seasons generation from coal is increasing while in rainy seasons their generation is dropping down. Especially, the drought seasons Turkey faced with between 2007 and 2008 made coal fired plants operate in their maximum allowable capacities.

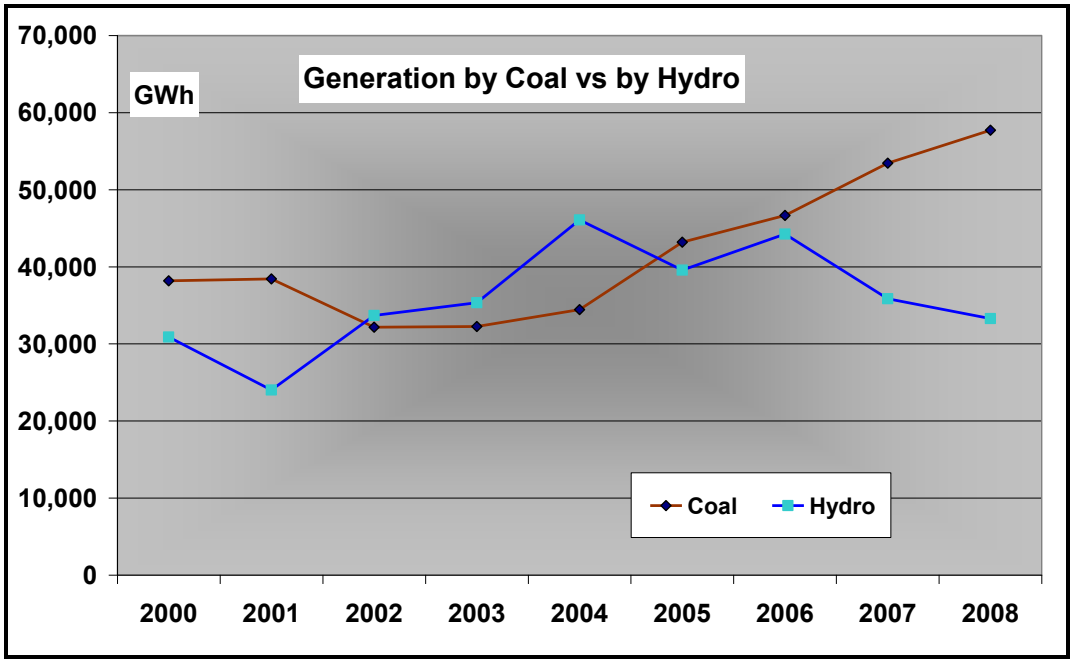

Figure 7.2 Electricity Generation by Coal and Hydro

7.4 Projecting Indigenous Coal Fired Plants Considering Reserves

7.4.1 Evaluation of Historical Data

Theoretically, a power plant can work maximum 8760 hours per year. However, when designing a power plant, usually a month is allocated for maintenance and some probable undesired breakdowns. Therefore, generally 6500 hours of operation period, i.e. a time utilization factor of 0.742 is accepted. A capacity utilization factor is also taken into account within that operation period. These two values help to determine the maximum operating period, maximum generation capacity and required fuel to be burned for a given power plant.

After looking at the past trend, it is seen that public thermic power plants in Turkey have been operated less than 6500 hours per year. In addition to wearing and management problems, seasonal behaviours like rainy years and pay or take agreements have also negatively affected that performance. Opposing of the State Planning Organisation to new investments putting forward privatization is another important factor.

The present power plants can be projected by looking at their last years of average generation or they can be projected using their design values. Their installed capacity and average working periods together can also be taken into account in their projections. There can be different combinations in projections. In this study, an average of previous years load is multiplied by operation period of 6500 in order to keep into view both time and capacity utilization factors.

Table 7.9 Historical and Calculated Load Data by Years (MW)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**Calculated Average**
Çatalağzı B	328	278	255	256	283	242	251	261	253	279
Afşin-Elbistan A	1,095	1,152	1,058	1,064	1,027	1,001	959	965	936	1,038
Afşin-Elbistan B							2,075	1,099	1,107	1,103
Çan							424	284	294	289
Kangal	405	464	386	348	370	353	367	369	370	368
Kemerköy	518	512	509	513	468	494	528	516	522	517
Orhaneli	220	198	182	180	176	181	177	179	188	196
Seyitömer	569	577	550	544	550	554	534	529	555	558
Soma B	849	829	845	848	814	779	798	789	812	822
Tunçbilek	285	332	264	273	321	326	333	381	384	377
Yatağan	571	563	530	528	508	529	532	562	590	572
Yeniköy	337	337	328	325	326	322	330	347	349	342
Total	**4,971**	**4,612**	**4,247**	**4,315**	**4,621**	**6,897**	**6,420**	**6,083**	**6,318**	**6,294**

Rainy and economically crises years have to be picked up from average, since those years will not reflect the real performance of power plants. So, operating periods of 2000-2001 and 2007-2008 are selected for the calculations

The above Table 7.9 shows past data and calculated load values for power plants while the belove Table 7.10 presents specific fuel consumption including past trend and calculated average. However, it is assumed that, data from latest operating years can best reflect specific fuel consumptions.

Table 7.10 Historical and Calculated Specific Fuel Consumption by Years (g/kWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2000-2008
Çatalağzı B	750	863	789	822	820	856	821	824	869	823.2
Afşin-Elbistan	2,318	2,348	2,474	2,375	2,575	2,686	2,417	2,473	2,577	2,421.1
Afşin-Elbistan							1,964	2,139	2,147	2,143.3
Çan							729	767	814	791.3
Kangal	2,201	2,154	2,154	2,242	2,223	2,248	2,284	2,331	2,396	2,230.4
Kemerköy	1,562	1,449	1,527	1,516	1,565	1,461	1,412	1,363	1,444	1,454.3
Orhaneli	1,013	987	950	1,043	1,004	1,003	1,113	1,230	1,114	1,077.4
Seyitömer	1,537	1,558	1,464	1,495	1,491	1,526	1,461	1,516	1,465	1,517.9
Soma B	1,364	1,401	1,385	1,227	1,361	1,484	1,441	1,282	1,284	1,337.9
Tunçbilek	990	1,001	878	958	1,055	959	1,028	839	908	861.0
Yatağan	1,293	1,278	1,377	1,348	1,420	1,298	1,359	1,323	1,260	1,286.9
Yeniköy	1,571	1,551	1,553	1,467	1,437	1,353	1,262	1,140	1,072	1,342.7
Total	**1,520**	**1,561**	**1,519**	**1,522**	**1,517**	**1,619**	**1,566**	**1,590**	**1,583**	**1,595**

Averages in the tables exclude Tunçbilek A Thermic Power plant since it is about at the end of its life. Soma A Thermic Power Plant is also excluded for the same reason. For Afşin-Elbistan A and Çan Thermic Power Plants latest two years are considered while the data between 2006 and 2007 is used for Kangal Thermic Power Plant in calculating averages.

7.4.2 Projections

One of the basic assumption in projecting generation is that a power plant works 6500 hours per annum in normal conditions. Using the average data in Table 7.9 and Table 7.10, first annual generation, then fuel consumption is calculated.

As mentioned in Section 7.2, remaining life of a power plant is found extracting operating years from 40, assumed total life. By the way, cumulative generation and fuel use are also forecasted.

It is known that some of the coal extracted is used for other purposes, such as steam production for manufacturing sector and space heating. The ratio of coal used for

other purposes is envisaged as 60% in Tunçbilek region, 40% in Zonguldak (Çatalağzı) region, 30% in Soma region while 10% in the other fields. The results are presented in the following Table 7.11.

Table 7.11 Forecasting Generation and Fuel Consumption

	Estimated Rest of Life (years)	Generation (kWh)		Fuel Consumed (tons)		
		Annual	Cumulative	Annual Thermic)	Cumulative Thermic	Cumulative Other
Çatalağzı B	20	1,811,985,830	36,239,716,599	1,490,494	29,809,890	19,873,260
Afşin-Elbistan A	18	6,744,502,045	121,401,036,806	17,030,302	306,545,427	34,060,603
Afşin-Elbistan B	36	7,171,440,013	258,171,840,463	15,370,838	553,350,164	61,483,352
Çan	39	1,878,936,256	73,278,514,002	1,486,839	57,986,726	6,442,970
Kangal	14	2,389,250,461	33,449,506,456	4,677,370	65,483,176	7,275,908
Kemerköy	25	3,361,492,921	84,037,323,030	4,951,490	123,787,240	13,754,138
Orhaneli	23	1,273,294,096	29,285,764,213	1,341,465	30,853,692	3,428,188
Seyitömer	20	3,626,416,550	72,528,330,996	5,449,026	68,112,821	7,568,091
Soma	25	5,344,591,737	133,614,793,421	7,249,793	181,244,826	77,676,354
Tunçbilek	10	1,634,422,780	16,344,227,802	1,406,626	14,066,265	9,377,510
Yatağan	15	3,719,443,890	55,791,658,343	4,905,931	73,588,963	8,176,551
Yeniköy	20	2,225,688,046	44,513,760,919	3,060,145	61,202,907	6,800,323
Total		**41,181,464,625**	**958,656,473,051**	**68,420,319**	**1,566,032,098**	**255,917,248**

According to the table, present coal fired public power plants would generate about 41.18 TWh per annum and need 68.4 million tons of coal for generation. Plants life is changing between 10 and 39 years affecting cumulative generation and consumption.

The second step is evaluation of the results together with coal reserves presented. It should be remind that, for each ton of saleable product, there are also losses coming from mining. Generally 10% for open-pit mines and 30% for underground mines are accepted as reasonable. Therefore, 35% loss for Tunçbilek mines, 30% loss for Zonguldak and Soma mines, , and 10% loss for other mines are considered in the calculations.

Table 7.12 presents total cumulative fuels consumed, total cumulative reserves exploited and remaining reserves after exploitation of those mines at the end of plants life. It can be seen easily that there would be still remaining reserves to be

allocated for power plants except Kangal Basin. Reserves within the Kangal Basin would be almost exhausted at the end of plant life which is envisaged as 14 years.

Table 7.12 Remaining Reserves After Decommissioning of Current Power Plants

Public Coal Fields	**Total Cumulative Fuel Consumed (tons)**	**Total Cumulative Reserves Explored**	**Reserves at the end of 2008**	**Reserves at the end of Plant Life**
		(tons)	**(tons)**	**(tons)**
Zonguldak Basin	49,683,150	70,975,928	534,620,488	463,644,560
Elbistan Basin (Sector A and B)	955,439,546	1,061,599,496	1,381,000,000	319,400,504
Çan Basin	64,429,695	71,588,550	82,924,000	11,335,450
Kangal Basin	72,759,085	80,843,428	83,200,000	2,356,572
Orhaneli Basin	34,281,880	38,090,978	99,401,000	61,310,022
Seyitömer Basin	75,680,913	84,089,903	152,509,000	68,419,097
Soma Basin	258,921,181	369,887,401	666,083,000	296,195,599
Tunçbilek-Tavşanlı Basin	23,443,775	36,067,346	283,017,000	246,949,654
Milas and Yatağan Basin	287,310,123	319,233,469	438,495,000	119,261,531
Total	**1,821,949,346**	**2,132,376,498**	**3,721,249,488**	**1,588,872,990**

The final step is allocation of the remaining reserves for new units. But, it is assumed that surface mining will be mostly replaced by underground mining at the end of plants lives in Soma and Tunçbilek regions.

At present about 30 million tons of reserves would be extracted by surface mining while the rest will be explored by underground mining. That is, before decommissioning existing plants, all the remaining reserves will be extracted by underground mining. Therefore instead of 35% mining losses, a 40% loss is accepted for forecasting new units.

Deniş Field, surface mining is being applied, in Soma basin would also be exhausted during operation of existing plants. For this reason with an additional 5% loses, totally 35% losses is assumed for exploration after decommissioning of plant life.

It is planned that underground mining will be dominant in the second planning period in Yatağan-Yeniköy Basin and so 30% mining losses instead of 10% is accepted.

For the other reserves, present losses are applied.

40 years of plant life is considered except Çan Basin where 30 years of a new unit is proposed.

The results of the new forecast study and proposals are presented in the following Table 7.13. In this table total cumulative fuel consumption includes, both thermic and other consumptions together with mining losses.

Table 7.13 Proposed New Units

Public Coal Fields	**Installed Capacity (MW)**	**Generation (kWh)**		**Fuel Consumption (tons)**		**Total Cumulative Reserves Explored (tons)**	**Reserves at the beginning of Projections (tons)**	**Reserves at the end of Plant Life (tons)**
		Thermic Annual	**Thermic Cumulative**	**Thermic Annual**	**Total Cumulative**			
Zonguldak Basin	360	2,340,000	93,600,000	1,924,826	128,321,722	183,316,745	463,644,560	280,327,815
Elbistan Basin (Sector A and B)	460	2,990,000	119,600,000	6,408,588	284,826,139	316,473,488	319,400,504	2,927,017
Çan Basin	55	357,500	10,725,000	282,897	9,429,892	10,477,658	11,335,450	857,792
Orhaneli Basin	180	1,170,000	46,800,000	1,232,641	54,784,023	60,871,137	61,310,022	438,886
Seyitömer Basin	140	910,000	36,400,000	1,367,359	60,771,512	67,523,902	68,419,097	895,195
Soma Basin	140	910,000	36,400,000	1,336,920	76,395,413	117,531,404	296,195,599	178,664,195
Tunçbilek-Tavşanlı Basin	160	1,040,000	41,600,000	895,051	89,505,087	149,175,146	246,949,654	97,774,509
Milas and Yatağan Basin	210	1,365,000	54,600,000	1,876,767	83,411,877	119,159,824	119,261,531	101,706
Total	**1705**	**11,082,500**	**439,725,000**	**15,325,048**	**787,445,665**	**1,024,529,304**	**1,588,872,990**	**564,343,685**

7.4.3 Remarks

The study shows that coal reserves in the Kangal Basin would be exploited totally after 14 years. However, first two units are almost 20 years old and the third one is 10 years old. This means that the units can work more than the reserve life. The fuel to be needed for the power plants has to be planned before exhausting the reserves.

Zonguldak, Soma and Tunçbilek have to be considered separately. Geologic conditions and administrable concerns are main obstacles over increasing production in Zonguldak region.

Eynez and Deniş Fields are the two largest coal fields having reserves of 380 and 160 million tons orderly. Explored Eynez coals and some little Deniş coals are dressed in two washing units, then sold to industry and residential sectors. The tailings of washing units are sent to the power plant. Most of Deniş coals are also directly sent to the power plant. This, in other words, means that Deniş Field will be exhausted during planning forecast period. The remaining fields have high calorific value and can be used for different purposes. A small unit might be constructed and fed by washery tailings and remaining other fields.

Therefore, the best way of forecasting Soma and Tunçbilek Basins is forming a detailed district plan and requires carefully management of mining and well established coordination with power plant

Kışlaköy and Çöllolar Sections of Elbistan Basin have also large reserves being able to feed a power plant having a capacity of 460 MW for about 40 years. In reality, the borders of the sections have to be drawn accordingly with new founded reserves.

High amount of coal will also remain in Milas-Yatağan Basin. Since underground mining would be applied in the region, only a unit having 210 MW is considered.

New units of 180 MW and 55 MW are also forecasted for Seyitömer and Çan regions. The new unit proposed for Seyitömer can be higher when taking into account the two old units of Seyitömer

When looking at the electricity demand to be needed in the forthcoming years, those units would contribute to decrease Turkey's energy dependency.

Elbistan, Çan, Orhaneli and Kangal regions the new units can be constructed before end of plant life, since it would be easier to increase production in open pit mines.

For the others a well designed district plans have to be applied in order to use reserves efficiently, especially in forecasting new units.

It should be underlined that best available clean coal technologies having higher efficiency have to be choosen in planning new units.

Investments required for the present units have to be put into operation as soon as possible. EÜAŞ is claiming that after investments there can be an extra capacity of 10 TWh per year. But, a well established investment plan including alternatives has to be prepared before initiating such an investment.

CHAPTER 8

CONCLUSIONS

Fossil fuels are main energy source throughout the world. Spreading widely, easy transportation, cheap cost of handling and lower price make coal advantageous over the other fuels.

Despite representing just 1% of the total production, renewable sources, excluding combustible ones, registered the most pronounced growth rates. In 2007, wind generation increased by 32%, solar thermal generation by 15% and solar photovoltaic by 48%.

In 2007, the top-five countries produced together half of the global GDP (in purchasing power parity), consumed 51% of total world energy and accounted for 46% of the total population.

Chine and India are new actors with their very fast growth and consumption rates.

The world global CO_2 emissions was doubled with an annual average growth rate of 0.28% from 14 btons to 28 btons between 1971 and 2007.

Fossil fuels are also main energy source in Turkey. However, indigenous sources are limited and so it has becoming more and more energy dependent.

Natural gas has entered the country's life in the second half of the 90s at a considerably fast pace.

Despite the economic crises Turkey faced with, she has been developing with a considerably high growth rate, making energy and electricity demand increase

Emissions have also increasing in parallel with Turkey's development.

Although Turk-Stat is responsible body in reporting the Turkey's emissions, there are differences between the activity data used for different gases. Therefore, all direct and indirect emissions are recalculated. MENR and TurkStat should consider using, Tier-2 and, if possible, Tier-3 approaches instead of using Tier-1 in the forthcoming calculations..

All lignite fired power plants except Çayırhan are state owned and constructed near coal fields. The reserves are exploited by TKİ except Afşin-Elbistan and Kangal.

The planned new indigenous coal fired plants have to be awarded as soon as possible in order to decrease import dependency.

Capacity factors and loads of all power plants are lower than their design values. Since most of them are old, they need investments. Privatization is main obstacle for new investments.

The present coal fired power plants is estimated to produce an electricity of about 41 TWh per annum that means a 1.6 billon tons of coal to be fired and when considereing other purposes, a total of 1.8 billion tons of coal to be consumed.

An additional production of 11 TWh per annum requiring 15 million tons of coal to be burned is also proposed. However, only in Elbistan, Çan, Orhaneli and Kangal regions the new units can be constructed before end of plant life, since it would be easier to increase production in open pit mines.

For the others a well designed district plans have to be applied in order to use reserves efficiently, especially in forecasting new units.

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