CRITICAL EVALUATION OF THE ENERGY RESOURCES OF TURKEY WITH RESPECT TO THE WORLD PROSPECTS

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ABSTRACT

CRITICAL EVALUATION OF THE ENERGY RESOURCES OF TURKEY

WITH RESPECT TO THE WORLD PROSPECTS

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Existing petroleum and natural gas reserves, which are the major supplies of primary energy demand of the world, are cumulated in a few countries. This causes a serious supply security problem for many countries. On the other side, greenhouse gas emissions caused by mainly fossil fuels are gradually increasing to a point which jeopardizes the future of the earth. By now, countries have to consider both their supply security and this global environmental problem while planning their energy future. For Turkey, a developing country, economic growth is to be added as a third parameter of the solution of this energy equation. In this study, firstly, Turkey's existing fossil and alternative energy resources potential is examined. In the second part, international acts against climate change problem and Turkey's position in this issue is analyzed. In the third part, the relation between economic growth, energy and environment is discussed. Finally, in consideration with supply security, climate change and economic growth, a brief analyze for Turkey is performed. Study shows that these three parameters are strongly interconnected, especially for fossil resources this leads to some conflictual situations. Comparing with OECD countries, energy is an important factor for economic growth in Turkey. Depending on this fact, Turkey can better give priority to supply security and take an environmental responsibility appropriate to its special condition. It is concluded that Turkey should start with the emission mitigation methods which do not threaten the supply security much, such as forestation, energy conservation and efficiency. Since coal is predicted to continue its popularity in the future, clean coal technologies and carbon capture-storage options gain more importance. For long term, state-sanctioned utilization of renewable resources and carefully planned nuclear development are found to be the most promising solutions for replacing coal and imported natural gas in power generation.

Keywords: Supply Security, Climate Change, Economic Growth, Energy Resources of Turkey, Renewable Energy

ÖZ

DÜNYADAKİ GELİŞMELER IŞIĞINDA TÜRKİYENİN ENERJİ KAYNAKLARININ GÜNCEL BİR DEĞERLENDİRMESİ

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Mayıs 2010, 138 sayfa

Dünya enerji talebinin önemli bir bölümünü karşılayan petrol ve doğalgaz rezervleri az sayıda ülkede toplanmış durumdadır. Bu durum birçok ülke için ciddi bir arz güvenliği riski oluşturmaktadır. Öte yandan çoğunluğu fosil yakıt kullanımından kaynaklanan seragazı emisyonları dünyanın geleceğini tehdit eder boyutlara ulaşmış durumda. Artık ülkeler enerji geleceklerini planlarken hem arz güvenliğini hem de bu küresel çevre problemini göz önünde bulundurmak zorundalar. Türkiye gibi gelişmekte olan ülkeler için ekonomik büyüme de üçüncü bir parametre olarak bu enerji denklemine eklenmelidir. Bu çalışmada öncelikle Türkiye'nin fosil ve alternatif enerji kaynakları potansiyelleri ve rezervleri incelendi. İkinci bölümde iklim değişikliği sorununa karşı uluslararası girişimler ve Türkiye'nin konumu analiz edildi. Üçüncü bölümde ise ekonomik büyümenin enerji ve çevreyle ilişkisi tartışıldı. Son olarak arz güvenliği, iklim değişikliği ve ekonomik büyüme parametreleri göz önünede bulundurularak Türkiye için bir enerji analizi yapıldı. Çalışma gösteriyor ki bu üç parametre birbirleriyle sıkı bir şekilde ilişkili ve bu ilişki özellikle de fosil kaynaklar söz konusu olduğunda tartışmalı durumlara sebep verebiliyor. OECD ülkeleriyle karşılaştırıldığında enerjinin Türkiye'nin büyümesinde önemli bir yere sahip olduğu görülüyor. Buna dayanarak Türkiye bu tartışmalı durumlarda arz güvenliğine öncelik verebileceği gibi çevresel anlaşmalarda da kendi şartlarına uygun bir sorumluluk üstlenebilir. Türkiye için arz güvenliğini çok tehlikeye atmayacak ağaçlandırma, enerji tasarrufu ve verimliliği gibi emisyon azaltım metotlarından başlamak daha uygun olacaktır. Kömürün yakın gelecekte de önemini

koruyacağının öngörülmesi karbon yakalama - depolama metotları ve temiz kömür teknolojilerinin önemini artırıyor. Uzun vadede ise özellikle elektrik üretiminde doğal gaz ve kömür bağımlılığından kurtulmak için devlet destekli bir yenilenebilir enerji atılımı ve iyi planlanmış bir nükleer gelişim en umut vadeden çözümler olarak görünüyor.
Anahtar Kelimeler: Arz Güvenliği, İklim Değişikliği, Ekonomik Büyüme, Türkiye'nin Enerji Kaynakları, Yenilenebilir Enerji

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CHAPTER 1

INTRODUCTION

With the industrial revolution in the 19th century, a transition began especially in Western Europe and North America from human and animal labour based production towards machine-based production. For several years coal was the main energy resource for generating the steam power necessary for the machines and also for electricity. In the 20th century, coal has lost its importance by the increasing availability of economical petroleum. Being a major fuel for transportation and having many areas of use, petroleum dominated all other energy sources in the 20th century. However, nowadays, this petroleum-dependent industry feels itself in danger in terms of supply security due to the decreasing reserve-production ratio over years.

By the population growth, urbanization and industrialization, consumption overwhelmingly increased and therefore the energy demand and production. On the other side, environmental awareness has not developed as rapidly as the industry and the population. In the late 1970's, majority of countries came to an agreement that the world is getting warmer and climate is changing due to the greenhouse gas percentage increase in the atmosphere originating from mainly human activities like fossil fuel usage and deforestation.

Supply security problems and environmental limitations are forcing countries to launch a new transition period from fossil fuel based production to a production supplied by alternative energy sources which are more clean, abundant and renewable. However, none of the energy sources seem to satisfy the increasing demand alone. Furthermore, some countries have economic priorities rather than environmental concerns. Therefore, the solution is not obvious this time. Solution requires both global agreement and local efforts and strategies.

Today’s energy problem has no explicit solution. However determining the parameters of the problem and the relations between them is a good starting point in order to walk through the most convenient direction on the way for solution. In this study, supply security, climate change and economic growth are thought to be the main important parameters in the energy problem. However, it is possible to add many more parameters such as politics, international trade etc. when defining the problem. It can be said that energy problem could not be analyzed properly without politics; on the other hand including politics would make the situation more complex and unpredictable.

Turkey, a developing country, has recently joined the international agreement, Kyoto Protocol and will probably be subjected to some environmental restrictions in the near future either by a new protocol or by EU, as a candidate country. Therefore, Turkey has to find a way to satisfy both the increasing energy demand driven by rapid growth and the emission reduction expectations of the international bodies. In order to build an appropriate strategy for Turkey, it is necessary to determine the potential of the energy resources of the country considering the environmental and economic aspects related with energy.

CHAPTER 2

ENERGY RESOURCES

2.1 Fossil Resources

2.1.1 Petroleum

Petroleum is a naturally occurring fossil fluid found in underground rock formations. It is composed of mainly hydrocarbons and some organic compounds such as nitrogen, oxygen, sulphur. Due to its high energy density, easy transportability and availability, oil is one of the most used energy in the world **[1].** The viscosity of oil is important. Crude oil can be categorized whether it is heavy or light. Lighter oil is extracted by conventional oil well drilling methods. However, it is more difficult and energy consuming to extract heavier unconventional oils like oil sands and oil shales. Oil sand (tar sand) is a very heavy and sticky form of oil and can be found in semi-solid form mixed with sand and water. Oil shale is an organic-rich fine-grained sedimentary rock containing significant amounts of kerogen (a solid mixture of organic chemical compounds) from which technology can extract liquid hydrocarbons (shale oil) and combustible oil shale gas **[2]**. Since the conventional oil resources are depleting, unconventional reserves seems to be a considerable alternative in the near future**.**

World Petroleum Facts

Oil reserves are classified as proven, probable and possible. Proven reserves are generally intended to have at least 90% or 95% certainty of containing the amount specified. Probable reserves have an intended probability of 50%, and the possible reserves an intended probability of 5% or 10% **[3].**

By the end of 2008 oil proven reserves of the world is estimated by BP as 1258 billion barrels **[Table 1].** According to the Oil & Gas Journal, as the beginning of 2009, world proved oil reserves were estimated at 1,342 billion barrels **[Table 1].** The huge difference between the BP's and Oil and Gas Journal's reserve estimates is originating from including or excluding the 150 billion barrels of oil sand reserves of

Canada. According to the Oil & Gas Journal, 56 percent of the world's proved oil reserves are in the Middle East **[Figure 1].** Just less than 80 percent of the world's proved reserves are concentrated in eight countries **[Table 1].** Global proved oil reserves in 2008 fell by 3 billion barrels, with an R/P ratio of 42 years **[4].**

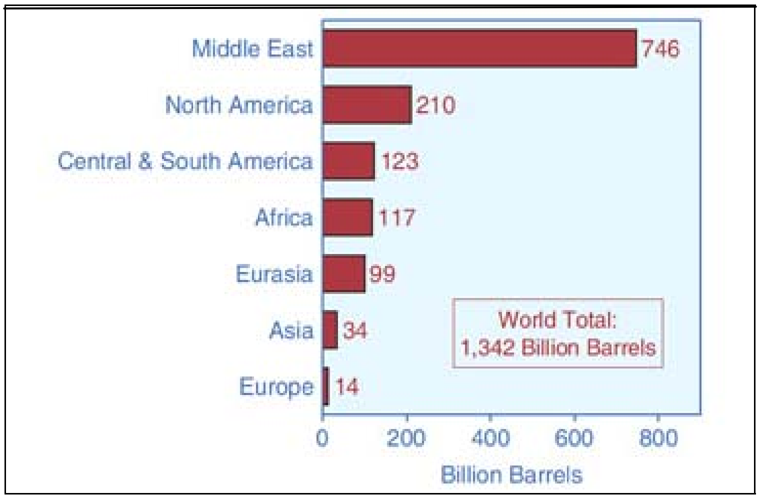

Figure 1: World proven oil reserves by geographic regions [5]

Table 1: World proven oil reserves [6, 7]

COUNTRY	BP Statistical Review end of 2008	Oil & Gas Journal January 1,2009	World Oil Year-End 2007	Share of Total
Saudi Arabia	264,209	266,710	264,825	21,0
Iran	137,620	136,150	137,000	10,9
Iraq	115,000	115,000	126,000	9,1
Kuwait	101,500	104,000	99,425	8,1
Venezuela	99,380	99,377	81,000	7,9
UAE	97,800	97,800	68,105	7,8
Russia	79,049	60,000	76,000	6,3
Libya	43,663	43,660	36,500	3,5
Kazakhstan	39,828	30,000	not reported	3,2
Nigeria	36,220	36,220	37,200	2,9
United States	30,460	21,317	21,317	2,4
World Total	**1.257,984**	**1.342,207**	**1.184,208**	**100,0**

Most of the easy-to-extract oil has been found **[8].** Due to the recent increases in oil prices after 2008, exploration activities in difficult locations (such as deeper wells, high downhole temperatures and locations where high technology is required) are increased**.** Unconventional oil is becoming an alternative by the increasing prices and decreasing recoverable conventional oil reserves. Nearly, 70 % of the world oil reserves are unconventional heavy oil **[Figure 2].** However, unconventional oil requires extra energy to refine, resulting in higher production costs and up to three times more greenhouse gas emissions per barrel **[9].**

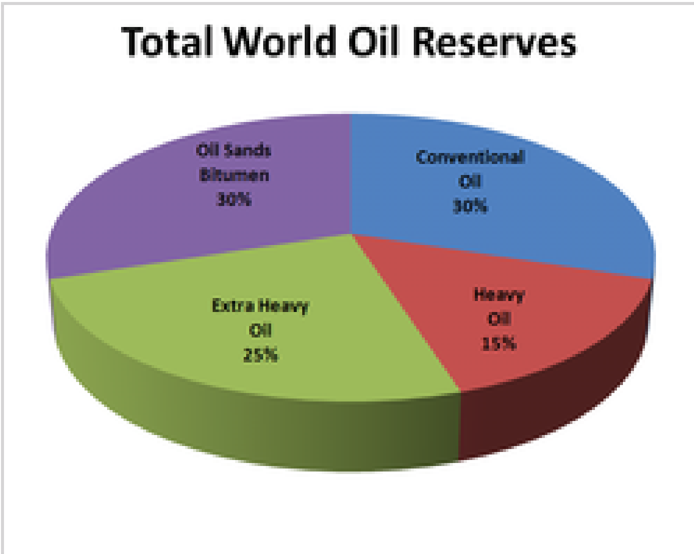

Figure 2: Total world oil reserves [10]

World wide oil discoveries have been less than annual production since 1980 **[11].** M. King Hubbert, who devised the peak theory, predicted in 1956 that oil production would peak in the United States between 1965 and 1970 and after that the production will start to a decline until the oil totally ends **[12].** His predictions became real. He predicted in 1974 that the world total production will come to a peak point in 1995 "if current trends continue" [**13**]. This time he was not successful, because the current trend had changed in the meantime. However, after Hubbert, a lot of people and institutions have tried to predict the peak point of the world oil production in order to act against a possible oil crunch. Here are some common peak oil predictions:

The Association for the Study of Peak Oil and Gas (ASPO), 2010 **[14]**

Sadad Al Husseini, former head of Saudi Aramco's production and exploration, 2006 **[15]** (which means peak level has already been reached)

The Energy Watch Group, a German research group, 2006 **[11]**

The UK Industry Taskforce on Peak Oil and Energy Security (ITPOES), 2013 **[16]**

In 2009, the IEA predicted a peak by 2020 with severe supply-growth constraints beginning in 2010 **[17].**

Whether optimistic or pessimistic, most of the predictions point out a latest peak around the year 2020.

In 2008, global oil production increased by 380,000 b/d while OECD production fell by 750,000 b/d. OPEC production increased by 990,000 b/d despite production cuts late in the year. **[4].** However, Worldwatch Institute observes that oil production was in a decline trend in 33 of the 48 largest oil-producing countries in the past few years **[Figure 3] [18].**

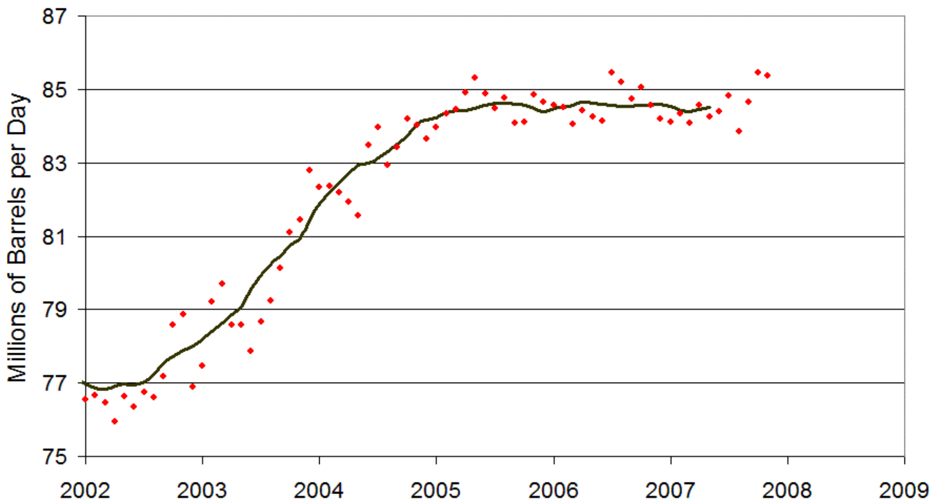

Figure 3: Total world oil production [19]

World crude oil demand grew an average of 1.76% per year from 1994 to 2006. In 2008, world oil consumption fell by 420000 b/d, the largest decline since 1982. OECD consumption fell by 1.5 million b/d, driven by a decline of nearly 1.3 million b/d in the US. However this decline is the result of the global economic recession and it is predicted to be a temporary decline. China again recorded the world's largest incremental growth, rising by 260.000 b/d despite the economic crisis. World demand for oil is projected to increase 37% over 2006 levels by 2030 (118 million barrels per day from 86 million barrels, mainly due to increases in consumption of the transportation sector) **[16, 20].**

Table 2: Top world oil consumer countries [21]

Top World Oil Consumers, 2008 (thousands barrel per day)		
Rank	**Country**	**Consumption**
1	United States	19,498
2	China	7,831
3	Japan	4,785
4	India	2,962
5	Russia	2,916
6	Germany	2,569
7	Brazil	2,485
8	Saudi Arabia	2,376
9	Canada	2,261
10	Korea, South	2,175

Despite the high growth rates of demand in the developing countries, the USA is still the world's largest consumer of petroleum **[Table 2][21]**. U.S. consumption grew from 17.7 million barrels a day to 20.7 million barrels a day between 1995 and 2005, **[22].** Rapid growing economies such as China and India are quickly becoming large oil consumers **[23].** India's oil imports are expected to more than triple from 2005 levels by 2020**[24].**

Table 3: Top world oil net importers [25]

Top World Oil Net Importers, 2008 (thousands barrel per day)		
Rank	**Country**	**Imports**
1	United States	10,984
2	Japan	4,652
3	China	3,858
4	Germany	2,418
5	Korea, South	2,144
6	India	2,078
7	France	1,915
8	Spain	1,534
9	Italy	1,477
10	Taiwan	939
11	Singapore	925
12	Netherlands	891
13	Belgium	706
14	Turkey	629
15	Thailand	572

Situation in Turkey

As of January, 2009, Turkey's proved oil reserves are at 300 million barrels and located mostly in the south-eastern region**.** Oilfields in the Southeast Anatolia (Hakkari Basin) are old and expensive to exploit, and production costs in Turkey are considered quite high **[26]**. Turkey's oil reserve is very limited and oil quality is low. Oil production is far from meeting the demand of the country. Turkey's 2007 domestic production produced only 8.7 percent of the nation's crude oil annual requirements of 200 million barrels **[27]**.

Since its peak in 1991, oil production in Turkey has continued its downward trend, reaching 2160 thousand tons in 2008 **[Table 4]**. Oil production of Turkey has been decreased by 24% during the last decade **[Figure 4]**.Since there are no further significant explorations and existing fields are very old, this decreasing trend is expected to continue in the next decade. Considering the current production rates, without exploration of new fields, Turkey's crude oil reserves is predicted to finish in 19,3 years time **[28]**.

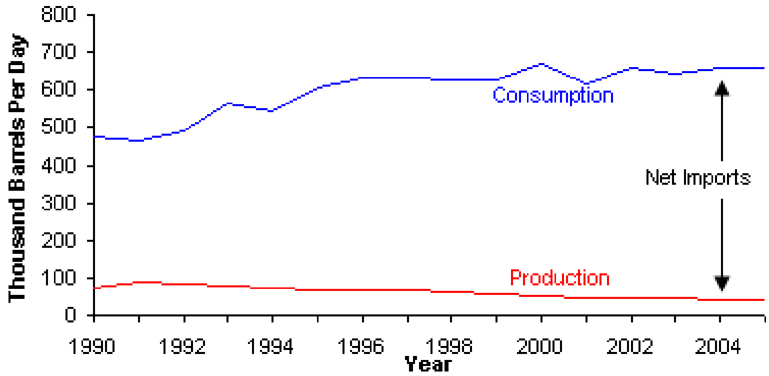

Figure 4: Turkey's oil production and consumption, 1990-2005 [26]

Turkey’s state-owned company Türkiye Petrolleri Anonim Ortaklığı [Turkish Petroleum Corporation)(TPAO) and foreign operators Royal Dutch/Shell and Exxon Mobil account for the majority of Turkey’s oil production. While TPAO currently pumps about 80 percent of Turkey’s production, operating more than 45 oil fields in the Siirt, Diyarbakir, Gaziantep and other southeastern provinces, its current production remains a drop in the bucket **[27]**.

Table 4: Crude oil activities in Turkey [thousand tones][29]

year	crude oil production	crude oil imports	total	refined crude oil	obtained products	imported products	exp. products	comsump.
1990	3716	20061	23778	22981	22169	2168	2075	21722
1991	4451	17606	22057	22557	21789	2191	2858	21160
1992	4280	19315	23596	23317	22696	2267	2052	22855
1993	3892	21769	25661	25670	24979	3716	2264	26075
1994	3686	21198	24884	24971	24205	2654	2124	24758
1995	3515	23510	27026	27039	26528	2978	1686	27160
1996	3499	22915	26415	26458	25454	5094	1630	28280
1997	3456	23336	26793	26668	26073	4602	1629	28255
1998	3223	23735	26959	27133	26654	5022	2074	28125
1999	2939	22983	25923	26162	25413	5585	2458	27661
2000	2749	21671	24420	24204	23646	8622	1323	29889
2001	2551	23242	25794	2586	25314	5791	2449	28630
2002	2441	23661	26103	26119	25345	7534	2768	29334
2003	2375	24096	26471	26488	25788	8111	3556	29909
2004	2275	23830	26105	25986	25374	9714	3824	30627
2005	2281	23389	25670	25489	24996	10403	4857	29486
2006	2175	23753	25929	26192	25275	11810	6237	29908
2007	2134	23445	25579	25589	24985	13018	6576	30942
2008	2160	21724	23884	24008	24345	13605	7621	29825

Turkey's oil consumption has continued to grow and reached a peak of 690,000 bbl/d in 2007, far exceeding the domestic production levels **[Figure 4].** Approximately, 42% of Turkey's total energy needs have been fulfilled by oil and roughly 90% of Turkey's oil supplies are imported **[30]**. In 2007, Russia surpassed Iran and became Turkey's top supplier of oil. Iran is followed by Saudi Arabia. Other suppliers with lesser volumes are Libya, Iraq, and Syria **[26]**.

Turkey, as an oil transit country, is an important actor in the world oil markets due to its geostrategic position **[26]**.The total amount of oil transported through the Turkish straits is expected to be around 200 million tons in 2009, posing continuing stress to the natural and cultural environment of Bosphorus and Dardanelles **[31]**.

In 2007, Turkish Petroleum Corporation (TPAO) announced plans to begin exploration in the eastern Mediterranean, although no work has yet been undertaken. Significant reserves are estimated to lie under the Mediterranean and Aegean Sea, but exploration activities have been restricted by the political conflict with Greece and Cyprus over the sovereignty of territorial waters **[26]**.

TPAO is also planning to explore oil in the Black Sea with some other international companies **[27]**. Recently there are some drilling projects going on the offshore platforms. Turkey believes that Black Sea holds some 10 billion barrels of oil and 1.5 trillion cubic meters of natural gas. TPAO Director General states that if oil is found in the Black Sea by 2010, production will be able to start between 2015 and 2016. He also claims that Turkish Black Sea reserves will meet Turkey's need for oil for the next 40 years, ending Turkish dependency on foreign countries for energy **[32]**.

2.1.2 Natural Gas

Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane. Natural gas is colorless, shapeless, and odorless in its pure form. It is found either in association with petroleum or non-associated or it can be found in coalbeds, too (coalbed methane). Unlike other fossil fuels, natural gas is clean burning and emits lower levels of potentially harmful byproducts into the air. Natural gas is generally used in power generation, domestic heating and industry. It is also used as a fertilizer and transportation fuel **[33].**

World Natural Gas Facts

World natural gas reserves have generally shown an increasing trend, historically **[Figure 5].** According to the Oil & Gas Journal, as the beginning of 2009 world proved natural gas reserves were estimated as 6,254 trillion cubic feet **[Table 5]**, 69 trillion cubic feet higher than the estimate for 2008 **[34].** Reserves have a relatively stable trend since 2004. However, despite growing demand for natural gas, thus far, producers have been able to continue replenishing reserves successfully with new resources over time **[35].**

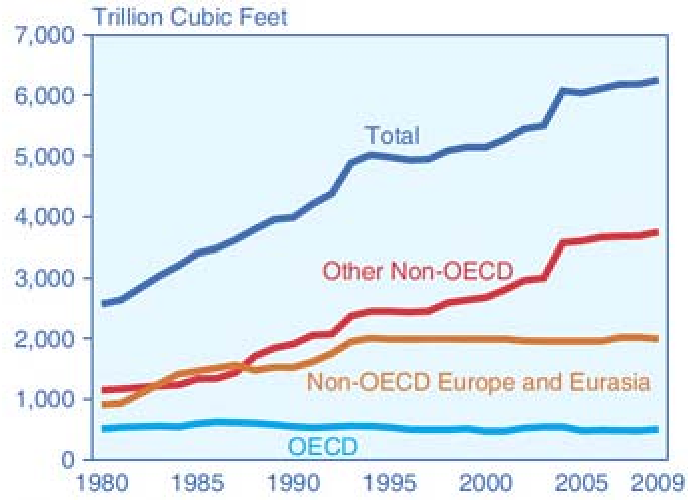

Figure 5: World natural gas reserves by country grouping, 1980-2008[35]

Middle East and Eurasia own almost 75 % of the total world proven reserves **[Figure 6]**. Nearly 57 percent of the world's natural gas reserves are located in Russia, Iran, and Qatar as the beginning of 2009 **[Table 5] [35].**

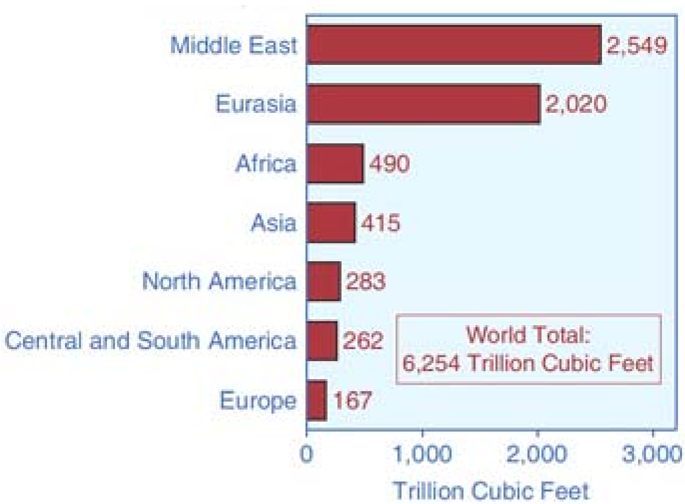

Figure 6: World natural gas reserves by geographic region as of January 1, 2009 [34]

Table 5: World natural gas reserves [trillion cubic feet] [36, 37]

COUNTRIES	BP Statistical Review end of 2008	CEDIGAZ January 1, 2008	Oil & Gas Journal January 1, 2009
Russia	1529,186	1585,644	1.680,000
Iran	1045,667	988,820	991,600
Qatar	899,284	904,064	891,945
Turkmenistan	280,555	94,644	94,000
Saudi Arabia	267,311	257,800	258,470
United States	237,726	237,726	237,726
United Arab Emir.	227,143	227,323	214,400
Nigeria	184,166	186,887	184,160
Venezuela	170,852	170,854	170,920
Algeria	159,057	159,059	159,000
Indonesia	112,470	105,945	106,000
Iraq	111,947	111,949	111,940
Norway	102,695	104,568	81,680
World Total	6534,011	6342,411	6.254,364

Despite the rapid increase in natural gas demand over the past decade, reserve-to-production (R/P) ratios for many fields are substantial. Worldwide R/P ratio is estimated at 63years **[37].**

World natural gas production grew by 3.8% in 2008, the strongest volumetric growth since 1984. Natural gas accounted for 24.1% of world energy use in 2008, the highest share on record. Global gas consumption grew by 2.5%, below the 10-year average in 2008. As a rapidly growing country China accounted for the largest incremental growth in world gas consumption by 15.8% **[38].** Another rapid developing country Turkey is one of the major importer countries **[Table 6].** Global natural gas consumption is increasing every year especially in power generation and it is predicted that growth will continue at least in the following two decades. According to International Energy Outlook 2009 **[39],** prepared by EIA, as the world economy recovers from the current down trend, consumers will prefer natural gas whenever possible due to its comperatively low price. Natural gas will keep its importance in power generation and industrial use. According to a scenario through 2030, 40 percent of the total natural gas supply will be used in the industrial sector and the share of power generation in the total natural gas consumption will reach to 35 percent in 2030 **[Figure 7].**

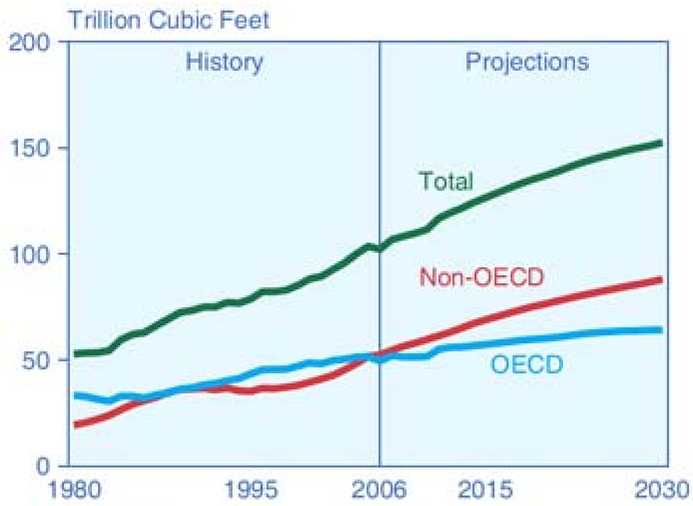

Figure 7: World natural gas consumption 1980-2030 [35]

Table 6: Natural gas importing countries [40]

Net importers	**bcm**
United States	112.7
Japan	95.4
Germany	92
Italy	76.9
Ukraine	64.2
Russia	56.9
France	49.4
Spain	38.6
Turkey	36.7
UK	36.5

Coalbed Methane (CBM), a form of natural gas produced from coal seams, is likely to get a higher share in the natural gas production. Methane has been produced from coal mines for many years, originally for miners' safety and later for commercial use. The CBM industry is growing rapidly. CBM development is most advanced in the USA where the industry comprises approximately 8% of domestic natural gas production **[41].**

Situation in Turkey

Turkey has very small proven reserves, comparing with her natural gas rich neighbours. By the end of 2008 recoverable reserves of Turkey is estimated by as 6.827 million cubic meter (According to The Oil & Gas Journal, Turkey's natural gas reserves are estimated at 300 billion cubic feet, as the beginning of 2009)**[42]**.Without further explorations, it is estimated that Turkey's natural gas reserves has a life of 6,7 years **[41]**. The major part of Turkey's proven natural gas reserves are in Thrace. North Marmara offshore field is the largest among 14 natural gas fields in Turkey **[42]**. Production of natural gas has an increasing trend after 2001 with new explorations in Thrace region and new production wells drilled in old fields. By the year 2008, production of natural gas reached the highest level of the history, 1013 million cubic meter **[43]**.Gas production is mainly carried out by three companies: TPAO, BP, and Shell.

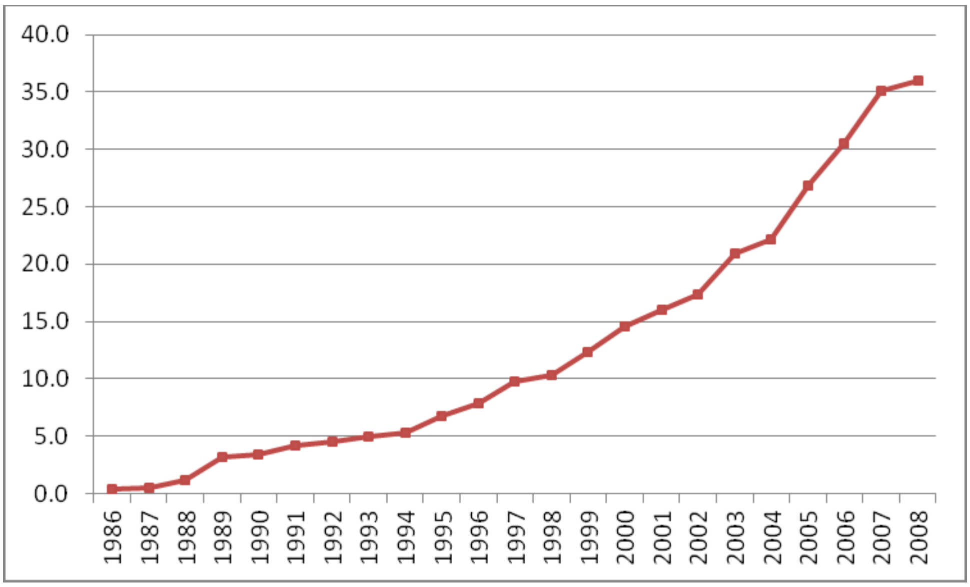

Figure 8: Natural gas consumption of Turkey [billion cubic meter] [43]

As can be seen in figure 8, consumption has increased rapidly, hitting a peak of 36 billion cubic meter(Bcm) in 2008 up from 3,4 Bcm in 1990. This is 1.19% of the world total natural gas consumption. The share of natural gas in primary supply of Turkey was less than 0.01% in 1983, however in 2005, the share of natural gas increase, to 25.4% **[44]**.

After the first natural gas based power generation in 1987, the share of lignite-fired power plants in electricity generation decreased from 42 % to 16.8 % in 2003. During this period, the share of natural gas-fired power plants increased from 17 % to 45.2 % **[45].** As can be seen from the Table 7, natural gas demand for power generation is expected to increase in the next decade.

Table 7: Turkey's Natural Gas Demand Forecast by State Pipeline Company [BOTAS] and Turkish Ministry of Energy and Natural Resources [MENR] [45]

Years	2000	2010	2015	2020
Residental	2928	8389	9396	9806
Industry	2415	10971	12238	15147
Fertilizer	839	929	929	929
Power	9418	34903	44903	56903
Total	15600	55192	67466	82785

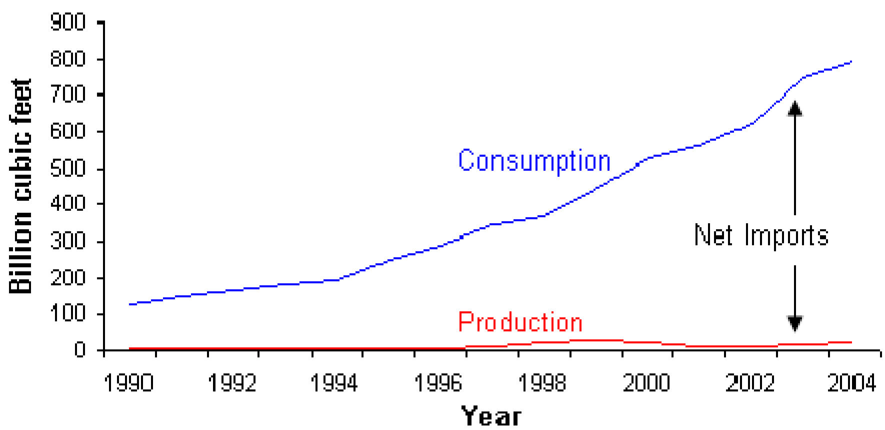

Figure 9: Turkey's Natural Gas Production and Consumption 1990-2004 [42]

Turkey has chosen natural gas as the preferred fuel for the massive amount of new power plant capacity to be added in coming years. Domestic use of natural gas has also an increasing trend. Since there is no enough natural gas production that will meet this increasing demand **[Figure 9],** Turkey is seeking to strengthen relations with Caspian and Central Asian countries, several of which are potentially large gas exporters **[44]**.

Russia is the biggest source of Turkey's natural gas imports. Russia is sends natural gas via Balkans to Northwest Turkey and via Black Sea (Blue Stream Pipeline) to Central Turkey. Azerbaijan and Iran are the other important sources of import via pipelines. Turkey also imports liquefied natural gas (LNG) from Nigeria and Algeria. Turkey began receiving gas from Azerbaijan's Shah Deniz field in 2007. Turkey had to request additional gas from Russia due to the increasing domestic demand and the erratic deliveries of gas coming from Iran in 2007 and 2008 **[Table 8] [42]**.

Turkey has an important role in the transportation of natural gas between the Caspian and the Middle Eastern substantial gas reserves and the World's second largest consumer, Europe. Nabucco gas pipeline project is proposed in order to transit that substantial gas to Europe via Turkey. Nabucco has been regarded as a vital project for the EU's long-term supply security strategy and for Turkey's strategy to be a gas transit country **[42]**.

Table 8: Natural gas import in Turkey [thousand cubic meter] [47]

Years	Russian Federation	Iran	Azerbaijan	Algeria	Nigeria	spot	total
1998	6.549.393			2.766.561		579.622	10.043.215
1999	8.697.517			2.964.531	69.318	300.433	12.325.810
2000	10.082.426	151.467		3.593.960	704.459		14.532.312
2001	10.928.235	114.368		3.625.983	1.197.665		15.866.251
2002	11.573.762	660.303		3.721.675	1.139.422		17.095.162
2003	12.459.656	3.461.345		3.795.484	1.107.343		20.823.828
2004	14.102.107	3.497.364		3.182.288	1.016.345		21.798.104
2005	17.523.697	4.248.679		3.814.557	1.012.671		26.735.909
2006	19.315.895	5.594.374		4.210.612	1.099.538		30.307.851
2007	22.753.211	6.054.156	1.257.735	4.204.735	1.395.708		35.873.577
2008	22.961.786	4.112.889	4.579.922	4.148.002	1.017.302	332.886	37.152.787

In order to be a gas transit country, Turkey must be able to import enough gas to satisfy the domestic demand and provide enough pipeline capacity to transport Caspian and Middle Eastern gas across to Europe. For today, Turkey has enough import capacity. However, as domestic demand increases, without further investment, surplus capacity is expected to decline **[42]**. The natural gas purchase agreements carry the condition that even if the declared amount of natural gas is not consumed annually; the purchasing party (i.e. Turkey) must still pay the cost of the natural gas that it has pledged to buy. It is very difficult to make accurate predictions of the country's natural gas or oil needs. Necdet Pamir, an energy analyst, states that underground natural gas storage facilities are essential to reduce the waste of money stemming from natural gas contracts and that Turkey's potential for storage is sufficient. However, Turkey has not efficiently utilized its potential to construct underground natural gas storage. There is a natural gas storage facility in İstanbul's Silivri district, but its capacity is only 1.5 to 2 billion cubic meters; thus, it is unable to meet the needs of Turkey, which consumes around 135 million cubic meters of natural gas per day. Work is under way to expand the capacity of the Silivri storage facility to 3 billion cubic meters. Furthermore, an underground storage facility with 13 wells is to be built near Tuz Gölü (Salt Lake), in a project that is financially supported by the World Bank, and there is another storage facility in İzmir solely for LNG, with a capacity of 5.2 billion cubic meters **[48].**

On the other hand, Coalbed methane (CBM) has a great potential for Turkey. As pointed by Mustafa and Balat **[49],** coalbed methane from the Zonguldak hard coal region could play a very significant role in Turkey’s energy economy. The CBM in-place resources in two districts of the Zonguldak hard coal region are presently estimated to be at least 3 trillion m3.

2.1.3 Coal

Coal is a fossil resource containing altered remains of prehistoric vegetation that originally accumulated in swamps and peat bogs **[50].** Having carbon content of 50-98%, coal is the fossil fuel with the highest carbon intensity **[51].**

Coal is classified in to mainly two types regarding its carbon content which also determines the quality of the coal: lignite and sub-bituminous coals are classified in low rank group (brown coal). They have low carbon content and contain a lot of moisture. They are mostly used in electricity generation. Bituminous coals and anthracite are called hard coals. They have high carbon content and low moisture. They are used for cement and steel industry and also for electricity generation **[52].**

Coal mining causes a number of problems for environment such as erosion and water pollution, dust, acid mine drainage, destruction on soil, vegetation and biodiversity. With the burning of coal, some gases (such as sulphuroxide and carbondioxide) and particles of ash (fly ash) are released. Besides developing clean coal technology, release of CO_2 and acid rain is still a matter waiting for an effective solution **[53].**

World Coal Facts

Coal provides 26% of global primary energy needs and generates 41% of the world's electricity. Coal reserves are available in almost every country worldwide, with recoverable reserves in around 70 countries **[54].** However, the lion's share of world proven coal reserves is concentrated in a few countries. 84% of world hard coal reserves located in 6 countries (USA, China, India, Russia, South Africa, and Australia) **[Table 9]**. From 2000 to 2005, the world proven R/P ratio of coal dropped by almost a third, from 277 to 155 years **[55].** Up to a more recent estimate, proven coal reserves will last 122 years with the current production levels **[54].**

Table 9: World shares of the top 10 richest countries in hard and brown coal reserves worldwide [%][55]

Region	Country	%Global share	
		Hard coal	Brown coal
North America	USA	23.3 (1)	31.4 (1)
South & Centr.America	Brazil	-	2.4 (6)
	Colombia	1.3 (10)	
Europe & Eurasia	Kazakhstan	5.9 (7)	
	Czech Rep.	-	0.8 (10)
	Germany	-	1.5 (7)
	Greece	-	0.9 (9)
	Poland	2.9 (9)	
	Russia	10.3 (4)	25.1 (2)
	Turkey	-	0.9 (8)
	Ukraine	3.4 (8)	4.2 (5)
Africa Asia Pacific	S. Africa	10.2 (5)	
	Australia	8.1 (6)	9.3 (4)
	China	13.0 (3)	12.2 (3)
	India	18.8 (2)	

Note: the relative ranking is given in brackets

Hard coal production is increased from 3489 Mt in 1990 to 5845 Mt 2008. Approximately 13% (around 717Mt) of total hard coal production is currently used by the steel industry and almost 70% of total global steel production is dependent on coal **[54].**

Coal is a vital substance also for developing countries, such as South Africa, Poland, China, Kazakhstan **[Table 10].** Despite having serious contribution to both climate change and pollution, coal is still the major source for electricity generation even in developed countries due to supply security problems.

Table 10: Percentage of electricity generation from coal [2007] [54]

Countries	%	Countries	%	Countries	%
South Africa	94%	**Israel**	71%	**Morocco**	57%
Poland	93%	**Kazakhstan**	70%	**Greece**	55%
PR China	81%	**India**	68%	**USA**	49%
Australia	76%	**Czech Rep**	62%	**Germany**	49%

The consumption of hard coal is much more than brown coal and the difference is growing continiously. Without further hard coal explorations, the world is going to run out of higher-quality coal much earlier than lower-quality coal **[56].**

Over the past decade, investments in the coal industry have decreased due to low prices, poor return on the investment and industry fragmentation. However, coal is expected to strengthen its position in the energy market with the advances in clean coal technologies, especially if coal remains cheaper than oil and gas **[55].**

Situation in Turkey

Turkey's main hard coal deposits are located in the Zonguldak basin, between Eregli and Amasra in north-western Turkey. The total hard coal reserve in Zonguldak Basin is 1,344 billion tons, while visible reserve here is at the level of 550 million tons **[57]**. Taurus Mountains and Diyarbakir region are thought to have large hard coal deposits with an estimated reserve of about 1,039 million tones **[58]**.

The state-owned Turkish Hard Coal Enterprises (TTK) is the biggest producer and distributer of hard coal in Turkey although there are no legal restrictions on private sector involvement **[Table 11]**. As the year 2006, hard coal import of Turkey was 16.5 million tones. Australia, South Africa and Russia are the most important suppliers of this amount **[58]**.

Table 11: 2000-2008 Hard coal production in Turkey [59]

Years	TTK production (Tones)	Private sector production (Tones)	Total production (Tones)
2000	2.259.227	135.019	2.394.246
2001	2.356.865	137.097	2.493.962
2002	2.244.385	74.647	2.319.032
2003	2.011.178	47.943	2.059.121
2004	1.880.847	65.124	1.945.971
2005	1.665.846	511.355	2.177.201
2006	1.522.698	795.931	2.318.629
2007	1.675.283	817.092	2.492.375
2008	1.586.532	1.043.909	2.630.441

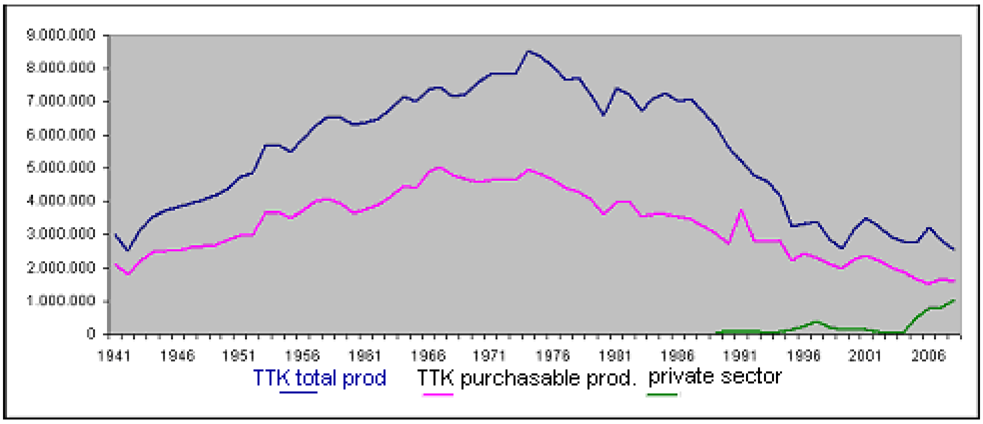

Figure 10: Turkey's Coal Production between 1941-2008 [59]

Hard coal production is maintained under very difficult geological conditions. The production depth reached 600–1000m in some regions. Such difficult working conditions caused that the unit costs increased and this affected the competitive power of the country in world’s markets. Furthermore, coal production of Turkey has been decreased to 2.63 from 9 million ton levels of 1970's **[Figure 10].** This production level can meet only 15–20 % of the overall consumption of Turkey, which is 17–18 million ton. A significant part of the produced hard coal is used for electricity production; the remaining coal is consumed for other purposes, such as iron and steel industry, household fuel, etc. **[60, 61]**.

Turkey’s hard coal mining industry is expected to decline over the next decade. An important indication supporting this estimation is that between 1990 and 2000, the number of workers in Turkey‘s coal industry fell from 63,993 to 35,665 **[58]**.

Turkey has around 10.4 billion tons of lignite reserves. Of this lignite reserves, around 46% is in Afsin-Elbistan basin. Lignite fields are spread across all regions of our country. The most important reserves are in the Afsin-Elbistan, Mugla, Soma, Tuncbilek, Seyitomer, Beypazari, and Sivas regions. The heating values of the lignite coal in these fields vary between 1000 and 5000 kcal/kg. About 68% the total lignite reserves in our country being of low calorie type, 23.5% is between 2000-3000 kcal/kg, 5.1% between 3000-4000 kcal/kg, and 3.4% above 4000 kcal/kg **[57]**.

Only 14% of Turkey’s coal reserves have moisture content below 20%. The average rate of moisture content is 40% in all lignites. Reserves bearing low ash contents are not abundant. The sulfur rate ranges from 1% to 6% **[62]**.

At world scale, Turkey is a middle-level country in terms of lignite reserves and production amounts, and lower-level in hard coal. Having about 1.6 % of World's total lignite reserves, Turkey's total lignite reserve was known to be 8.1 billion tons. However, the number of probes increased five folds within the last five years, which prospecting work by General Directorate of Mineral Research and Exploration (MTA) yielded as of May 2008 to new lignite reserves of 2.3 billion tons in addition to the existing reserves of 8.1 billion tons **[Table 12]**. Work in this area is planned to continue at the same pace, and the amount of coal reserves is expected to increase **[57]**.

Table 12: Distribution of Newfound Lignite Reserves by Regions, as of May 2008 [57]

Lignite Reserve Regions in Turkey	Reserve Amount
Afsin-Elbistan*	732 million tons
Elbistan*	420 million tons
Konya-Karapinar	550 million tons
Thrace	498 million tons
Manisa-Soma-Eynez	100 million tons

*Lignite from Afsin-Elbistan is within a lower heating value of 1000 to 1500 kcal/kg. About half of the total lignite reserve of our country is in this region.

Lignite production is set to increase in order to meet growing power requirements and to provide a cost effective basis for Turkey's long-term energy needs. Total production is expected to reach 160 million tons by 2010, and 185 million tons by 2020. Compliance of power plants with international environmental standards is necessary for lignite to be able to maintain its substantial share in the Turkey's power market **[58]**.

Table 13: TKİ Production and Sell [63]

Million tones	2004	2005	2006	2007	2008	2009
Production	24.8	29.33	31.07	30.5	36.9	35.08
Sell	25.3	28.4	29.8	31.5	36.4	34.4
1) Termic	19	22.4	23.4	25	29.4	27.7
2) Market	6.3	6	6.4	6.5	7.0	7.4

Furthermore, having a low heating value, majority of our lignite is typically used at thermal power plants. About 75% of Turkey's Lignite is used as a fuel for generating electric power **[Table 13] [57]**. Most of the coal-fired power plants in Turkey use lignite. Some small power stations are using the domestic hard coal from the Zonguldak basin while imported hard coal is used in a big power plant in Iskenderun. The Turkish coal-fired plants have a total capacity of approximately 9 GW **[58]**.

In Turkey, coal consumption has showed a stable trend during the past decade and currently accounts for about 24% of the country's total energy consumption. As the government tends to close down the geologically difficult, unprofitable hard coal mines, lignite production is expected to increase. Although hard coal production is still subsidized; lignite production appears to be more economical than hard coal. The government plans to rely increasingly on imports in hard coal **[Table 14] [64].**

Table 14: Production – Consumption- Import Statistics between 1994-2007 [59]

YEARS	PRODUCTION	IMPORT	STOCK CHANGE	TOTAL CONSUMPTION
1994	2.839	5.463	-110	8.192
1995	2.248	5.941	359	8.548
1996	2.441	8.272	179	10.892
1997	2.513	9.874	150	12.537
1998	2.156	10.361	629	13.146
1999	1.990	8.864	508	11.362
2000	2.259	12.990	144	15.393
2001	2.357	8.028	654	11.039
2002	2.319	11.693	-182	13.830
2003	2.425	16.166	1.056	17.535
2004	2.070	16.427	-407	18.904
2005	1.900	17.360	-161	19.421
2006	2.319	20.286	-193	22.798
2007	2.492	22.946	214	25.224

There are some other reserves in Turkey, out from the conventionally used coals. Vein-type deposits of asphaltite in economical thickness are found in Sirnak and Silopi regions. Conducted surveys and probes have yielded to 82 million tons of asphaltite reserves. 45 million tons of this reserve is visible. On top of that, it is estimated that there is a total bituminous schist reserve of 5 billion tons **[57]**.

Substantial amounts of methane (CH4) are continuously emitted from the coal mines in the West Black Sea Region of Turkey. Coal bed methane (CBM) potential in the Zonguldak hard coal region could be an important source of gas for Turkey if it can be utilized. Recovery and use of this methane could be beneficial for everyone because of reduced future methane-related hazards to miners and improvement to the local and global environment. The CBM in-place resources in two districts of the Zonguldak hard coal region are presently estimated to be at least 3 trillion m3. Development of coal bed methane gas resources may alleviate some of the current and future shortages of energy in Turkey **[64]**.

2.2 Renewable Energy Resources

2.2.1 Solar Energy

The amount of the solar energy received by the earth in one hour is far more than the human primary energy demand in one year **[65].** There are some methods to transform sunlight in to a usable form of energy for different purposes. Mainly, solar energy is used for heating, cooling and lighting and for generating electricity. Photovoltaics (PV) are the most common method for generating electricity. Solar cells are used to convert solar energy into electricity. Solar cells are used on buildings, on devices, vehicles and either used in a power plant. By the advances in the technology the cost of electricity generation from solar energy declined and therefore the usage of PV started to increase **[66].**

Thermal utilization of solar energy can be either in active or passive forms. Passive solar energy is related to the design of buildings for collecting and transforming solar energy used for heating, day lighting and natural ventilation. Active solar energy is related to the use of solar collectors for water or space heating and cooling purposes, heat pumps, desalinization and industrial high temperature heat generation. The solar collector technology may be considered mature but continues to improve **[67].** Passive solar energy is generally considered as an issue related with the energy demand and efficiency rather than an energy supply. In the industrialized world, buildings use 35 to 40 % of total primary use of energy. 50 to 75% of the energy demand of a building can be satisfied or eliminated with passive solar systems, through an intelligent design, energy efficient systems and devices and many other applications. However, passive solar energy could not be included in the energy statistics due to the high costs of collecting data from each building **[67].**

Solar energy use is increasing all over the world since it has many advantages. Solar energy is generally a domestic energy source for a country. Both solar collectors and solar PV systems are usually installed on the buildings or near to where it is needed. By not using any fuel, solar energy does not contribute to recovery, transportation and waste storage costs and problems. After the initial investment has been recovered, the energy from the sun is practically free and renewable **[68].** Solar energy is also a clean energy. Electricity generation or solar thermal activities have no or little contribution to greenhouse effect and air pollution.

Besides these advantages of using solar energy, there are also some drawbacks. Solar energy is intermittent, which means it is available only during day-time and is influenced by the presence of clouds or pollution in the air. The initial cost is the main disadvantage of installing a solar energy system, largely because of the high cost of the semi-conducting materials used. Unequal distribution of the solar radiation (mostly between 30° north and 30° south latitude) is another barrier for solar energy become widespread **[67, 68].**

World Solar Energy Facts

The South-Western United States, some areas of Southern America, the Middle East, central Asian countries from Turkey to parts of India and China, North Africa, South Africa, and parts of Australia are amongst the most promising areas of the world in terms of solar radiation potential **[Figure 11].** It is interesting that almost all of the countries in those solar-rich regions have no emission reduction commitments due to the Kyoto Protocol. Contrarily, even the sunniest European countries, most of which have emission reduction targets, can only be rated a second choice for the quality of their direct solar radiation resource **[67].** The importance of the quality of solar radiation in solar energy utilization can be realized by looking at the recent effort of European countries to produce and import solar energy from the North Africa **[69].** The difference in solar resource more than offsets the costs of transmissions.

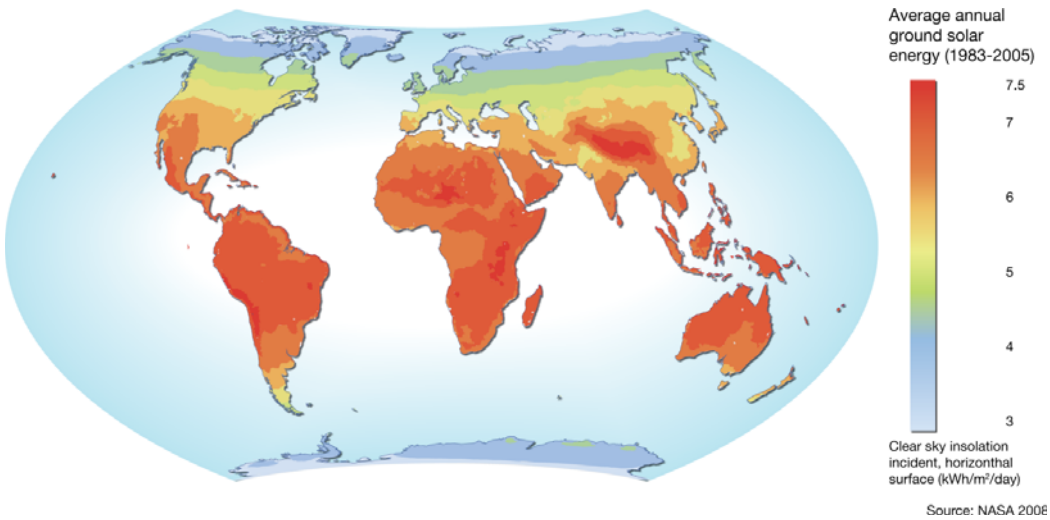

Figure 11: World insolation map [70]

This map shows the amount of solar energy in hours, received each day on an optimally tilted surface during the worst month of the year.

In this section, the solar activities and the potential is discussed in two parts: Solar power (PV) and Solar Thermal energy.

World Solar Power Facts

According to different sources of information, about 5,56 GW **[65]** or 6,94 GW **[66]** of PV capacity were installed during 2008, which brought the total installed capacity to 14,7 GW or 19,2 GW**[Table 15].** Whatever the exact numbers are, this means an increase of about more than 150 % over the previous year. By far the greatest proportion (75 %) was installed in Spain and Germany alone. If Italy, the US, Korea and Japan are also included, then it can be said over 96 % of PV installations in 2008 occurred in six countries **[Table 15] [71].**

Table 15: Cumulative Installed Solar Photovoltaic Capacity in Ten Leading Countries and the World, 2008 [72]

Country	Cumulative Installed Capacity
Megawatts	
Germany	5.308
Spain	3.223
Japan	2.149
United States	1.173
South Korea	352
Italy	350
China	145
India	90
France	87
Belgium	70
World Total	**14.730**

The solar-cell market has been growing on average by 31% a year for the past decade **[Table 16].** An industry analysts, denotes the volume of industry will increase from about US$12 billion in 2005 to as much as $70 billion in 2010 **[65].**

Although being a fast-growing industry, solar PV is dwarfed by wind power and hydroelectricity, simply because the technology is much more expensive. Experts' opinion does not expect such a growth in the field that will change the picture very much. It is claimed that a 25% annual growth in installed capacity for the next 15 years would still end up with solar photovoltaic producing just 1% of the world's energy **[65].**

Table 16: World Solar Photovoltaic Production, 1975-2008 [72]

Year	Annual Production	Cumulative Production
	Megawatts	
1990	47	275
1991	55	330
1992	58	388
1993	60	448
1994	69	517
1995	78	595
1996	89	683
1997	126	809
1998	155	964
1999	201	1.165
2000	277	1.442
2001	371	1.813
2002	542	2.355
2003	749	3.105
2004	1.199	4.304
2005	1.782	6.086
2006	2.459	8.544
2007	3.715	12.259
2008	6.941	19.200

Situation in Turkey

Solar power is considered an important renewable energy source for Turkey as the country is geographically well situated with respect to solar energy potential and lies in a sunny belt **[71].** 4600 km2 area of Turkey was calculated as having a solar energy potential of over 1 650 kWh/(m^2. y) and is expected to produce 380 000 GWh energy per year by EIE **[73].** However, electricity generation from solar energy is still in its infancy in Turkey. After four years of stable trend, in 2008 nearly 750 kW of PV were installed in Turkey. 94 % of the total installed PV capacity of about 4 MW is off-grid applications **[71].** According to the preliminary works, the main off-grid photovoltaic applications include power systems for telecommunications, signaling, water pumping, lighting and the electrification of remote regions without a regular supply of electricity. There are also some grid-connected photovoltaic power systems (1 – 94 kWp) at some research institutes and universities, municipalities and department stores **[73].**

The government has declared to increase the share of wind and solar power capacities in the total installed capacity from its current value of 0,5 % to over 10 % by 2020. The amendments to the related law in 2008 allow the utilization of the utility grid as an energy reserve until 500 kW power for renewable energy sources without any permission. The Republic of Turkey Ministry of Energy and Natural Resources has announced that the government will add some support mechanisms to the existing renewable energy law for solar electricity and the government will apply feed-in tariffs for grid-connected PV power systems. Following the revision of the renewable energy law to support solar electricity, the number of PV installations is expected to increase significantly **[73].** The newest 5 year development plan, being prepared, foresees a more ambitious program and estimates approximately 40MW installed power by the year 2010 **[74].**

World Solar Thermal Energy Facts

The global solar market had a growth rate 20% in 2006, about 15% in 2007. Global solar heating and cooling potential continues to grow. The solar thermal collector capacity in operation worldwide equaled 171 gigawatts thermal (GWth) corresponding to 244 million square meters at the end of 2008. With respect to the cumulative installed capacity China ranks first 100 GWth, followed by USA 22 GWth (unglazed collectors); with approximately 8 GWth each Turkey and Germany rank third. Solar thermal energy for domestic hot water preparation is common all over the world with significant market penetration in Australia, China, Europe, Israel, Turkey and Brazil. So-called solar "combi systems" for combined hot water preparation and space heating show a rapidly growing market in European countries. The energy produced in 2007 was about 89 Twh or 319 PJ or 7,6 million tones oil equivalent (Mtoe). Still it represents less than 1 % of the global primary energy demand, however passive solar inputs are not accounted for in the statistics **[75].**

In the absence of affordable ways to store large amounts of heat from one season to another, the contribution of solar heat to space heating needs is currently limited. Domestic hot water and process heat are less sensitive to climatic conditions and thus more favorable for solar heat. To date, only solar water heating has entered in to use on a significant scale **[75].**

Table 17: Solar hot water installed capacity, Top 10 Countries/EU [76]

COUNTRY	additions 2007	existing 2007
	gigawatts-thermal	
China	16	84
EU	1,9	15,5
Turkey	0,7	7,1
Japan	0,1	4,9
Israel	0,05	3,5
Brazil	0,3	2,5
USA	0,1	1,7
India	0,2	1,5
Australia	0,1	1,2
Jordan	0	0,6
other countries	<0,5	<3

Table 18: Cumulative installed solar water and space heating capacity in ten leading countries and the world, 2007 [73]

Country	Cumulative Installed Capacity
Thermal Megawatts	
China	79.898
Turkey	7.105
Germany	6.054
Japan	4.866
Israel	3.456
Brazil	2.512
Greece	2.501
Austria	2.095
United States	1.734
India	1.505
World Total	120.511

The IEA Outlook Energy 2008 foresees a contribution from solar thermal of 180 Mtoe or about 18 % of the total forecasted heat demand of the world in 2050 **[74].**
The European Solar Thermal Industry Association forecasts an installed capacity of 1019 GWth by 2030 in the European Union, supplying about 15 % of the low temperature heat demand, by 2030 **[77].**

Situation in Turkey

The energy used for heating and cooling of buildings constitutes more than on ethird of the Turkey's total energy consumption, which corresponds to 21.6 mtoe as the year 2005. More than 60 % of the residential energy consumption is caused by space heating. The cooling demand is also increasing rapidly especially in the south and west region at the summer season due to increasing intrernal cooling loads and higher comfort requirements **[78].**

Table 19: Total monthly solar energy potential of Turkey. [79]

Months	Total monthly solar energy		
	(kcal/cm2-month)	(kWh/m2-month)	(hour/month)
January	4,45	51,75	103,0
February	5,44	63,27	115,0
March	8,31	96,65	165,0
April	10,51	122,23	197,0
May	13,23	153,86	273,0
June	14,51	168,75	325,0
July	15,08	175,38	365,0
August	13,62	158,40	343,0
September	10,60	123,28	280,0
October	7,73	89,90	214,0
November	5,23	60,82	157,0
December	4,03	46,87	103,0
Total	**112,74**	**1311,00**	**103,0**
Average	308,00	3,60	7,2
	cal/cm2-day	kWh/m2-day	hour/day

Table 20: Average Solar energy potential of regions in Turkey. [79]

Region	Total average sun energy	Average insolation hour/year
Southeast Anatolia	1460	2993
Mediterranean	1390	2956
East Anatolia	1365	2664
Central Anatolia	1314	2628
Egean	1304	2738
Marmara	1168	2409
Blacksea	1120	1971

Turkey has an insolation potential of 110 days. In other means insolation corresponds to a solar energy production potential of 1100 kWh/ per m2, which can be considered high **[79, 80].**

According to Table 19, June is the most productive month of the year and December has the least potential. Southeastern Anatolia Region and the Mediterranean coasts of Turkey have the biggest solar insolation potential **[Table 20].** Average annual insolated hours, excluding Black Sea region), is 2640 h. It is claimed that these estimated values may be less than the real potential of Turkey. Therefore, two state institutions, EIE and DMI, started a new research, and it is predictied that new values will probably be about more than 20-25% of the previous calculated values **[79].**

Current installed solar collectors are about 12 million m2, and the annual production is 750000 m2 including a certain amount of export. Annual solar heat produced at 2007 is 420 thousand tones oil equivalent **[79**]. Turkey's solar thermal production has been increasing at a consistent rate for ten years **[Table 21].** Cumulative installed solar water and space heating capacity is about 7105 MWth by the year 2007. Turkey has the second biggest capasity in both solar water and total solar water and space heating industry after China. Turkey is also a solar collector exporting country.

Table 21: Solar thermal production of Turkey [79]

solar energy production	
[thousand tonnes oil equivalent]	
years	production
1998	210
1999	236
2000	262
2001	290
2004	375
2007	420

2.2.2 Wind Energy

Wind is major source of energy since the ancient times of the world. Electricity generation by using wind is also not a new idea. It has been known and applied since a Danish scientist first generated electricity from wind in 1892 **[81].** However the popularity of producing energy from the wind has fluctuated with the price of fossil fuels. When the price of oil increased extremely in the 1970s, so did worldwide interest in wind turbine generators. The wind technology was improved step by step since the early 1970s **[82].** By the rapid increasing of greenhouse emissions mainly due to the use of fossil fuels in energy generation, wind energy, which is one of the cleanest energy sources, became a favourable altenative energy. Some important advantages and disadvantages can be summarized as follows.

- Besides the initial construction costs, wind is a cheap source of energy. Actually wind is free and also manufacturing and distribution costs can be considered low compared with fossil fuel production. Wind power is almost the least expensive one among renewable sources in terms of both investment and generation cost **[83].** The U.S. DOE estimates that wind energy can be produced for as low as 4 to 6 cents per kilowatt hour **[84].**

- Even though some countries may be "windier" than others, wind energy is available all over the World. Therefore, unlike fossil fuels, the product has not to be transported to the other side of the world with tankers or pipelines.

Wind energy is a domestic source of energy so it does not cause conflicts between countries **[85].**

- Wind turbines take up less space than the average power station. Windmills only have to occupy a few square meters for the base; this allows the land around the turbine to be used for agriculture or any other purposes.
- Wind is a clean and a renewable energy source. Unlike fossil fuels, it has no contribution to greenhouse gas emission in the production.

Besides these advantages, wind energy has also some drawbacks **[85, 86]:**

- Wind is an intermittent source of energy and when connected to the electrical grid it provides an uneven power supply.
- The initial production and construction cost of a wind turbine is one of the main disadvantages, however government subsidies, tax breaks and long-term costs may alleviate much of this. Even though the costs of wind energy are decreasing, it still has to compete with the ultra low price for fossil fuel power plants.
- Wind turbines generally produce less electricity than the average fossil fuelled power station so it requires multiple wind turbines to be built in order to produce more.
- The storage of excess energy from wind turbines in the form of batteries, hydrogen or other forms still needs to be developed to become commercially viable.
- Noise pollution may be the only environmental problem of the wind turbines for the people living near to a wind energy plant. However, comparing with fossil fuels, this is a negligible environmental effect.

World Wind Energy Facts

By the end of 2008, wind energy generation worldwide was 260 TWh per annum, which constitutes more than 1,5 % of the global electricity consumption. This number can be considered low in the world's fossil fuel dominated energy industry; however the increasing trend in the installed capacity of wind energy per year shows that it will have an important role in meeting the increasing energy demand of the world **[87].**

Worldwide capacity reaches 121,188 MW, out of which 27,261 MW were added in 2008 **[Table 22].** The growth rate worldwide went up steadily since the year 2004, and 23,8 % in 2005, 25,6 % in the year 2006, after 26,6 % in 2007, reaching 29,0 % in 2008 **[87].**

According to World Wind Energy Association's estimates, taking into account some insecurity factors, wind energy will be able to contribute in the year 2020 at least 12 % of global electricity consumption. This rapid increase in the growth rate created a fast growing wind sector, representing a turnover of 40 billion in 2008; therefore, the wind sector became a global job generator and has created 440,000 jobs worldwide **[87].**

Table 22: Added and existing wind power, top 10 countries, 2008 [87]

Country	Added in 2008 (MW)	Cumulative at the end of 2008	Growth Rate
USA	8360	25170	49,7
Germany	1670	23900	7,4
Spain	1610	16740	10,5
China	6003	12210	106,5
India	1800	9650	22,1
Italy	1010	3740	37
France	950	3400	38,7
Un. Kingdom	840	3240	37,6
Denmark	80	3180	1,1
Portugal	710	2860	34,4

Note: Figures rounded to nearest 10 MW.

Wind power penetration has reached relatively high levels in several countries. By the year 2008, Denmark produces 19 % of its electricity from wind. The share of wind is 11% in Spain and Portugal, and 7% in Germany and the Republic of Ireland. As of May 2009, eighty countries around the world are using wind power on a commercial basis **[88].**

In 2006, the European Commission released new scenarios for 2030 on energy efficiency and renewables. If EU electricity demand develops as projected in the European Commission's "combined high renewables and efficiency" case, wind energy's share of electricity demand will predicted to reach 5.2 per cent in 2010, 14.3 per cent in 2020 and 28.2 per cent in 2030 **[83].**

Figure 12 shows the growth rates of top ten countries.The increase in the average growth rate in the previous 5 years is mainly due to the fact that the two biggest markets, USA and China, showed growth rates far above the average: USA 50 % and China 107 %. Turkey showed a dynamic growth far above the average **[88].**

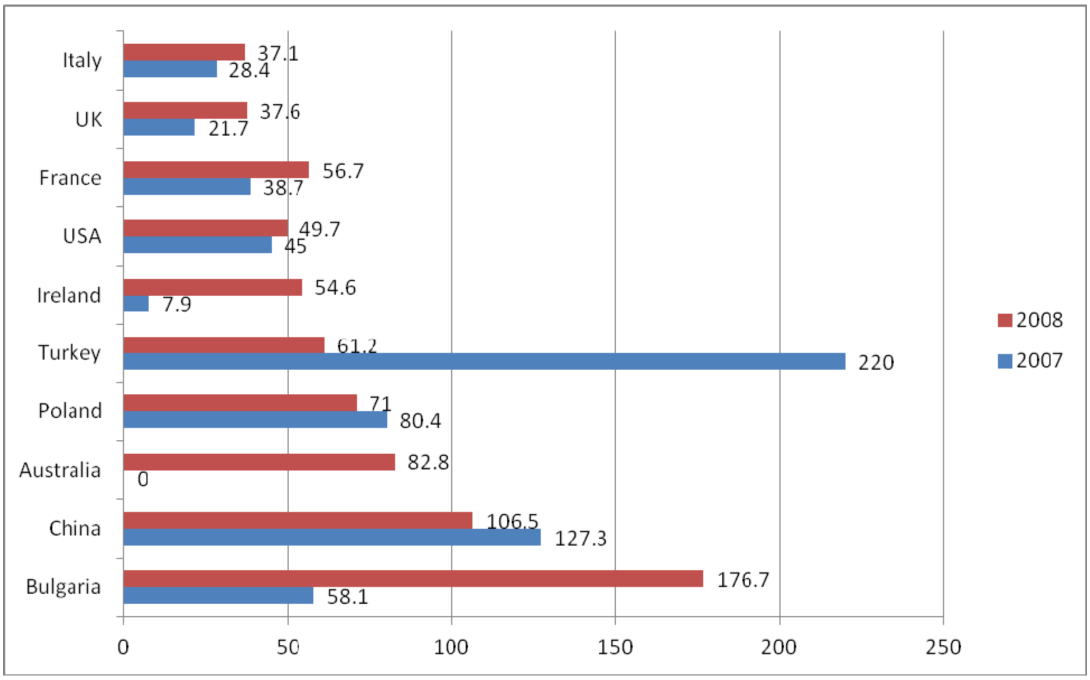

Figure 12: Top ten countries with highest growth rates in wind power (countries with more than 100 MW installed capacity) [88]

Table 23: Wind potential of European OECD countries [82]

Country	Territory (thousand km^2)	Specific wind potential (thousand km^2)	Side potential (km^2)	Technical potential MW TWh/year	
Turkey	781	418	9,96	83000	166
UK	244	171	6,84	57000	114
Spain	505	200	5,12	43000	86
France	547	216	5,08	42000	85
Norway	324	217	4,56	38000	76
Italy	301	194	4,16	35000	69
Greece	132	73	2,64	22000	44
Ireland	70	67	2,68	22000	44
Sweden	450	119	2,44	20000	41
Iceland	103	103	2,08	17000	34
Denmark	43	43	1,72	14000	29
Germany	357	39	1,4	12000	24

Situation in Turkey

General Directorate of Electrical Power Resources Survey and Development Administration (EIE) and State Meteorology Organization published the Wind Atlas of Turkey **[Figure 13],** after long efforts together with scientists. This study shows that some parts of Turkey are endowed with strong wind conditions. Particularly, south of the Marmara region, coastal and some inner parts of the Aegean region, some parts of the Black Sea, the eastern part of the Mediterranean, and locations with rugged mountains in Eastern Anatolia are especially promising regions **[89].**

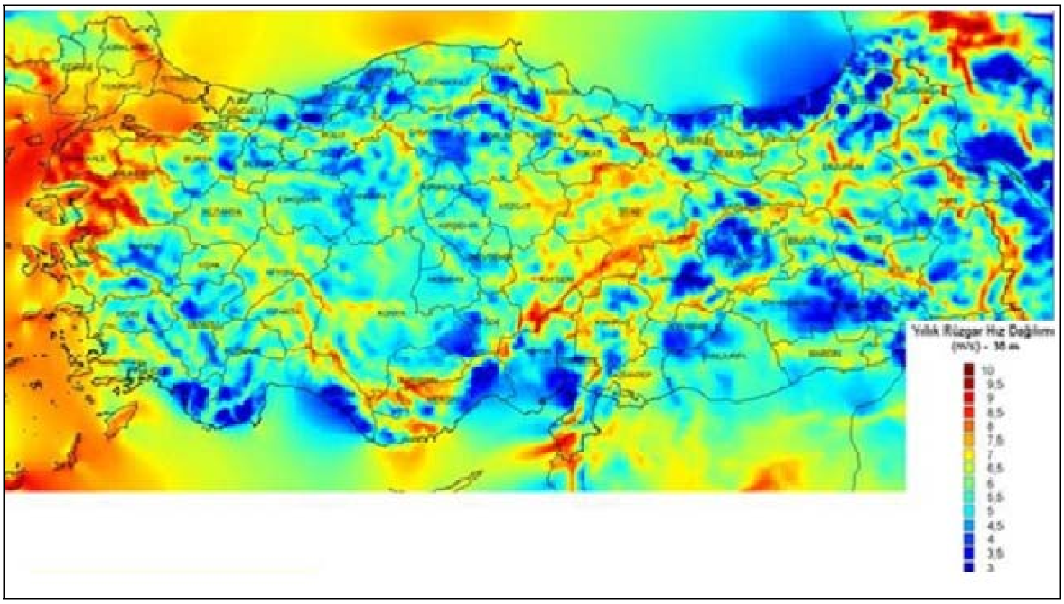

Figure 13: Wind energy atlas of Turkey [90]

Wind velocity is the most important parameter for evaluation of the wind energy resources. Any choice of wind turbine design must be based on the average wind velocity at the selected wind turbine construction site **[91].** According to EIE data, wind velocity in Turkey is enough for electricity generation in most of the regions of Turkey. However especially, northwest coast of Turkey has an important potential in terms of wind velocity. The Marmara region, The Southeast Anatolian and The Aegean regions are other suitable regions for wind energy applications **[92].**

Theoretically available wind power potential of Turkey is calculated as 80,000 MW. Economically feasible potential is about 10000 MW. Turkey has the highest technical potential among European countries with 166 TW/year in. It is more than the current total electricity consumption of Turkey **[Table 23] [82].**

Table 24: Wind power activities in Turkey [82]

Years	Production and consumption (GWh)		Installed capacity (MW)			
	Wind power production	Total power consumption	Wind power installed capacity	Total installed capacity	Share of wind power in total consumption (%)	Share of wind power in total installed capacity (%)
1998	6	114,023	9	23,263	0.005	0.039
1999	21	118,485	9	26,125	0.018	0.034
2000	33	128,276	19	27,264	0.026	0.070
2001	62	126,871	19	28,332	0.049	0.067
2002	48	132,553	19	31,752	0.036	0.060
2003	61	141,151	19	35,564	0.043	0.053
2004	58	150,018	19	36,824	0.039	0.052
2005	59	160,794	21	38,82	0.037	0.054
2006	127	174,23	59	40,519	0.073	0.146
2007			206,8	40,755	-	0.395
2008			333,4	41,806		0,797

As of September 2008, there are 18 wind power plants in Turkey with the installed power of 333.4 MW **[Table 24].** Power capacity of each of these wind power plants vary from 0.85 to 90 MW. When taking into account the power capacity of 515.66 MW that is under construction, the installed capacity is expected to reach 757.36 MW in total **[93].** Considering the fast growth rates experienced in the previous 4-5 years, and the new renewable energy law providing advantegous investment opportunities, the contribution of wind energy to total electricity generation is expected to exceed 1% level in the next few years. According to the 9th Development Plan of Energy Special Expertise Commissioner Report, total electric power installation is expected to increase 52863 MW while the 2163 MW of this total is expected to be contributed from wind power plants. Total wind energy generation is targeted to be 5939 GWh as of 2013 **[93].**

2.2.3 Geothermal Energy

The main sources for geothermal energy are the heat flow from the earth's core and mantle, and that generated by the gradual decay of radioactive isotopes in the earth's continental crust. Although it is known that the world's geothermal heat resources are enormous, their generally hidden nature makes it difficult to accurately determine potentials on a global basis. By the advances in the technology, that is used to develop the geothermal resources, their technical, economic potentials and the cost of production changes. Therefore, there are considerable uncertainties in estimating the global geothermal resource potentials, and revisions have to be made when more information and new technologies become available **[94].**

Geothermal energy can be utilized in two ways. One is the direct use of hot water or hot steam for residental heating, industrial use (such as aquaculture, thermal baths and hot springs). The other area that geothermal energy used is power generation. **[95].**

Electricity through geothermal energy is generated in three types of power plants:

Dry steam plants are the simplest and oldest design. They directly use geothermal steam of 150°C or more to turn turbines **[96].** Flash steam plants require fluid temperatures of at least 180°C, usually more. This is the most common type of plant in operation today **[97].** Binary cycle power plants are the most recent development, and can accept fluid temperatures as low as 57°C **[98].**

Geothermal energy has many advantageous characteristics and also has some drawbacks. First of all, the most important, geothermal energy is a clean and renewable energy. Its contribution to global warming is relatively negligible comparing with fossil fuels. A geothermal energy unit has a small areal foot-print **[94].** The main environmental burdens for geothermal energy due to the material and equipment production and power plant construction, which is a common problem for most renewable energy sources **[99]**. Contribution to water pollution, disposal of waste fluids and the small quantities of chemicals (e.g. arsenic) and gases (H2S and CO2) contained in them is the other issue. However, comparing with the fossil fuels, environmental effects of using geothermal energy are marginal. Geothermal sources show an indigenous nature with an extensive global distribution. Geothermal energy production is independent of season, weather conditions or climate **[94].** Since power plants are constructed where the geothermal resources occurs, they avoid transmission losses and increase flexibility in system use. Furthermore, geothermal power generation helps to develop a decentralized form of electricity generation **[99].**

World Geothermal Energy Facts

Geothermal Power Generation

The world has a huge geothermal resource that can be utilized for direct use, but there are just 24 countries which experience temperatures high enough for the generation of electricity. These 24 countries have a total geothermal power installed capacity of 10715 MWe by the year 2010. Six countries account for 81% of the geothermal generation capacity in the world. The USA ranks the first with 3040 MW. Turkey showed one of the highest output growth between 2005-2010 was with a 308% increase in installed capacity **[Table 25] [100].**

Table 25: Installed geothermal power capacity and geothermal electricity generation in top 13 countries [95, 100]

Country	Geothermal Power Capacity MW	Geothermal Electricity Generation GWh	% of National capasity	Change Between 2005-10 %
United States	3093	16603	0,3	21
Philippines	1904	10311	12,7	-1
Indonesia	1197	9600	2,2	50
Mexico	958	7047	1,9	1
Italy	843	5520	1	7
New Zealand	628	4055	6	44
Japan	536	3064	0,2	0
Iceland	575	4597	22,3	184
El Salvador	204	1422	14	35
Costa Rica	166	1131	8,4	2
Kenya	167	1430	11,2	29
Nicaragua	88	310	11,2	14
Turkey	82	490	< 1	308

As shown in Table 25**,** geothermal energy provides an important contribution to the national capacity and national generation of energy for some countries. The world average contribution to national installed capacity is 9.4%, and the corresponding average contribution to national electricity generation is about 11.6% **[2].** On average, 0.31% of all world electricity is produced from geothermal sources **[101].**

During the period 1980-2005, the worldwide geothermal installed capacity increased by a factor of about 2.3, at a very uniform rate of nearly 200 MWe/yr **[95].** However, since 2005, an increase in geothermal development has become evident, with a linear trend of about 350 MWe/yr to 2010, or a total increase of 20% **[100].**

Direct use of geothermal energy

As compared to geothermal electricity, the direct use of geothermal energy supports higher energy efficiency and involves lower investments of initial capital **[102].** Therefore, geothermal direct-heat utilization is growing much faster than geothermal power, with a recent growth rate of 79 % between 2005-2010 **[103].** Iceland leads the world in direct heating usage, supplying some 85 percent of its total space-heating needs from geothermal **[104].** Turkey is one of the most active countries in direct applications of geothermal having an installed capacity of 2084 MWth by the year 2010 (6th biggest installed geothermal power capacity) **[Table 26].**

Table 26: Geothermal direct use installed capacity [103]

Country	Installed thermal power (MWth)
USA	12611
Sweden	4460
Norway	3300
Germany	2485
Japan	2100
Turkey	2084
Iceland	1826
France	1345
Switzerland	1061
Italy	867
Finland	857
Total	50583

If the temperature of the resource is too low for conventional direct application, geothermal heat pumps can be used for space heating **[105].** About half of the existing geothermal heat capacity exists as geothermal heat pumps (also called ground-source heat pumps) **[106].** Ground Source Heat Pumps are one of the fastest growing forms of geothermal energy, with annual increases of well over 10% in about 30 countries over the past decade **[95].**

Situation in Turkey

Turkey is located on the Alpine-Himalayan orogenic belt which serves a high geothermal potential **[107].**

Figure 14: General tectonic and volcanic features and important geothermal fields of Turkey [108]

According to General Directorate of Mineral Research and Exploration (MTA) records, there are nearly 274 geothermal fields and occurrences in Turkey. About 25 of them are already being utilized for direct and indirect use. Balneological use of geothermal resources is common in Turkey **[101].**

The geothermal resources in Turkey are mostly moderate and low-temperature ones. Most of the geothermal sources with high temperature which are suitable for direct use projects and power generation are discovered primarily in the graben structures of Western Anatolia. Other important resources are distiributed at the Central and Eastern Anatolia volcanic regions **[Figure 14] [101].**

Conventional electrical power production is limited to fluid temperatures above 150 C, but considerably lower temperatures can be used in binary cycle systems **[109].** In table 27, the 17 fields that have the necessary conditions for generating electricity in Turkey can be seen**.**

Table 27: Geothermal fields suitable for electricity generation in Turkey [110]

Geothermal fields	Temperature °C
Denizli-Kızıldere Field	242
Aydin–Germencik	232
Manisa–Salihli–Gobekli	182
Canakkale–Tuzla	174
Aydin–Salavatli	171
Kutahya–Simav	162
Izmir–Seferihisar	153
Manisa–Salihli–Caferbey	150
Aydin–Yilmazkoy	142
Izmir–Balcova	136
Izmir–Dikili	130
Aydin-Sultanhisar	145
Aydin Atca	125
Manisa-Kavaklidere	213
Aydin-Pamukoren	187
Aydin Umurlu	155
Aydin-Hidirbeyli	143

Turkey, possessing one-eighth of the world's total geothermal potential, has significant geothermal energy production. Much of this potential is of relatively low enthalpy that is not preferable for electricity production but still useful for direct applications **[111].**

Table 28: Turkey's geothermal power generation [109, 110]

Power Plant	Commissioned in (year)	Installed capacity (Mwe)	Max Temp. C	Under cons. or planned (MWe)
Kızıldere-Denizli	1984	17,8	243	60
Dora-I Salavatlı-Aydın	2006	7,35	172	7,5
Bereket Enerji-Denizli	2007	7,5	145	
Gürmat-Germencik-Aydın	2009	47,4	232	47,4
Tuzla- Çanakkale	2009	7,5	171	7,5
Dora-II Salavatlı-Aydın	2010	9,7	174	7,5
Total		81,61		129,9

Geothermal power installed capacity of Turkey is 81.61 MWe **[Table 28]** and the installed geothermal heat capacity is 2084 MWt by the year 2010 **[110].** Turkey is the sixth country in the World in operating geothermal direct use applications by the year 2010. 1494 MWt (which equals the heat requirement of 201,000 residences equivalance) of this is being utilized for geothermal heating including district heating, thermal tourism facilities heating and 2300000 m2 geothermal greenhouse heating. The remaining 552 MWt of this potential is being utilized for balneological purpose. Geothermal water is used in 260 spas for balneological purposes (402 MWt) **[110].**

The geothermal electricity generation capacity potential of Turkey is estimated at 2000MW (16 TWh/year). The overall geothermal heat generation potential of Turkey is about 31,500 MW, which is one of the biggest 10 potentials in the world **[33].** The 9th Development Plan (2007-2013) contains 2013 targets for both electricity production and direct use. The electricity production is predicted as 550 MWe, based on the potential from 13 fields and the direct use target is 8000 MWt, of which 4000 MWt would be for district heating, 1100 MWt for balneology, 1 700 MWt for greenhouse heating, 300 MWt for cooling, 500 MWt for drying and 400 MWt for fish farming and other applications **[113].**

According to EIE (General directorate of electrical power resources survey and development administration), if Turkey fully utilizes its geothermal potential**,** Turkey will be capable of meeting 5% of her electricity need and 30% of heat requirement from geothermal sources, which corresponds to 14% of her total energy need.1000 Mwe electricity (power demand equivalent to 3.000.000 houses); 500.000 houses heated, 30000 decare greenhouse heating, 400 thermal spa and pools; 1000000 capasity hotels, 250000 people employed, annual income and savings total estimated as 6.8 billion $. According to Turkish Geothermal Association, total geothermal heating potential of Turkey is 1.250.000 residence equivalent (10000 MWt). This corresponds to a fuel oil save of 2.800.000 tons/ year or in other words 2.7 billion USD/ year with current prices **[114]**.

The economics of geothermal power depends on several factors. Cost is primarily dependent on technology and is affected from production technology. The characteristics of geothermal resource and the evolving market rules are the most significant factors contributing to geothermal energy value. As additional geothermal capacity is developed, these variables will be quantified more precisely **[99].**

2.2.4 Hydroenergy

Hydropower is the power that is derived from the force or energy of moving water, which can be utilized by generating electricity in hydroelectric power plants. Modern hydro turbines can convert as much as 90% of the available energy into electricity whereas the best fossil fuel plants are only about 50% efficient **[115].**
The main advantageous characteristics of hydropower can be listed as below **[116]**:

- Hydropower is renewable because it draws its essential energy from the sun and particularly from the hydrological cycle. It is the most widely used form of renewable energy.
- Water resources are widely spread around the world. Hydropower potential exists in about 150 countries and about 70% of the economically feasible potential still remains to be developed.
- Generating electricity from water is a proven and well-advanced technology, with more than a hundred years of experience, with modern power plants providing the most efficient energy conversion process that has been developed up to now.
- It has the lowest operating and maintenance costs and the longest plant life (50–100 years and more) compared with other large scale generating options.
- Hydropower definitely has very low contribution to climate change comparing with fossil fuels.
- Generally, dams provide flood protection.
- Hydropower industry creates job opportunities.
- Hydropower generation neither consumes nor pollutes the water. Therefore, it sustains fresh water and food supply
- Produces no atmospheric pollutants and only very few GHG emissions

Besides having numerous advantages, hydropower usage has also some drawbacks **[117, 118]**:

- Construction of a hydropower plant requires high initial investment and long-term planning.

- Hydropower plants have very large footprints. Building large dams with hundreds of massive barriers of concrete and rock across rivers and creating huge artificial lakes, besides creating a major power supply, irrigation and flood control benefits, on the other side floods large areas of fertile land and displaces thousands of local inhabitants.
- There are also numerous environmental problems that can result from such major interference with river flows. Hydropower plants may cause modifications on hydrological regimes, aquatic and other habitats (i.e. barriers for fish migration).

Because of these many environmental and social negative impacts of large hydropower plants, small hydropower (<10MW) construction is becoming a strong alternative. The life of a small hydro system is nearly 50 years or more and needs little maintenance. It is also in many cases cost competitive with fossil-fuel power stations. **[117].**

Precipitation is another critical issue in hydroelectricity generation. Water availability varies from year to year, making causing to a succession of dry years, as in 20 sub-Saharan countries experienced from 1981 to 1984 and California and more recently east and southeast Turkey from 1999 to 2001 **[119].**

World Hydroenergy Facts

The hydroelectric power potential of a river or a country can be determined at three levels:

Gross potential: It depends on potential of water basins and the foreseen development projects of the region.

Technical potential: It corresponds to the technically available part of the gross potential. It can slightly increase with advances in technology or decrease with a permeable geological formation.

Economic potential: It corresponds to the economically advantageous part of the technical potential, compared with alternative energy resources **[120].**

One-fifth of the world's electricity is generated by hydropower and majority of power supply in 55 countries is provided by hydropower plants. Hydropower is the only domestic energy resource for several countries. Presently the role of hydropower in electricity generation is substantially greater than any other renewable resource. Many developed countries have already utilized their economical potential. On the other side, the remaining potential of the less developed countries is vast **[121].**

Table 29: Hydroelectricity net generation of some countries [122, 123, 124]

Hydroelectricity Net Generation (Billion Kilowatthours)					change 2008 over 2007 [123]	2008 share of total [123]	% of hydro in electricity generation [124]
Countries	2005 [122]	2006 [122]	2007 [122]	2008 [122]			
China	393,05	431,43	429,96	522,42	21,5	18,5%	14,8
Canada	359,99	351,79	364,72	368,66	1,1	11,7%	57,6
Brazil	334,08	345,32	370,28	361,41	-2,4	11,5%	84,0
United States	270,32	289,25	247,51	248,09	0,2	7,9%	6,3
Russia	170,95	171,62	175,28	160,61	-8,4	5,5%	17,6
Norway	134,31	118,16	132,60	137,97	4,0	4,4%	98,2
India	100,71	112,58	122,57	113,85	-7,1	3,6%	15,4
Venezuela	74,28	81,29	83,03	86,71	4,4	2,7%	72,3
Japan	75,71	86,65	73,27	70,76	-3,4	2,2%	7,4
France	51,23	55,58	57,61	61,91	7,5	2,0%	
Turkey	39,17	43,80	35,49	32,95	-7,2	1,0%	17

As can be seen from the table 29, Brazil, Canada, Norway and Venezuela are the countries in the world where hydroenergy constitutes the great majority of the domestic power generation. Norway is a very successful country in utilizing hydro sources, producing 98–99% of its electricity from hydropower plants **[125].**

Like other renewable sources, hydropower is expected to increase its importance in the future. Hydroelectricity production of the World has grown with an average rate of 2.3% per year since 1980. It is estimated that average growth rate will be nearly 3.6% per year up to the year 2020 **[126]**. The highest growth rates are expected in developing or strongly industrializing countries with high, yet unexploited hydropower potential **[126].**

Small hydro currently accounts for over 40GW of world capacity. After 20 years of decline in the hydropower industry in Europe, small hydro power plants are believed to trigger a new hydropower development in the next decade **[118].**

Small-scale power generation is necessary for decentralized development which means bringing electricity to remote and rural communities. Larger hydropower systems feed the regional grid systems. So that the further development of hydropower can be discussed and planned on a wide range of scales (large, medium or small) to meet diverse needs and market conditions **[121].**

Situation in Turkey

Contrary to the general belief, Turkey is not a country with abundant water resources. The annual water potential per capita is at around 1500 m3 but expected to reduce to 1000 m3 with the estimation of 100 million populations in the year 2030. Turkey can be considered relatively ‘‘water-rich’’ when compared with some Middle Eastern countries with 150–400 m3/year per capita water potential. But being a ‘‘water-rich’’ country requires having 8000–10,000 m3/year water per capita **[115].** Turkey’s total water potential per year is calculated as 110 billion cubic meters and annual water amount per capita is 1486 cubic meters as the year 2004. Precipitation differs considerably both from year to year and among the river basins. The annual depth of precipitation is as high as 250 cm in the Eastern Black Sea region and as low as 30 cm in some parts of Central Anatolia. The Southeast region has the richest water resources contributing 28% of Turkey’s total water potential **[119].**

Table 30: Hydropower potential and capacities of the basins [127]

Basin	Gross potential (GWh)	Economically feasible potential (GWh)	Installed power (MW)
Firat (euphrates)	84.122	39.375	10.345
Dicle (tigris)	48.706	17.375	5.416
Eastern Black Sea	48.478	11.474	3.257
Eastern Mediterranean	27.445	5.216	1.490
Antalya	23.079	5.355	1.537
Çoruh	22.061	10.933	3.361
Ceyhan	22.163	4.825	1.515
Seyhan	20.875	7.853	2.146
Kızılırmak	19.522	6.555	2.245
Yeşilırmak	18.685	5.494	1.350
West Black Sea	17.914	2.257	669
Western Mediteranean	13.595	2.628	723
Aras	13.114	2.372	631
Sakarya	11.335	2.461	1.175
Susurluk	10.573	1.662	544
Others	30.744	1.788	546
TOTAL	440.981	126.1	188.169

Despite not being a water-rich country, Turkey has considerable hydropower potential, one of the highest in Europe. Turkey is the second richest country after Norway in Europe for its gross hydroelectric potential which is 440 TWh/ year. Technically useable potential is 215 TWh/year, and economic potential is 126.1 TWh/year (nearly 60% of technically feasible potential) according to State Hydraulic Works (DSI) estimations **[Table 30] [128].** In a further analyse, Yuksek **[127],** reevaluated the Turkey's hydropower potential and concluded that Turkey's annual economically feasible hydropower potential is about 188 TWh, nearly 47% greater than the previous estimation figures of 128 TWh.

Despite the big hydropower potential, Turkey has utilized only 35% of its economic potential so far. Table 31 shows how successful some European countries are in utilizing their hydropower potential. Sweden, Norway and France have already utilized almost all of their economic potential and they are now approaching to their technical limits. According to MENR's (Ministry of Energy and Natural Resources) projections, hydropower plants will be generating 103.7 TWh electricity in the year 2020, which still contributes nearly half of the total technical hydropower potential of Turkey **[128].**

Table 31: Technical [T] and utilized [U] hydroelectric potential of some countries [128]

country	Canada	France	Japan	Norway	Sweden	Turkey	USA
T (Twh/year)	592,9	82	132,4	171,4	80	216	366
U(Twh/year)	332	72	102,6	142	79	44,4	322,1
U/T (%)	56	87,8	77,5	82,8	98,8	20,4	85,7

Table 32: Ratio of the hydroelectrical energy production, to the total gross electrical energy production in Turkey [120] and [129]

Year	%	Year	%	Year	%
1978	45,7	1988	34,5	1998	38,0
1979	48,8	1989	43,0	1999	29,8
1980	51,1	1990	40,2	2000	24,7
1981	53,4	1991	37,7	2001	19,6
1982	41,5	1992	39,5	2002	23,4
1983	43,9	1993	46,0	2004	30,5
1984	35,2	1994	39,1	2005	24,4
1985	29,9	1995	41,2	2006	25,0
1986	42,0	1996	42,7	2007	18,7
1987	60,3	1997	38,6	2008	17,3

Table 32 and Figure 15 show the ratio of the hydropower production to the total gross production and it can be derived from the table that the mean of 26 years is 39.7 %. It shows hydropower has been an important source for the electricity demand of the country, historically. The unusual trend in the years 1999, 2000, 2001 and 2002 was due to the drought. After 2002 the ratio had an increasing trend up to 30.50 in 2004, however by the year 2008 the share of hydropower is decreased to a very low percentage of 17,3 **[120].**

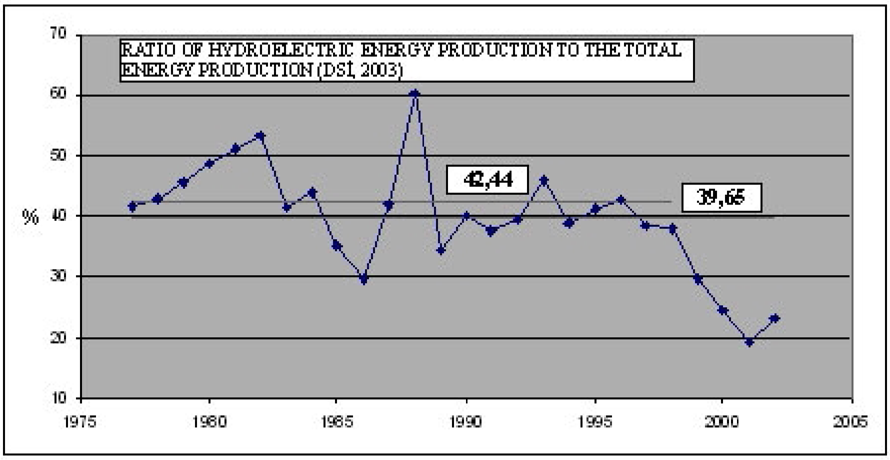

Figure 15: Ratio of hydropower production to total energy production in Turkey [120].

Table 33: Operation, maintaenance cost and installed power unit prices by resources [120]

Resource type	Operation and Maintenancecosts [cents/ kWh]	Fuelcosts [cents /kWh]	Total operationalcosts [cents / kWh]	Installed power,unit prices [$/kW]
Natural gas	0,415	3,609	4,024	795
Lignite	1,495	1,839	3,334	1500
Imported coal	1,413	1,965	3,378	1325
Nuclear	0,780	1,000	1,780	2000
Hydroelectric	0,203	-	0,203	1200 –1500

Table 33, summarizes the operation and maintenance costs (necessary payment in order to produce 1 KWh electrical energy) and unit prices of the installed power **[120].** Hydropower is obviously cost-effective compared to the fossil fule power generation.

The government is planning the construction of 332 more hydroplants to utilize the remaining hydropower potential. This would bring the number of hydropower plants to 485, and add more than 19 GW of capacity to the hydrosystem **[128].**

The scale of hydropower development is an important issue for Turkey. Priority has been given to large-scale hydropower projects to be able to meet the growing energy demand of Turkey as a developing country. On the other side, small and micro hydropower development is necessary when considering the environmental and social concerns. During the last three decades, the average annual increase of small hydropower capacity was 5–10% **[130]**.

2.2.5 Bioenergy

Bioenergy is the energy obtained from the various kinds of organic sources. Biodiesel, biogas, bioalcohols are some types of bioenergy **[131].** Bioenergy has less negative environmental effects compared with fossil fuels. Bioresources have low sulphur content and emits less amounts of CO_2 when burned **[132].** By using biofuels instead of petroleum-based gasoline and diesel, nearly 50-70% of CO_2 is saved; when it is replaced with road fuel gases, CO_2 saving is around 30% **[133].**

Biodiesel is a domestic resource generated from some agricultural residues. Biodiesel is an alternative for petroleum-based diesel fuel so that it can reduce the dependency on imported petroleum products **[134].** Furthermore, bioenergy is the only source that can be an alternative for fossil fuels in all energy markets; heating, power generation and transportation **[135].**

The bioenergy industry has a potential to create a new large market which may provide a source of income for small farmers **[136],** and result in rural development and therefore a better income distribution **[132]**. The growing biofuel market colud be an important advantage for especially developing countries since they have more agricultural lands available and relatively favourable conditions **[136]**.

On the other hand, bioenergy has some drawbacks:

Biofuel production is more expensive than that of petroleum based fuels partly due to the cost of raw material **[132].** Raw material cost accounts for almost 80% of the total bioenergy production **[137].** Collecting, transporting and storing biomass is also expensive. Marketing, distribution and service are a bit costly since they are not yet well organized. At the moment, biofuels are about 2.3 to 2.8 times more expensive than fossil fuels depending on the fluctuations of crude oil price **[132].** There is a growing trend especially in developed countries towards using more efficient technologies for bioenergy conversion which in turn may result in a more competitive bioenergy market in the total energy market **[138].**

Excess use of water, soil nutrients and abundant use of fertilizers and manure for bioenergy production may cause serious environmental problems. Besides that reserving agricultural lands for bioenergy production may threaten the food security [**132].**

Inefficiency of the production process is another problem for bioenergy development. Cultivating, harvesting and processing of biomass require big amounts of energy. Agricultural products used in bioenergy production have lower energy content than other fossil resources **[132].**

There are some practical limitations for biofuels to replace fossil fuels. If the USA, Canada and the EU were to replace only 10% of their current transport fuels with biofuels, it would require an investment of between 30% and 70% of their national crop areas **[139].**

World Bioenergy Facts

Biomass, contributing nearly the 77% of all renewables, is the most common energy source all over the world **[Figure 16].** Biomass contributes nearly 20-30% of the total energy supply in especially developing countries. In the less developed countries, biomass is more important having a share of more than 50% in total supply. Most of the biomass used in these countries are non-comercial and utilized in cooking and residential heating in rural and poorer regions of the country [**140, 141, 142].**

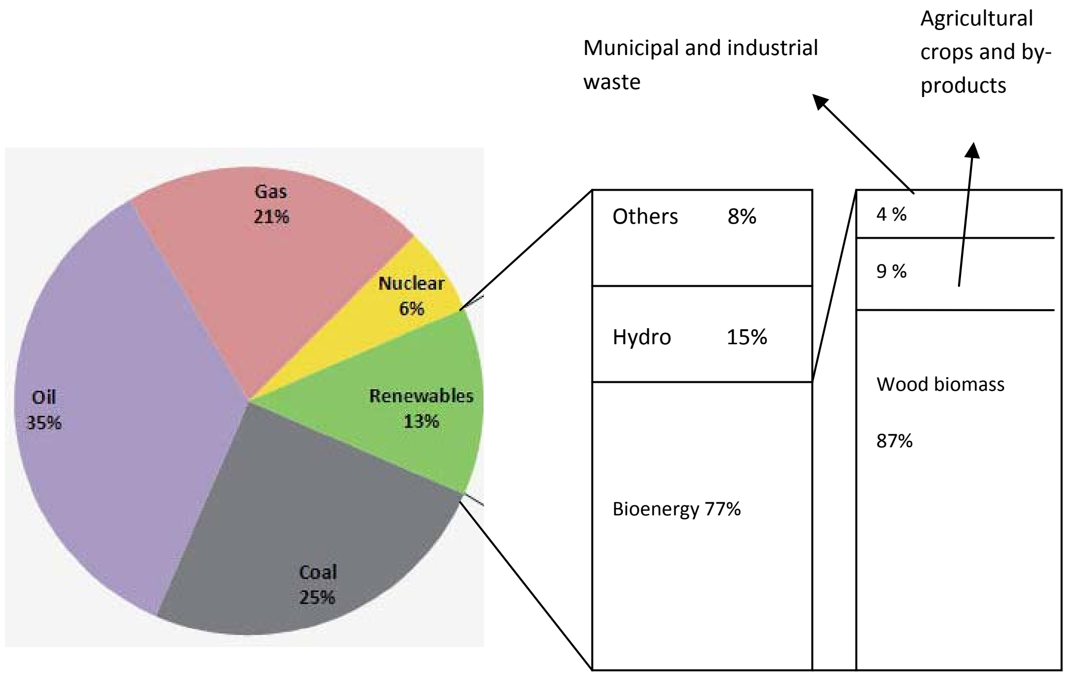

Figure 16: Share of bioenergy in the world primary energy mix [135]

Biomass power generation continued to increase at both large and small scales. Total biomass installed power capacity is 52 GW, with an increase in 2008 about 2 GW.

The EU is responsible for about two-thirds of world biodiesel production. EU now has a biofuel target, most for 5.75 percent of transport fuels by 2010 **[143].**

Situation in Turkey

Biomass contributes about two-thirdsof the totsl renewable energy production of Turkey. Important biomass sources of Turkey are wheat straw, grain dust and hazelnut shell. The annual biomass potential of Turkey is approximately 32 Mtoe, 17.2 Mtoe of which is recoverable. **[144].** Turkey's present and planned biomass energy production is shown in Table 34 **[145].**

Table 34: Present and planned biomass energy production in Turkey [145]

Years	Total biomass production [ktoe]
2000	6982
2005	7260
2010	7414
2015	7320
2020	7520
2025	7810
2030	8205

Turkey has 28 million hectares of cultivated land that accounts for nearly 36% of the country's total surface area. There are many abandoned agricultural land in Turkey that are not being utilized. Creating demand for biomass fuel would help to bring these areas back into economic exploitation **[132].**

Table 35: Turkey's annual biomass energy potential [146]

Type of biomass	Annual potential (million tons)	Energy potential (mtoe)
Annual crops	55	14,9
Perennial crops	16	4,1
Forest residues	18	5,4
Residues from agro industry	10	3
Residues from wood industry	6	1,8
Animal wastes	7	1,5
Other	5	1,3
Total	117	32

Agricultural residues in Turkey can be considered in three categories **[147]:**

1) Annual crop residues that remain in the field after crops are harvested. The main annual crops in Turkey are cereals, maize, cotton, rice, tobacco, sunflower, groundnuts, and soybeans. Energy potential of total annual crop residue is 14,9 mtoe, which is the highest among other agricultural residues **[Table 35].**

2) Perennial residues in Turkey are the ones that remain in the field after pruning of trees, shells, kernels etc.

3) Agro-industrial residues such are; cotton-ginning, seed oil industries, olive oil industries, corn industries, wine and kernel factories.

Table 36: Total energy value of agricultural residues in Turkey [147]

Regions	Field crops (PJ)	%	Fruits (PJ)	%	Animals (PJ/year)	%
Mediterranean	57	25	8	11	4,5	7
Aegean	24,2	11	15,3	20	6	10
Marmara	41	18	9,5	13	6,2	10
Central Anatolia	31,3	14	1	1	8,9	15
East Anatolia	8,2	4	0,9	1	10,9	18
Southeast Anatolia	37,1	16	4	5	3,1	5
Black sea	29,6	13	36,1	48	20,5	34
Total	**228,4**	**100**	**74,8**	**100**	**0,1**	**100**

The percentage of main residues left from field crops are Maize 33,4%, Wheat 27,6%, Cotton 18,1%; main fruit residues are Hazelnut 55,8%, Olive 25,9%. As seen from the table Black sea region has relatively high potential in field crop, fruit and animal waste **[Table 36] [147].**

The type and quantity of crops that form the basis of agricultural sector in Turkey (wheat, barley, tobacco, cotton, rice etc.) give rise to huge amounts of agricultural residues. The highest estimated amounts of residues are of wheat and maize followed by barley and cotton. Mainly residues from the production of industrial agricultural products are left over the field. These residues are treated in an uncontrolled manner; either burnt in open-air fires or disposed to decay. In both situations, residues causes to significant environmental impacts while useful resources for energy are wasted **[147].**

Most of the biomass produced in Turkey is consumed for residential heating, cleaning and cooking purposes in rural areas. Wood is still a primary source for heating in nearly 6.5 million homes in Turkey. Animal wastes of the country is preferred for agricultural use rather than for biofuel production. The only waste power plant of Turkey is built in Adana, in 1991 **[148].**

In order to increase supplies, the Turkish Government is considering providing incentives for the production of canola. Erdin **[149]** states that canola, a source of bio-diesel production, is drawing investors to Turkey. He claims that cost-effective production, transportation and labor force make Turkey an attractive center for canola production **[149].** On the other side, Kleindorfer and Öktem **[150]** states that farmers in the Black Sea, Mediterranean and Aegean regions are knowledgeable and they know that the ground and climate are more suitable for growing a large variety of valuable crops than canola. Hence the opportunity to grow canola in these regions is limited. Since the commercial biomass use is very new in Turkey, production and investment on bioenergy is still a problematic issue. Away from that kanola example, Erdoğdu (2008) has stated a list of possible barrier that the producers and investors may meet **[132]:**

-In contrast to fossil fuels, biomass fuels are characterized by their low density, and sources of biomass are small, dispersed, disparate and seasonal.

-A unique aspect of many agricultural waste materials is their seasonality. The seasonality of agriculture is seen to be a key risk, for both establishing viable fuel supply businesses and for maintaining year-round fuel supplies for potential energy plants.

-The high capital cost of agricultural waste or biomass power plants is a major disincentive to investors. Further, the upper size limit of biomass plants is lower than fossil fuel-fired plants, because long-distance transport of low-density biomass fuels is generally not considered feasible (for financial and environmental reasons).

-A further important consideration is that the core business for the wood or agro-industry plant owners and managers is not energy based. If a capital sum is available for investment, improvements to their core business are likely to take precedence over any potential energy-related business expansion

- Insufficient available information about existing and possible future costs of biomass utilization,

- Insufficient detailed biomass energy resource assessments and data banks pertaining to Turkey,

- Insufficient credit facilities, particularly for small-scale projects,

- Administrative and time-consuming obstacles for foreign investors,

- Need for support for infrastructure and management knowhow at a local level,

-Insufficient policy and market instruments (including available subsidies) in the environmental, agricultural and energy sectors,

- Need for public acceptance and willingness

2.3 Nuclear Energy

A nuclear reactor produces and controls the release of energy from splitting the atoms of certain elements [**151].** The fuel is basically uranium **[152].** Uranium is milled and processes to create uranium oxide. The conversion plant removes impurities and chemically converts the material. This process, which makes the uranium usable as a fuel for the reactor, is called enrichment. In the reactor, nuclear fission produces energy to heat water and create steam that powers generators to produce electricity. After a cooling period, nuclear power plants store used fuel on site in steel and concrete vaults. Than it is transported to a recycling site or to a geologic repository which is known as the best method of managing nuclear waste **[153].**

Nuclear energy is best applied to medium and large-scale electricity generation on a continuous basis (i.e. meeting "base-load" demand) **[152].** Nuclear energy is a highly efficient energy and it has also negligible greenhouse emissions. On the other hand, nuclear energy has some disadvantages.

Cost: Nuclear power reactors are expensive to build but relatively cheap to operate **[152].** The fuel uranium is relatively abundant. However extremely high initial costs and long construction time of a nuclear power plant is an important disadvantage **[154].**

Safety: Safety is a vital issue in operation and constructing a nuclear power plant. The Three Miles Island (1979) and The Chernobyl (1986) accidents are the worst experiences showing the importance of safe nuclear systems. Nearly one-third of the total cost of a reactor is safety system cost **[152].** Recently, by the advances in nuclear reactor design, risk of a serious accident is getting lower **[154].**

Waste: Radioactive wastes produced by nuclear energy generation are the most unpleasant and dangerous wastes of all the industry. However, these unwanted nuclear wastes are in great amounts. Safety of the storage and safety of the waste transport are other important issues to consider **[152].**

Proliferation: The current international safeguards regime is inadequate to meet the security challenges of the nuclear development of the countries. The reprocessing system now used in Europe, Japan, and Russia that involves separation and recycling of plutonium presents unwarranted proliferation risks **[154].**

World Nuclear Energy Facts

As of January 2010, 29 countries worldwide were operating 437 nuclear reactors for electricity generation and 55 new nuclear plants were under construction in 14 countries. Nuclear power plants provided about 14 percent of the world's electricity production in 2008. In total, 15 countries relied on nuclear energy to supply at least one-quarter of their total electricity **[155].**

Table 37: Countries generating the largest percentage of their electricity in 2008 from nuclear energy [155]

Country	Percent
France	76.2
Lithuania	72.9
Slovakia	56.4
Belgium	53.8
Ukraine	47.4
Sweden	42.0
Slovenia	41.7
Armenia	39.4
Switzerland	39.2
Hungary	37.2
S. Korea	35.6
Bulgaria	32.9

The United States produces the most nuclear energy, with annual nuclear power generation of 837 Twh **[Table 38],** providing 20% **[156]** of the electricity it consumes. France produces the highest percentage of its electrical energy from nuclear reactors, 76.2% as of 2008 **[Table 37]**. In the European Union as a whole, nuclear energy provides 28.9% of the electricity by 2006 **[157].** World nuclear association predicts that, even on a low boundary scenario nuclear power capacity will grow about 2,050 GW levels, which represents more than a five-fold increase over today's nuclear capacity of 370 GW **[158].**

Table 38: World nuclear power producers [159]

Producers	TWh	%WorldTotal
United States	837	30.8
France	440	16.2
Japan	264	9.7
Russian Federation	160	5.9
Korea	143	5.3
Germany	141	5.2
Canada	93	3.4
Ukraine	93	3.4
Sweden	67	2.5
United Kingdom	63	2.3
Rest of the world	418	15.3
World	**2 719**	**100.0**

The average age of the 435 nuclear power plants that are currently operating worldwide is 25 years and in Western Europe, 75 percent of the plants are in the last half of their operating life and around 20 percent have been running for more than 30 years. Recently, 15 countries are planning to construct total 55 new nuclear power plants in the next decade. China is planning to have the biggest increase in nuclear capacity. As can be seen from the table 39, most of the European countries except East European countries have almost no plans of increasing their power capacity. By the time, with the old units finishing production, it can be said that there would be possible decreasing trend in Western industrialized countries' nuclear capacity in the near future.

Table 39: Nuclear units under construciton world wide [155]

Country	Total Mwe
Argentina [1]	692
Bulgaria [2]	1906
China [20]	19920
China, Taiwan [2]	2600
Finland [1]	1600
France [1]	1600
India [5]	2708
Iran [1]	915
Japan [1]	1325
Pakistan [1]	300
Russia [9]	6894
Slovak Republic[2]	810
South Korea [6]	6520
Ukraine [2]	1900
USA[1]	1165
Total	50855

Situation in Turkey

There are no nuclear power plants in operation or under construction in Turkey. The Turkish Electricity Transmission Company (TEIAS) prepared a report in 2004, entitled "Electricity Energy Generation Planning Study for Turkey (2005-2020)", and this report provides guidance for the decision makers, investors and market actors on the timing, composition and capacities of the additional electricity generation sources needed for the next 15 year period. According to this planning study, it is planned to add about 5000 MWe total nuclear capacity until 2015 with the consideration of high demand scenario. The procedures and principles regarding the requirements to be met by the companies bidding for the competition, for the nuclear power plants to be constructed are stated under a nuclear power law **[160].**

Studies to build a nuclear power plant in Turkey were started in 1965. However due to some financial and regulative factors, this project is postponed up today **[160].** By the January 2010, Turkey decided to build the power plant in a governmental cooperation with Russia **[161].**

CHAPTER 3

CLIMATE CHANGE

3.1 Global Warming and Climate Change

Nearly one-third of the solar energy that reaches the top of Earth's atmosphere is reflected directly back to space. The remaining two-thirds are absorbed by the surface and by the atmosphere. To balance the absorbed incoming energy, the Earth radiates nearly the same amount of energy back to space however at much longer wavelengths. Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere and radiated back to Earth. This is called the Greenhouse Effect. The greenhouse effect comes mostly from water vapour, carbondioxide (CO2), methane (CH4), nitrous oxide (N2O), ozone and several other gases that are present in the atmosphere. Water vapour and CO2 are the most important contributors to this greenhouse effect. However by the increase in the amount of CO2, the atmosphere warms and as a consequence the concentration of water vapour increases. This causes a further intensifying in the greenhouse effect. Thus, adding CO2 alone causes a double greenhouse effect by indirectly increasing vapour in the atmosphere **[162].**

If there was no greenhouse effect on the atmosphere, the earth would be much colder than now, which means that it would not be a habitable place for human. However, human activity, primarily the burning of fossil fuels and destroying forests, since the Industrial Revolution, has seriously increased the amount of greenhouse gases in the atmosphere and therefore increased that natural greenhouse effect. This overintensified greenhouse effect, caused mostly by human, resulted in an increase in the earth's average temperature, which is called "global warming".

Considering that the mean temperatures during the last ice age were about 4°C lower than today, it is expected that a few degrees of increase in the mean temperature of the world will result in serious and dangerous changes in the climate of the earth **[163].**

There are a number of scientists who are skeptic about the effect of human activity on global warming and the possible impacts of climate change. However, majority of world scientists agree that the earth is warming faster since the industrial revolution and the most important cause of global warming is the human activity. Researches show that the concentrations of CO_2 and methane have increased by 36% and 148%, respectively, since 1750 **[163].**

These basic conclusions have been endorsed by more than 40 scientific societies and academies of science, including almost all national science academies of the major industrialized countries **[164].**

Here are the key results of the 3 assessment reports of International Panel on Climate Change (IPCC) **[165]**:

"The balance of evidence suggests a discernible human influence on global climate." (IPCC, 1995)

"Most of the warming of the past 50 years is likely (>66%) to be attributable to human activities." (IPCC, 2001)

"Warming is unequivocal, and most of the warming of the past 50 years is very likely (90%) due to increases in greenhouse gases." (IPCC, 2007)

Compared to its previous assessments, it is important to note that the IPCC (2007) is stronger in its conclusions regarding the effects of human influence on the climate system **[165].**

3.1.1. Current impacts of climate change

Below there is a list of some scientific facts stated in the IPCC 4th Assessment Report 2007 **[166]**:

i. Changes in the atmosphere

- The amount of carbon dioxide, methane and nitrous oxide in the atmosphere in 2005 exceeds by far the natural range of the last 650,000 years. CO2 (379 ppm)-natural range (180 to 300 ppm), Methane (1774 ppb)-natural range (320 to 790 ppb), Nitrous oxide (319 ppb)-pre-indutrial value (270 ppb)

ii. Changes in the temperature

- Cold days, cold nights, and frost events have become less frequent. Hot days, hot nights, and heat waves have become more frequent.
- Eleven of the twelve years in the period (1995–2006) rank among the top 12 warmest years in the instrumental record (since 1850)
- Warming in the last 100 years has caused about a 0.74 °C increase in global average temperature.
- Average Arctic temperatures increased at almost twice the global average rate in the past 100 years.

iii. Ice, snow, permafrost, rain, hurricanes and the oceans

- Increases in wind intensity, decline of permafrost coverage, and increases of both drought and heavy precipitation events observed.
- Mountain glaciers and snow cover have declined on average in both hemispheres.
- Losses from the land-based ice sheets of Greenland and Antarctica have very likely (>90%) contributed to sea level rise between 1993 and 2003.
- There has been an increase in hurricane intensity in the North Atlantic since the 1970s, and that increase correlates with increases in sea surface temperature.

3.1.2 Projected impacts of climate change

This report also describes some of what might be expected in the coming century, based on studies and model projections **[166]**:

i. Fresh water

- Dry regions are projected to get drier, and wet regions are projected to get wetter.
- Drought-affected areas will become larger.
- Heavy precipitation events are very likely to become more common and will increase flood risk.

- Water supplies stored in glaciers and snow cover will be reduced over the course of the century.

ii. Ecosystems

- The resilience of many ecosystems is likely to be exceeded this century by a combination of climate change and other stressors.
- Carbon removal by terrestrial ecosystems is likely to peak before mid-century and then weaken or reverse. This would amplify climate change.

iii. Coastal systems

- Coasts will be exposed to increasing risks such as coastal erosion due to climate change and sea-level rise.
- Increases in sea-surface temperature of about 1-3 °C are projected to result in more frequent coral bleaching events and widespread mortality unless there is thermal adaptation or acclimatization by corals.

3.1.3 Global Warming & Turkey

In the article "Climate change scenarios for Turkey" **[167]**, trends in precipitation and temperature in Turkey since 1951 are reported. Based on data from 113 stations of the State Meteorological Service, the authors observed that winter precipitation in western Turkey has decreased significantly whereas autumn precipitation has increased at stations in the northern parts of central Anatolia. It is reported that summer temperatures are increasing mostly in the western and southwestern parts of Turkey while winter temperatures show a general tendency to decrease. The more significant changes are concentrated in coastal stations. Stream flow data, measured between 1969-1998, indicate a decreasing trend in western and southwestern regions and some increase in the north. Researchers denote that the reason behind these changes is not certainly determined, and the need for more comprehensive study is underlined.

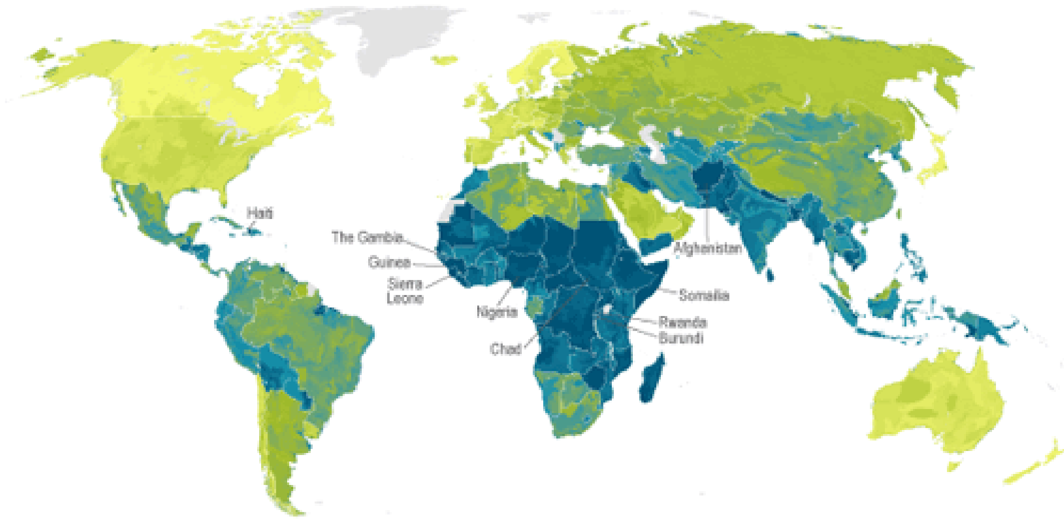

Figure 17: Maplecroft's climate change vulnerability index (CCVI) [168]

Maplecroft's Climate Change Vulnerability Index (CCVI), which is a very important attempt to quantify and map the vulnerability of countries to the possible impacts of climate change, can be seen in Figure 17. In this analysis climate change vulnerability factors are divided into six groups: economy; natural resources and ecosystems; poverty, development and health; agriculture; population, settlement and infrastructure; institutions, governance and social capital. According to this map, Norway is the best-equipped country in facing the challenges of climate change. Its low population density, excellent health-care and communication systems, good governance and a strong institutional framework are the factors carrying Norway to the best position in this list. Additionally, Norway's overall food, water and energy security are high and its ecosystems are well protected. Finland, Japan and Canada are the following lowest risk countries **[168].** Turkey is placed between the medium to high risk rank considering these vulnerability factors. This report shows that Turkey has still many things to do in order to confront the challenges of climate change.

3.2 International Acts for Climate Change

The fact that increasing CO2 and other greenhouse gases in the atmosphere may cause in a climate change was first claimed by S. Arrhenius, a Swedish scientist, in 1896 **[169].** However, the first social impact of this idea appeared in the 1st Climate Conference in 1979, held by World Meteorology Organisation (WMO) **[170].** After this first international awareness of climate change, in 1988 United Nations Environment Program (UNEP) was prepared and Intergovernmental Panel on Climate Change (IPCC) was founded in order to make researches on climate change and collect necessary data for the other researches **[171]**. In 1992, in the United Nations Conference on Environment and Development in Rio de Janerio, people agreed on the idea of acting together to stop the climate change. Although there are opponents of the idea, most of the scientists claim that 90% of the global warming is the responsibility of human and it should be controlled. In the Rio Conference, an international treaty, United Nations Framework Convention on Climate Change (UNFCCC) was set and opened for signature **[172].**

The UNFCCC established a long-term objective of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system **[172].** The UNFCCC agreed to a set of a "common but differentiated responsibilities" for the parties of the treaty. The parties agreed that **[172]**:

1. the largest share of historical and current global emissions of greenhouse gases originated in developed countries;
2. per capita emissions in developing countries are still relatively low;
3. the share of global emissions originating in developing countries will grow to meet social and development needs

Signatories to the UNFCCC are split into three groups **[172]**:

- **Annex I** countries
- **Annex II** countries
- Developing countries. (non-annex I countries)

Annex I countries (industrialized countries): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America

(40 countries and separately the European Union)

Annex II countries (developed countries which pay for costs of developing countries): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States of America

(23 countries and separately the European Union; Turkey was removed from the annex II list in 2001 at its request to recognize its economy as a transition economy.)

Annex I countries agree to reduce their emissions of greenhouse gasses to targets that are mainly set below their 1990 levels. They may do this by allocating reduced annual allowances to the major operators within their borders. Annex II countries are a sub-group of the Annex I countries. They comprise the OECD members, excluding those that were economies in transition in 1992 **[172].**

3.2.1 Kyoto Protocol

The treaty of UNFCCC originally set a voluntary goal of reducing emissions for developed countries **[172].** However in 1997, a legally binding international protocol is opened for signature in Kyoto, Japan **[173].**

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions **[Table 40].** Under the Kyoto Protocol, industrialized countries agreed to reduce their collective green house gas (GHG) emissions by 5.2% from the level in 1990 **[173].**

Below is the Article 3.1 in the Kyoto Protocol, stating the responsibilities of the Annex I countries **[173].**

"The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012."

Table 40: Annex B of Kyoto Protocol, assigned emission targets [173]

Countries or parties	Target [1990*/2008-2012]
EU-15**, Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland	- 8 %
US***	-7%
Canada, Hungary, Japan, Poland	-6%
Crotia	-5%
New zealand, Russian Federation, Ukraine	0
Norway	+1%
Australia	+8%
Iceland	+10%

*Some EITs have a baseline other than 1990.**The 15 States who were EU members in 1990 will redistribute their targets among themselves, taking advantage of a scheme under the Protocol known as a "bubble", whereby countries have different individual targets, but which combined make an overall target for that group of countries. The EU has already reached agreement on how its targets will be redistributed. *** The US has indicated its intention not to ratify the Kyoto Protocol. Note: Although they are listed in the Convention's Annex I, *Belarus* and *Turkey* are not included in the Protocol's Annex B as they were not Parties to the Convention when the Protocol was adopted.

According to article 25 of the protocol **[173]**, it enters into force "on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties included in annex I which accounted in total for at least 55% of the total carbon dioxide emissions for 1990 of the Parties included in annex I, have deposited their instruments of ratification, acceptance, approval or accession." Of the two conditions, the "55 parties" clause was reached on 23 May 2002 when **Iceland** ratified. The ratification by **Russia** on 18 November 2004 satisfied the "55%" clause and brought the treaty into force, effective 16 February 2005.

One of the biggest parties of the protocol, Australia ratified the agreement at 2007. Up to the Conference of the Parties (COP 15) at Copenhagen almost all countries had signed the protocol. By the year 2010, the USA, the biggest greenhouse gas emitter country of the world, responsible of nearly 25% of all CO2 emissions, has not been ratified the Kyoto Protocol **[174].**

The enforcement of the Kyoto Protocol is stated as follows:

" Where the enforcement branch has determined that the emissions of a Party have exceeded its assigned amount, it must declare that that Party is in non-compliance and require the Party to make up the difference between its emissions and its assigned amount during the second commitment period, plus an additional deduction of 30%. In addition, it shall require the Party to submit a compliance action plan and suspend the eligibility of the Party to make transfers under emissions trading until the Party is reinstated" **[175].**

Kyoto mechanisms

The Protocol provided a certain degree of flexibility by allowing Annex I countries to achieve their mitigation commitments through three innovative mechanisms. The three Kyoto mechanisms are: Joint Implementation (JI), the Clean Development Mechanism (CDM) and Emissions Trading (ET)

i. Joint Implementation

According to the joint implementation mechanism, if any country from the Annex 1 invests in emission reduction projects in an other country, which has a emission reduction target, gains additional emission reduction units. This is an alternative way to reach the emission reduction targets in stead of reducing domestic emission. It may lower the costs if a country invests in a country having cheaper reduction opportunities **[176].**

ii. Clean Development Mechanism

According to clean development mechanism, if a country from the Annex 1, invests in an emission reduction project in a developing country which is not assigned a target, gains certified emission reduction units. It is a two dimensional mechanism beneficial for both the developing country and the developed country. By the year

2007, total volume of clean development mechanism reached to 4.4 billion $, which is one third of total greenhouse gases emissions **[177].**

iii. Carbon trade

Carbon trade is a mechanism giving the opportunity to countries which have emission reduction targets, buy and sell emission reduction credits in order to reach the targets. According to this mechanism, if a country reduces emission more than its assigned target, it can sell the reduction units to another country which needs more credits **[178]**.

To implement the Kyoto Protocol, the EU and other countries have set up 'cap and trade' systems, under which companies are obliged to match their greenhouse gas emissions with equal volumes of emission allowances. The Government allocates a number of allowances to each company. Any company that exceeds its emissions beyond its allocated allowances will either have to either buy allowances or pay penalties. A company that emits less than expected can sell its surplus allowances to those with shortfalls. Besides buying allowances, in the EU companies also have the opportunity to buy Carbon Credits from JI and CDM projects in order meet their compliance targets **[179].** Considering the CO2 emissions of the countries in the recent years, the biggest potential purchaser countries are USA (if signs the Kyoto Protocol), Japan and some European Union Countries **[180].**

Carbon trade mechanism will probably become a very important economic actor with an estimated volume of tens of billions dollars. This amount may change depending on the USA's decision whether to sign Kyoto or not. The USA, constituting the 4% of the whole world population, is responsible 25% of all greenhouse emissions **[181].** If they involve in the carbon trade mechanism, it is estimated that the price of emission reduction units may increase 100 $/tone or higher level, but without US it will probably move around 0-10 $/tone.

The limitations that the Kyoto Protocol sets create difficulties for industrial institutions due to the fact that it is necessary to make significant infrastructural investments in order to achieve the target decrease in emissions. At this point carbon trade offers a new opportunity to the companies and creates a situation which should be taken seriously. The action that the companies should take is to compare the costs of technology to decrease emission and the profit that they will get out of carbon trade. In fact, the basic idea of carbon trade system is the assumption that while this mechanism will activate the market, it will also encourage companies to search the cheapest ways of producing carbon emission under their limits. In other words, it will force them to a competition to find the cheapest way to decrease their emissions.

The size of the carbon trade market is growing day by day. The figures that the Carbon Finance Unit of the World Bank declared shows how fast it grows **[182]**: While 78 million metric ton CO_2 trade took place in 2003, with an increase of 41%, it reached to 110 million metric ton in 2004. In 2005, it reached to an amount like 374 million metric ton with an increase of 240%. In terms of US $, the volume of the carbon market according to World Bank is 11 billion $ in 2005, 30 billion $ in 2006 and 64 billion $ in 2007, 126 billion $ in 2008

Kyoto Protocol & Turkey

Being a member of the OECD, Turkey was initially listed in both Annex I and Annex II of the UNFCCC in 1992. Under the convention, Annex II countries are responsible to provide financial assistance to developing countries. This responsibility is too heavy for a country like Turkey, because comparing with the other countries included in these annexes, Turkey is at a relatively early stage of industrialization and economic development level is not enough to assist other developing countries. Turkey is herself, a developing country. Therefore, Turkey rejected to be listed both in Annex I and II and considering her special economic condition, requested to be removed from Annex II at least. Turkey carried out a serious diplomatic struggle through this aim in the COP 5 and 6 conferences. Turkey succeeded to be omitted from the Annex II list in the 7^{th} COP held in Marrakech in 2001 and its special circumstances was recognized as an Annex I country. Turkey signed the UNFCCC as the 189th participant in 2004. However, Turkey did not sign the Kyoto Protocol until 2009. Turkish refusals to sign the protocol were mainly related to its expected excess implementation costs and consequently the fear of degrading her competitiveness unfairly in international trade. However, finally, on February 5, 2009, Turkish Parliament ratified an agreement to sign the Kyoto Protocol after intense pressure from both the European Union and international and national environmental organizations. Three voted against as 243 deputies voted in favor of the protocol **[183].**

Parties are invited to recognize the special circumstances of Turkey, which places Turkey, after becoming a party, in a situation different from that other parties included in Annex 1 to the Convention. As Turkey was not a Party to the UNFCCC at the time the Protocol was adopted, it was not included in the Annex B of the Protocol which defined quantified emissions limitation or reduction commitments for Annex I parties. Therefore, Turkey does not have a quantified emissions limitation or reduction commitment in the first commitment period between the years 2008-2012 under the Protocol. However Turkey is responsible for **[184]**:

-Submission of regular reports; National communication and GHG inventories.

-Implement policies and measures in climate change mitigation, adaptation, systematic research, education, training and public awareness.

On the other hand, as a candidate country, Turkey has to satisfy the strict environmental obligations of European Union (EU), in order to qualify for full membership. According to the Commission of the European Communities, the EU aims at reducing environmental pollutants 30% below the 1990 levels by 2020 **[185].** Thus, Turkey has been under strong pressure from the EU to comply with the Union's regulations on environmental policy, even though pollutant emission reduction is not currently a membership criterion **[186].**

3.2.2 Post Kyoto Period

i. COP 13, 3-14 December 2007,Bali, Indonesia

Parties agreed on Bali Road Map which includes Bali Action Plan in order to guide discussions with the aim of creating a new agreement to tackle climate change for the post-2012. The Bali Action Plan mandated the parties to conduct negotiations by addressing issues which are grouped into four main building blocks: mitigation, adaptation, technology and finance **[186].**

ii. COP 14, 1-12 December 2008, Poznán, Poland

Resulted with a clear commitment from governments to shift into full negotiating mode in 2009 in order to shape an ambitious and effective international response to climate change, to be agreed in COP 15 **[186].**

iii. COP 15, Copenhagen

The general objective of COP 15 was to create a new legally binding agreement that will control the increase in the emission of greenhouse gases and keep them within a limit in order to lighten the severity of climate change. In June 2009, G8 countries with many large developing countries, reached a consensus that the average temperature rise should be limited to 2°C; the agreement that will be formed during the Copenhagen conference (COP 15) would therefore most likely constitute this as an objective. During the conference it is also aimed to form new goals for industrialized countries to reduce their carbon emissions. Adapting to climate change through securing fresh water and crop stocks and building sea defenses would also be central to the COP15. Another key objective of the summit is to provide finance for developing countries in order to both reduce their emissions and adapt to climate change. Limiting deforestation will also be a part of the agreement. The crucial date for these commitments is likely to be 2020, although some countries are looking at later dates **[186].**

The 2009 United Nations Climate Change Conference, commonly known as the Copenhagen Summit, was held in Copenhagen, Denmark, between 7 December and 18 December. The conference included the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change and the 5th Meeting of the Parties (COP/MOP 5) to the Kyoto Protocol. According to the Bali Road Map, a framework for climate change mitigation beyond 2012 was to be agreed there **[187].** However, parties, having seriously different expectations, could not come to a solution in two weeks time. Negotiations were stucked between the developed countries and developing countries' governments.

At the end of long discussions a document is drafted by China, USA, India, Brazil and South Africa. The document included no legally binding commitments for reducing greenhouse gas emissions. The document recognised that climate change is one of the greatest challenges of the present and that actions should be taken to keep any temperature increases to below 2°C **[188].**

Groups for New Commitment Period

On the road to new commitment period after 2012, most of the parties are looking for a better agreement than Kyoto Protocol. However, there is a serious controversy between the expectations of parties. Parties with similar conditions and expectations, get together and formed groups in order to be more powerful in the negotiations. In the following paragraphs, the main arguments of those groups are summarized **[189]:**

a. China - G77

The Group calls for an amendment to the Kyoto Protocol such that developed countries undertake higher binding reduction commitments as a requirement of their historical responsibilities. The Group proposes the view that Annex-I countries should undertake emission reduction targets of at least 40% below the 1990 level during the second commitment period which they want it to cover the years 2013-2020. The Group objects to the proposals that developing countries should undertake binding emission reduction commitments and emphasizes the need for support to developing countries through financial resources and technology transfer in the context of mitigation and adaptation

b. EU

Developed countries should collectively reduce their GHG emissions by 25 to 40 % by 2020 compared to 1990 levels, through domestic and international efforts, and transform their economies over the coming decades in order to collectively reduce their GHG emissions by 80 to 95% by 2050 compared to 1990 levels. Copenhagen agreement should contain binding quantified emission limitation or reduction commitments for at least all Parties listed in Annex I to the UNFCCC and all current EU Member States, EU candidate countries and potential candidate countries that are not included in Annex I to the UNFCCC. This means that EU has an intention to force candidate countries to be involved in the new commitment period.

c. USA

The US recognized its unique position as the largest historical emitter of greenhouse gases and as a country with important capabilities, but underscored that the US alone cannot provide the solution to the climate change problem. The essence of the US position is that all major emitters should take part in the mitigation efforts. Therefore, in addition to industrialized countries, the emerging economies with high and growing current GHG emissions should assume binding reduction obligations. They suggest each country should decide its own mitigation pledges in a way reflecting these national circumstances.

d. Japan- Australia-Russia

Japan wants a fair and effective single framework, a new single agreement, not just extension of the Protocol into new commitment period, and thus participation of all major developing countries with mitigation actions.Australia wants quantified emission reduction commitments for developed countries and NAMAs (nationally appropriate mitigation action) for developing countries.

Russia is a critical country within the climate change regime due to its high emissions levels and what is called the "Russian hot air". It has accumulated a large volume of assigned amount units (AAUs) under the Protocol because its emissions are still well below 1990 levels. At the last EU-Russia Summit, Russian President indicated that the country would adopt a 25% reduction target.

e. Mexico - South Korea

Mexico adopted a voluntary emission target and announced that it will reduce emissions 50% below 1990 levels in 2050. Mexico's proposal on financing climate change measures has drawn attention in the negotiations and received support of some Parties South Korea also announced a voluntary emission reduction target. The country pledged to reduce its emissions 30 % below expected levels by 2020

f. AOSIS

AOSIS, consisting of countries which are highly vulnerable to risks associated with climate change, maintains a strong position urging for a strengthened climate change regime with more stringent post-2012 emission limitation and reduction targets and adaptation measures. The Group calls for an agreement that should contain a set of goals for long term global action, including stabilizing atmospheric concentrations of GHGs at the level below 350 ppm CO_2equivalent, limiting global average surface temperature increase below 1.5° C above pre-industrial levels and reducing global GHG emissions by more than 85% below 1990 levels by 2050. They call on developed countries to undertake a pioneering role given their historical responsibility for climate change. In this effect, AOSIS wants Annex I parties to reduce their aggregate GHG emissions by more than 45% below 1990 levels by 2020, and more than 95% below 1990 levels by 2050.

g. The African group

The African Group representing the countries most vulnerable to adverse effects of climate change wants climate change be addressed in the context of development and seeks support from developed countries for adaption measures. The Group urges Annex I Parties to commit themselves to at least 40% emission reductions by 2020 with strict limitations on the use of offsets. In this sense, the Group wants continuation of the Kyoto Protocol with amendment setting stronger binding targets. Supported by other developing countries, including G77 and China, the Group's action was seen as a signal to Parties about the prospect of negotiations in Copenhagen.

Position of Turkey in the New Commitment Period

On the road to new commitment period, Turkey is expecting her national special circumstances to be taken in to consideration and negotiating for an appropriate position in the new agreement. Here are some statements that Turkish Governments made along the road to new commitment period:

On 29 August 2007 during the 4th workshop of the Convention Dialogue, Turkey made the following statement **[189]**:

"…Turkey as a developing country with high aspirations strives to continue its economic development following the principles of sustainability. However, as a country having lower greenhouses gas emissions per capita than other OECD countries and transition economies, the major issue for Turkey is how to contribute to reducing the burden on global resources at a low cost and without jeopardizing its economic and social development prospects."

By the end of February 2008, a section from Turkey's submission emphasizing her special circumstances is given below **[189]**:

"*Turkey, although being an OECD country, is neither a developed industrialized country nor in the group of countries, the economies of which are in transition. Special circumstances of Turkey, which place Turkey, in a situation different from that of other Parties included in Annex I to the Convention was recognized in the 7th Conference of the Parties (COP-7) held in Marrakesh in 2001, which also deleted its name from Annex II. Some might say that the Marrakesh decision improved the status of Turkey. However, the most realistic solution would have been to be deleted from both Annexes. Turkey's status as an Annex I Party in the framework of the Convention, doesn't reflect its actual industrialization level.*"

On 1 April 2009**,** Turkey has outlined her case in the Bonn Climate Change Talks. The followings are the highlights of Turkey **[189]**:

• Turkey is a *sui generis case vis-à-vis* (in a unique position) the Annex-I Parties. The Decision adopted in Marrakesh in the 7th COP, deleted Turkey's name from Annex-II and placed it in a situation different than the other Annex-I Parties;

• Turkey has a negligible historical responsibility;

• Turkey has many similarities with developing country Parties;

• Turkey plans to take NAMAs for emission limitation and adopt "no-lose target" strategy;

• Turkey has already been taking many important steps and actions to fulfill its responsibilities under the UNFCCC in conformity with her economic and social development objectives and priorities, and to the extent allowed by her national capacity;

• Turkey's success in future climate change regime will be proportional to the international financial and technological support, the level of access to flexibility mechanisms and new technologies such as carbon capture and storage**.**

3.3 Greenhouse Gas Emissions of Turkey

Ratifying the Kyoto Procol, Turkey is now responsible for monitoring her emission of greenhouse gases and submitting them in regular reports. It is also important to map the sectoral emission rates in order to manage the national emission mitigation policies. Through this aim, Turkey Institute of Statistics (TÜİK) has been preparing a yearly report of emissions by collecting data from all sectors and governmental institutions.

Table 41: Direct greenhouse gas emissions by sector (%) [190]

	1990	1995	2000	2005	2007
CO_2					
Energy	**90,76**	**90,40**	**92,52**	**92,05**	**92,77**
1. Energy and conversion	24,37	27,53	34,31	34,53	35,01
2. Industry	26,89	24,43	26,75	26,17	26,28
3. Transportation	18,59	19,10	15,62	15,80	16,75
4. Other	20,92	19,33	15,83	15,55	14,73
Industrial activities	**9,24**	**9,60**	**7,48**	**7,95**	**7,23**
1. Mineral Production	7,96	8,61	7,08	7,54	7,23
2. Chemical Industry	0,59	0,56	0,07	0,23	0,00
3. Mining Industry	0,69	0,44	0,34	0,18	0,00
CH_4					
Energy	**15,18**	**10,17**	**8,50**	**7,88**	**7,85**
A. Fuel burning	**10,28**	**6,78**	**5,22**	**4,87**	**4,47**
1. Energy and Conversion	0,04	0,04	0,06	0,06	0,07
2. Industry	0,22	0,16	0,23	0,26	0,30
3. Transportation	0,24	0,28	0,28	0,25	0,23
4. Other	9,78	6,30	4,66	4,30	3,87
B. Fugitive Emissions	**4,90**	**3,40**	**3,28**	**3,01**	**3,38**
Industrial Activities	**0,17**	**0,12**	**0,10**	**0,03**	**0,10**
Agricultural Activities	**62,78**	**41,96**	**32,46**	**31,76**	**33,48**
Waste	**21,87**	**47,75**	**58,95**	**60,33**	**58,56**
N_20					
Energy	**79,02**	**17,58**	**22,71**	**44,11**	**16,43**
1. Energy and Conversion	9,19	2,56	4,05	7,13	3,03
2. Industry	11,21	2,29	4,07	6,88	2,94
3. Transportation	20,77	5,29	7,16	19,18	6,75
4. Other	37,85	7,43	7,43	10,92	3,71
Industrial Activities	**10,19**	**80,43**	**74,78**	**51,28**	(*)
Agricultural Activities	**10,80**	**1,99**	**2,51**	**4,61**	**83,57**(1)

Note: Agricultural soil and fertilizer management emissions are not included in the "agricultural activities"

Table 42: Total greenhouse gas emissions by sectors (million tones CO_2 equivalent) [190]

	1990	1995	2000	2005	2007
Energy	132,13	160,79	212,55	241,45	288,33
Industrial activities	13,07	21,64	22,23	25,39	26,18
Agricultural activities	18,47	17,97	16,13	15,82	26,28
Waste	6,39	20,31	29,04	29,75	31,85
Total	**170,06**	**220,72**	**279,96**	**312,42**	**372,64**
Increase since 1990 (%)	-	**29,8**	**64,6**	**83,7**	**119,1**

Turkey's total Greenhouse Gas (GHG) emissions have grown from 170 to 372 million tons of CO2eq from 1990-2007 which corresponds to an increase of 119.1 %. **[Table 42]** Turkey's emissions are the 12th highest among Annex 1 countries and 23rd highest in the world constituting 0.8% of global emissions. The growth of Turkey's GHG emissions excluding LULUCF is the highest among Annex 1 countries **[Figure 18]**.

The growth in emissions is caused by the rising energy demand (driven by Turkey's rapid economic growth, industrialization and steady population growth) and reliance on fossil fuels. CO2 emissions per capita in 2005 were much lower in Turkey at 3.5 tCO2 than EU27 average of about 9.3 tCO2/capita. However, while per capita emissions have been stable in the EU, Turkish emissions have increased from 2.5 tCO2 in 1990 and are projected to continue to rise in the future **[191].** Main sources of CO_2 and N_2O emissions in Turkey are energy related activities. However, most of the methane emissions arise from agricultural activities **[Table 41].**

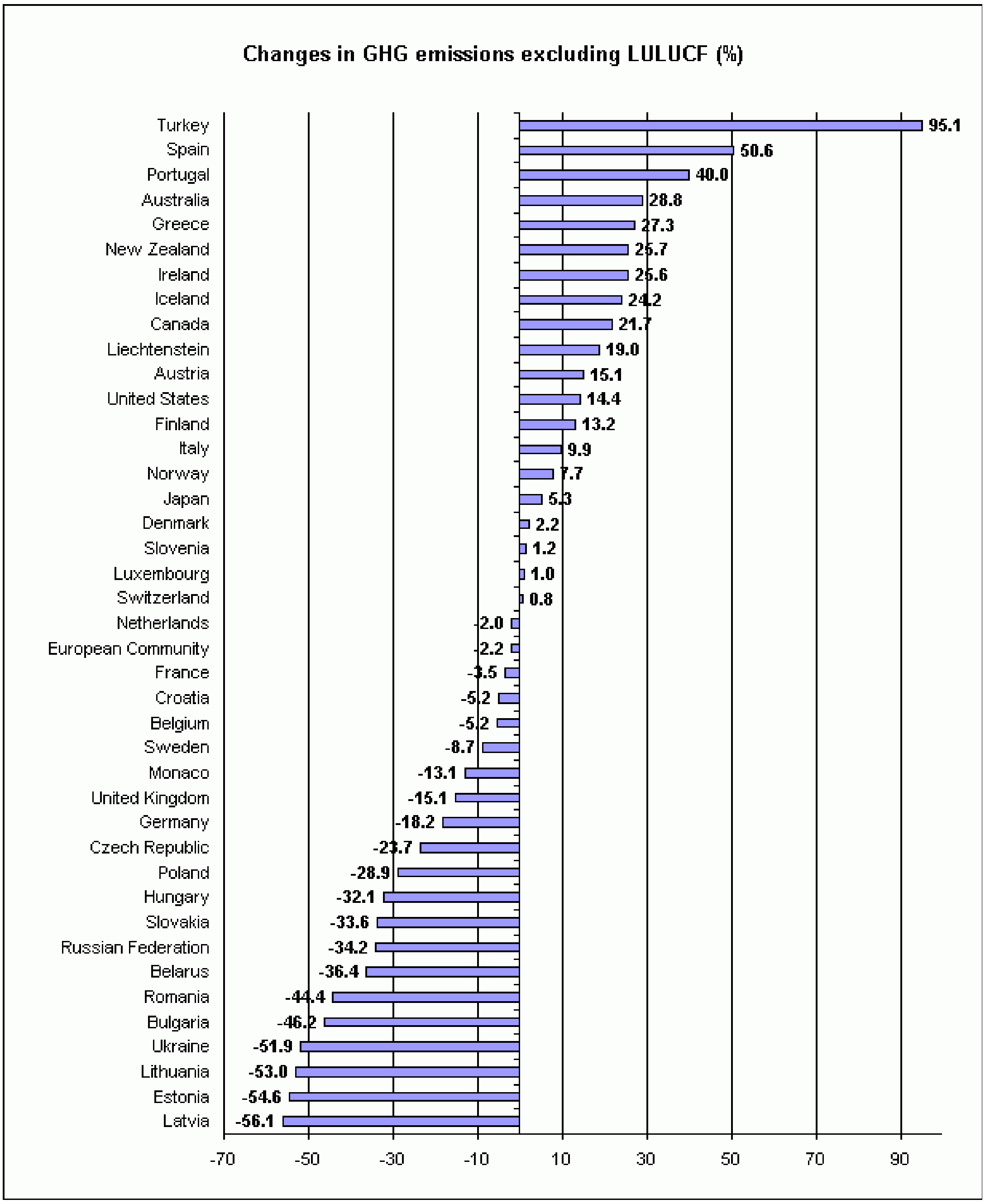

Figure 18: Changes in GHG emissions excluding LULUCF [192]

3.4 Emission Mitigation

Agreeing on the target of limiting global warming at 2 C degree level, countries became responsible for preparing programs in order to reduce their emissions, whether they are assigned a reduction target or not. There are lots of emission mitigation methods, some of them have been applied for a long time and some still need further development. In this section, some of the common mitigation methods are discussed.

3.4.1 Energy efficiency and conservation

- Urban Planning

Inefficient land use in the development of the cities increases infrastructure costs as well as the amount of energy needed for transportation, community services and buildings. Therefore, energy saving possibilities should be considered in urban planning.

Between 1982 and 1997, the amount of land consumed for urban development in the United States increased by 47 percent while the nation's population grew by only 17 percent **[193].** This means urban development without efficiency plans resulted in disproportional land use and therefore high energy consumptions.

-Building Design

Emissions from housing are substantial, and government-supported energy efficiency programmes can make a difference **[194].** New buildings can be constructed using passive solar building design and low-energy building design. Existing buildings can be made more energy efficient through the use of insulation and other available techniques.

- Transportation

Using energy efficient technologies, such as electric and hydrogen cars would be useful to reduce the emission from fossil fuels. A shift from domestic air and land transport to rail transport and public transportation are some common possible ways of reducing emissions from transport, which is one of the most emission producing sectors.

- Industry

Energy efficiency can be maintained by improving the existing installations through replacement with energy efficient components. Alternatively, energy efficiency investments can occur at the design and planning stage of new plants [**195].**

Situation in Turkey

Up to recent, there had been no important efforts for energy efficiency and conservation in Turkey. Recently, efficient use of energy is started to be promoted in all sectors by energy efficiency legislation. For efficiency in residental, commercial and public buildings, program includes lighting (especially fluorescent bulbs), heating/cooling systems, refrigerators and insulation. There are lots of things to do in order to set up a sustainable energy efficiency program for all areas. Significant potential for energy efficiency improvements exists in the industry sector (including iron and steel, cement, textiles, chemicals) where a switch-over to new process technologies, as well as replacement of generic equipment (like motors, compressors, pumps) can produce substantial energy savings. It is proposed that consumption in Turkish steel and cement plants could be cost-effectively reduced by 22% and 28% respectively **[196].** Insufficient monitoring of the energy consumption and insufficient evaluation of energy saving potential in each sectors are still important problems for the industry. Lack of financial support is another barrier for energy efficiency invesments **[197].**

Transportation is one of the energy inefficient sectors in Turkey. Insufficient use of urban public transportation, increasing number of vehicles in the traffic and countinuing utilization of old vehicles, decreasing share of railways both in long distance and urban transportation are the main problems of the transportation sector in terms of energy efficiency **[197].**

3.4.2 Alternative Energy Sources

Shifting to clean energy sources (renewable and nuclear) from fossil fuels is one of the most effective ways of emission mitigation. As it can be seen in Table N, CO_2 emission from fossil fuels is obviously much higher than the emission from renewable and nuclear resources. Natural gas emits relatively smaller amounts of CO_2 among other fossil fuels.

Table 43: Carbon intensity of energy resources [198, 199]

Fuel / Resource	Thermal g[CO_2-eq]/ MJ_{th}	Electric g[CO_2-eq]/kWh_e
Coal	88	955
Oil	73	893
Natural gas	51	599
Geothermal Power	3	T_L 0-1 T_H 91-122
Nuclear Power [Uranium]		W_L 60 W_H 65
Hydroelectricity		15
Concentrating Solar Power		40 ± 15
Photovoltaics		106
Wind Power		21

T_L = low-temperature/closed-circuit, T_L = low-temperature/closed-circuit, W_L = Light Water Reactors, W_H = Heavy Water Reactors

Turkey has a considerable potential of renewable energy resources. Hydroelectricity has been the most important renewable energy source for years. Recently, other renewables such as geothermal and wind energy gained importance, investments are encouraged by the new renewable energy law as the climate change issue came in to the agenda.

Renewable Energy Law

The Renewable Energy Law of Turkey came into force in 2005. The aim of the law is to provide more incentives and governmental support for renewable energy projects. The Renewable Energy Law is covering the projects of wind, solar, geothermal, biomass, biogas, wave, stream, tidal, river and arc type hydroelectric generation facilities and hydroelectric projects with a reservoir area of less than fifteen km^2 **[200].**

The main consequences of the new law are as follows **[200]**:

- Renewable energy investors shall only pay 1% of the total license acquisition fee and do not pay annual license fee for the first 8 years following completion of the construction of the related facilities. The Turkish Electricity Transmission Company (TEIAS) and distribution companies are required to give priority status for renewable energy facilities' systems connection.

-Holders of retail licenses are obliged to purchase a percentage of their total uptake from licensed generation companies holding a REC (Renewable Energy Source Certificate).

-The fees to be paid for using public lands shall be reduced by 85% for renewable energy investors.

-The need for heat energy in the municipalities where there are sufficient geothermal energy resources will be primarily met by geothermal and solar thermal energy resources.

-The price of the electricity to be purchased under the Renewable Energy Law should be the country average of the electricity wholesale price of the previous year to be determined by the EMRA (Energy Market Regulation Authority).

The renewable energy law is a good attempt to encourage the private investment to renewable energy projects, however there are still some points need to be improved. The Law did not provide any tax advantage to renewable resource based power generation projects. Another critisizm is about wind and solar energy projects. For wind energy, investors argue that the wholesale price of power is not sufficient for reaching commercial viability even at the windiest available sites and seasons. An additional premium is expexted to be provided for the wind and solar energy in the Law considering the comparatively high initial costs **[201]**.

Turkey's clean energy potential is discussed in Chapter 2 with more details.

3.4.3 Reforestation and avoided deforestation

Deforestation is the loss or degradation of naturally occurring forests by the processes of logging and burning of trees. A tree is comprised of about 50 percent carbon. Trees therefore forests are important actors of the Carbon cycle. CO_2 is captured by trees by through photosynthesis. This carbon is stored in their bodies and some certain amounts of carbon are released back into the atmosphere through respiration. However, huge storage capacity offsets the negative effects of respiration. The Union of Concerned Scientists estimates that U.S. forests absorb between one million and three million metric tons of carbon dioxide each year, perhaps offsetting between 20 percent and 46 percent of the country's greenhouse-gas emissions **[202].** This numbers gives idea about the emission reduction capacity of forests**.** Every year, more than 15 million hectares of tropical forest of the world are cut down, releasing millions of tons of carbon emissions into the atmosphere **[203]**. Deforestation and forest degradation produce about 20% of the world's greenhouse gas emissions **[204].**

A 2006 study commissioned by the U.K. Treasury has concluded that reducing deforestation offers a major opportunity to reduce emissions at a relatively low cost than other emission mitigation options **[203].**

Situation in Turkey

In Turkey, total forest area constitutes nearly 13,2 % of total land areas. Other wooded lands have a nearly same percentage. Compared with the European countries, this number is way below European average. (i.e. Finland 73,9 %, Sweden 66,9 %, Austria 46,7 %) **[205].**

Turkey has recently launched national mobilization campaign in order to rehabilitate degraded forests that cover about 2.3 million hectares. Rehabilitated forests capture 5 times more CO2 than degraded forests.

Forest fires are also a big problem for Turkey like other Mediterranean countries. 60% of Turkey's forests are in high risk fire area. Thus, early warning system has to be established for combating forest fires effectively **[206].**

There has been no emission calculation researches made yet considering the LULUFC for Turkey. (Land use, Land-use change and forestry).

3.4.4 Carbon Capture and Storage

Carbon dioxide (CO2) capture and storage (CCS) is a process consisting of the separation of CO2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere **[207].**

Briefly, the steps of the process are as follows:

Extraction: Carbon dioxide is separated from the flue gas of a fossil-fuel burning power station. Economically, this is the limiting step due to the high cost of isolating and compressing carbon dioxide from industrial processes injection.

Injection: Injection technology is readily available and several demonstration plants are already in operation. The injected carbon dioxide is supercritical and lighter than the surrounding brine, so rises upwards following injection.

Storage: The CO_2 is kept in place only by the impermeable rock above. Suitable formations include disused oil fields (capacity estimated at 700 Gt), unmineable coal beds (3-200 Gt), and saline aquifers (over 1000 Gt) and oceans **[208].** Monitoring long term storage of CO2 is a bit costy operation

Fossil fuel based power plants, natural gas production and some major industries are the largest point sources of CO_2. Today's technology could capture 85-95% of the CO_2 processed in a capture plant. A power plant with a CCS system needs 10-40% more energy than a power plant without a CCS. Fore secure storage of the CO_2, enhanced oil recovery (EOR) methods are used to inject and store the CO_2 captured **[208]**. Thus, CO_2 storage in oil fields will result in a two-sided profit by increasing the oil or natural gas produced produced. Ocean storage and its possible impacts still need to be developed. Transportation of the carbon is another issue to be considered.

Pipelines are used for transporting large amounts of CO_2 for distances up to around 1,000 km. Use of ships could be more economical for transportation of smaller amounts **[208].**

Through the processes of CCS, the most expensive part is the capture of the CO2 from a power plant or an industrial source. Except from the ocean storage, geological storage is not a costly operation even if the potential revenues from EOR are not included **[Table 44].** CCS is an important method for mitigation for developing countries having an increasing energy demand but limited clean sources. On the other side, CCS is a cost-intensive technology and difficult to be implemented in developing countries without significant incentives outside **[209].**

Table 44: Average costs for carbon capture and storage operations [207]

CCS system components	Cost range	Remarks
Capture from a coal- or gas-fired power plant	15-75 US$/t CO_2 net captured	Net costs of captured CO_2, compared to the same plant without capture
Capture from hydrogen and ammonia production or gas processing	5-55 US$/t$CO_2$ net captured	Applies to high-purity sources requiring simple drying and compression.
Capture from other industrial sources	25-115 US$/t$CO_2$ net captured	Range reflects use of a number of different technologies and fuels.
Transportation 1-8 US$/t$CO_2$	1-8 US$/t$CO_2$ transported	Per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) MtCO_2 yr-
Geological storage	0.5-8 US$/t$CO_2$ net injected	Excluding potential revenues from EOR or ECBM.
Geological storage: monitoring and verification .	0.1-0.3 US$/t$CO_2$ injected	This covers pre-injection, injection, and post-injection monitoring, and depends on the regulatory requirements
Ocean storage	5-30 US$/t$CO_2$ net injected	Including offshore transportation of 100-500 km, excluding monitoring and verification
Mineral carbonation	50-100 US$/t$CO_2$ net mineralized	Range for the best case studied. Includes additional energy use for carbonation.

Situation in Turkey

In The First National Report on Climate Change of Turkey, published in 2007, the CO2 emission of 240 million ton in 2004 is predicted to increase to 600 million tons in the year 2020.

The recent project **[210]**conducted by METU Petroleum Research Center together with TPAO and Ministry of Energy and Natural Resources had surveyed several industrial plants and thermal power plants in Turkey to assess their yearly CO2 emissions. Additionally the storage possibilities in abondoned or mature oil/gas fields, soda caverns, deep saline aquifers, natural CO2 reservoirs were studied. According to this project, natural CO2 field in Dodan is a possibility for geologic storage of CO_2, which has produced 6774 million m^3 of CO_2 for the Batı Raman EOR project. An alternative is considered as the injection of CO_2 from captured sites to Batı Raman field where CO_2 injection as EOR application is continuing. It is stated that EOR applications had to be converted to storage applications before they are considered as storage sites. In general because the oil fields are small in Turkey only emissions from small industrial sites can be handled if they are to be considered as storage sites.

Another possible storage sites are deep saline aquifers which seems to be the recent trend in the industry. Data indicated that deep aquifers as encountered during oil and gas exploration activities are present in Thrace region, CentralAnatolia and South Eastern Turkey. However, their capacity can be estimated if additional data is available from new wells that should be drilled if CO_2 storage is planned. **[210]**

CHAPTER 4

ECONOMIC GROWTH & ENERGY & ENVIRONMENT

4.1 Economic Growth & Energy

Economic growth can be defined as the increase in economy-wide production, usually measured by an increase in gross domestic product (GDP); also, the process of the economy growing over time **[211].** Energy is one of the essential inputs of the production process and it is known in theory problems in energy availability could effect economic growth in the longrun **[212].** Energy and growth relation has been a matter of discussion for many years in Economics. There is not much attention given to the role of energy and natural resources in the mainstream theory of economic growth. After the 1970's oil crisis, "productivity slowdown" started to be discussed. There have been many critics of the mainstream theory of growth especially on the basis of the implications of thermodynamics and technology for economic production and the long-term prospects of the economy **[212].**

Ecological economics has given much more attention to the role of energy and natural resources rather than the mainstream theory. Ecological economists focus on the material basis of the economy such as limits to substitution of the resources and limits to technological progress as ways of mitigating the scarcity of resources. They claim that if these two processes are limited then limited resources or excessive environmental impacts may restrict growth. When these limitations and changes in the composition of final energy use are accounted for, energy use and the level of economic activity are found to remain fairly tightly coupled **[212].**

There has been extensive debate concerning the trend in energy intensity in the developed economies, especially since the two oil price shocks of the 1970s. The principal findings are that energy used per unit of economic output has declined, but this is to a large extent due to a shift in energy use from direct use of fossil fuels such as coal to the use of higher quality fuels, and especially electricity. It is commonly asserted that there has been a decoupling of economic output and resources, which implies that the limits to growth are no longer as restricting as in the past.**[212]** US economy is a good example to see the change in energy consumption and GDP relation after 1980's up to today **[Figure 19].**

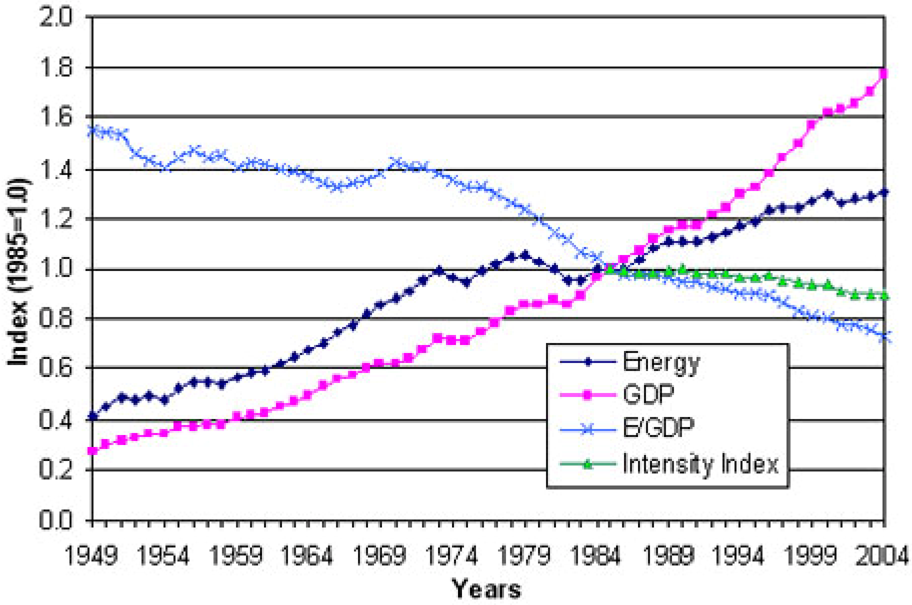

Figure 19: Energy Use, GDP, and E/GDP for the U.S. Economy, 1949-2004 [213]

On the other side, the situation is not similar in most of the developing countries. In Turkey, for instance, the trend of GDP growth and energy use (or demand) is much or less parallel **[Figures 20 and 21]**. With a rapid economic growth and a population of 73 million people, Turkey has today become the world's 17th largest economy. After 1980's, by the rapid urbanization and industrialization, the Turkish economy has undergone a transformation from agricultural to industrial. Turkey's gross national production has grown at an average annual rate of 5% since 1983, ranking it at the top of the OECD countries, although the growth pattern has been uneven. Turkey's energy demand has risen rapidly as a result of this social and economic development. Besides this rapid increase in the total energy consumption, Turkey still has a very low energy use per capita value compared with the OECD countries **[Figure 22][214].**

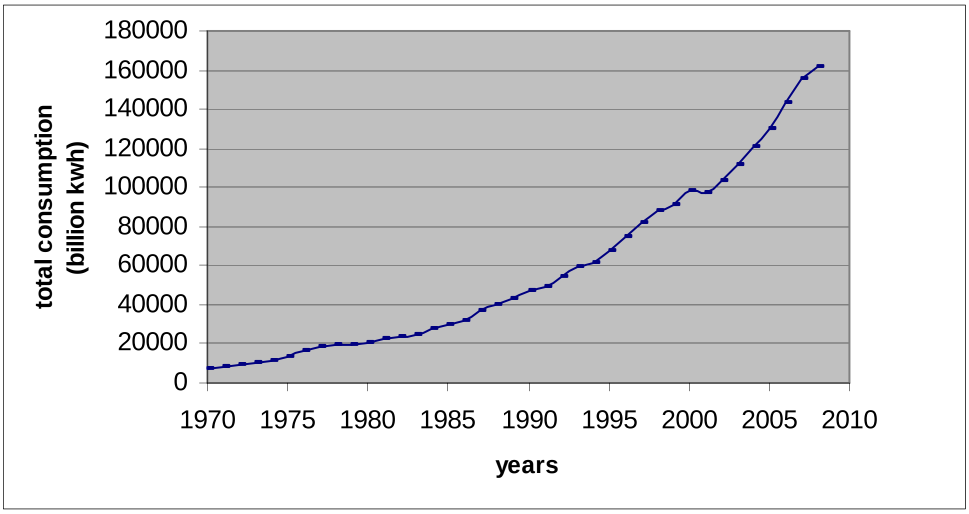

Figure 20: Total power consumption of Turkey 1970-2008 [Source data: TEDAŞ] [215]

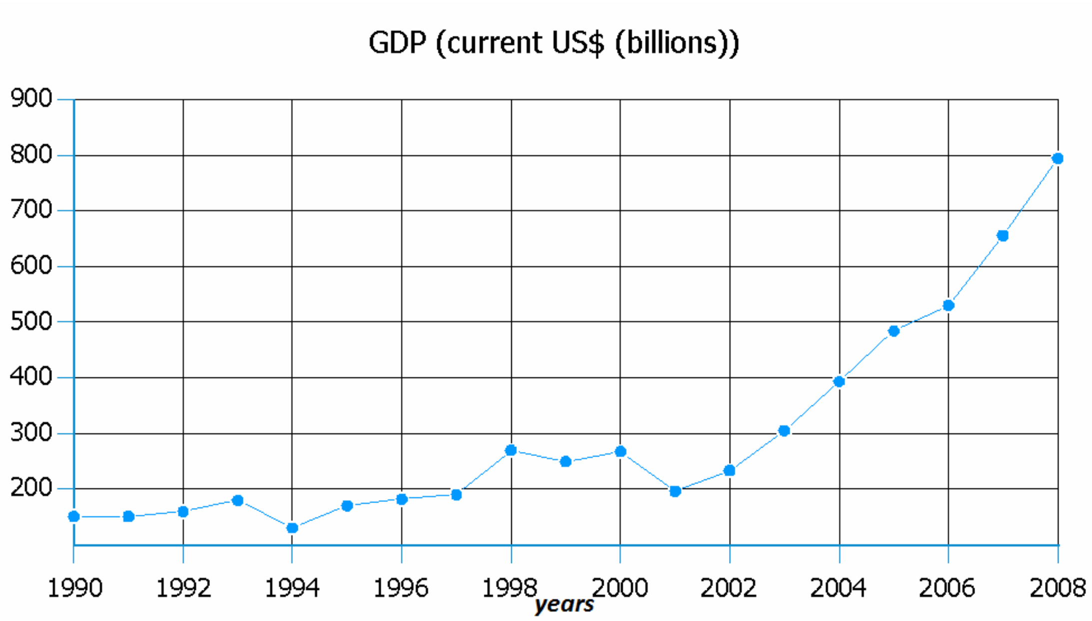

Figure 21: GDP of Turkey between 1990-2008 [216]

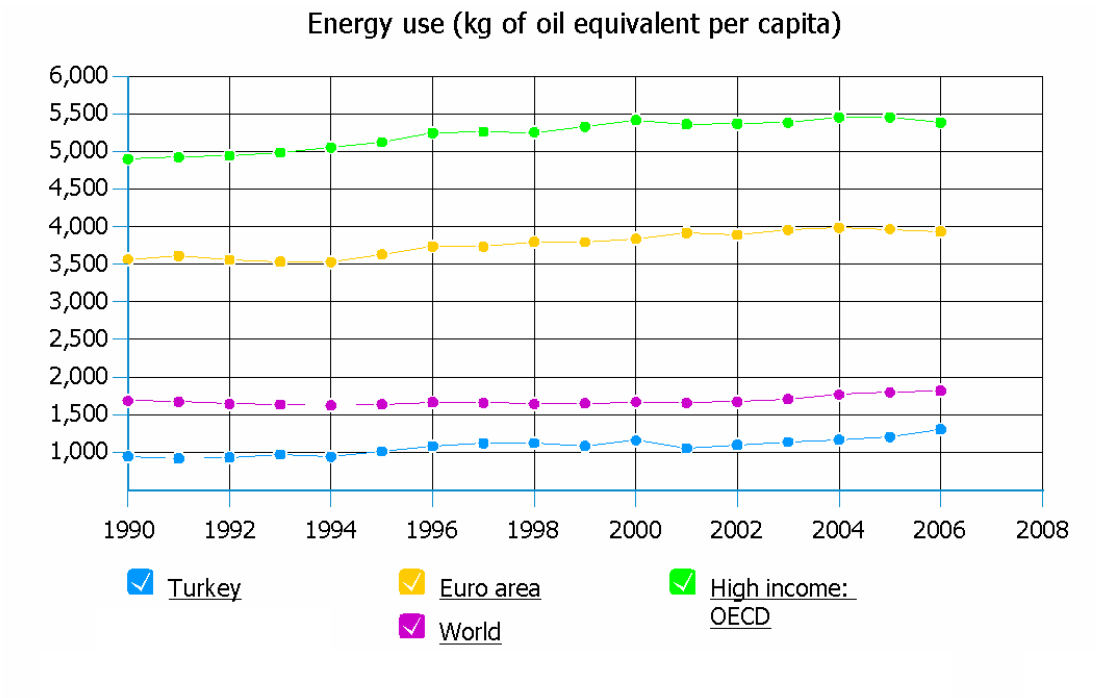

Figure 22: Energy use of Turkey between 1990-2008 in comparison with other countries [216]

Table 45: Contribution of Factors of Production and Productivity to GDP Growth in Selected Countries, 1980-2001 [217]

Countries	Ave.annual GDP growth [%]	Contribution of factors of production and productivity to GDP growth [% of GDP growth]			
		Energy	Labour	Capital	Total factor productivity
Brazil	2.4	77	20	11	-8
China	9.6	13	7	26	54
India	5.6	15	22	19	43
Indonesia	5.1	19	34	12	35
Korea	7.2	50	11	16	23
Mexico	2.2	30	60	6	4
Turkey	3.7	71	17	15	-3
USA	3.2	11	24	18	47

Typically, during the process of economic growth the output mix changes. In the earlier stages of development there is a shift away from agriculture towards heavy industry, while in the later stages of development there is a shift from the more resource intensive and heavy industrial sectors towards services and lighter manufacturing. Different industries have different energy intensities. It is often argued that this will result in an increase in energy used per unit of output in the early stages of economic development and a reduction in energy used per unit output in the later stages of economic development **[212]**. Developing countries differ at that point considering the relation between energy use and economic growth. Most of the developing countries are still at the resource intensive growth stage. On the other side in developed countries, service sector comprises the major percentage of GDP. Service sector is not as energy intensive as industrial sector. Energy intensity is also directly related with the advances in technology. Industrial sector is less energy intensive in developed countries by means of energy efficient technologies. As can be seen from the figures, Turkey is one of those developing countries which are still in heavy industrialization stage of development and have an energy intensive industry. Therefore energy is an important factor in Turkey's development process **[Table 45].** As seen from the figure 23, 24 and 25 sectoral compositions in the total GDP are different in Turkey and in OECD countries. However, the sectoral composition is in a transition trend and moving through service sector dominated economy at the same time.

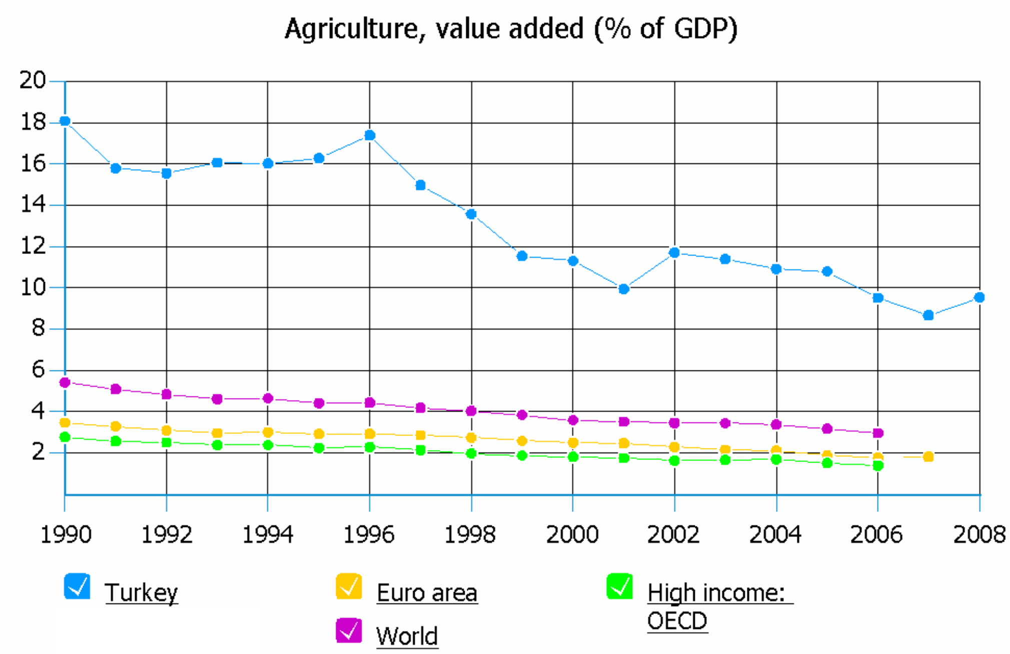

Figure 23: Added value of agriculture in GDP [216]

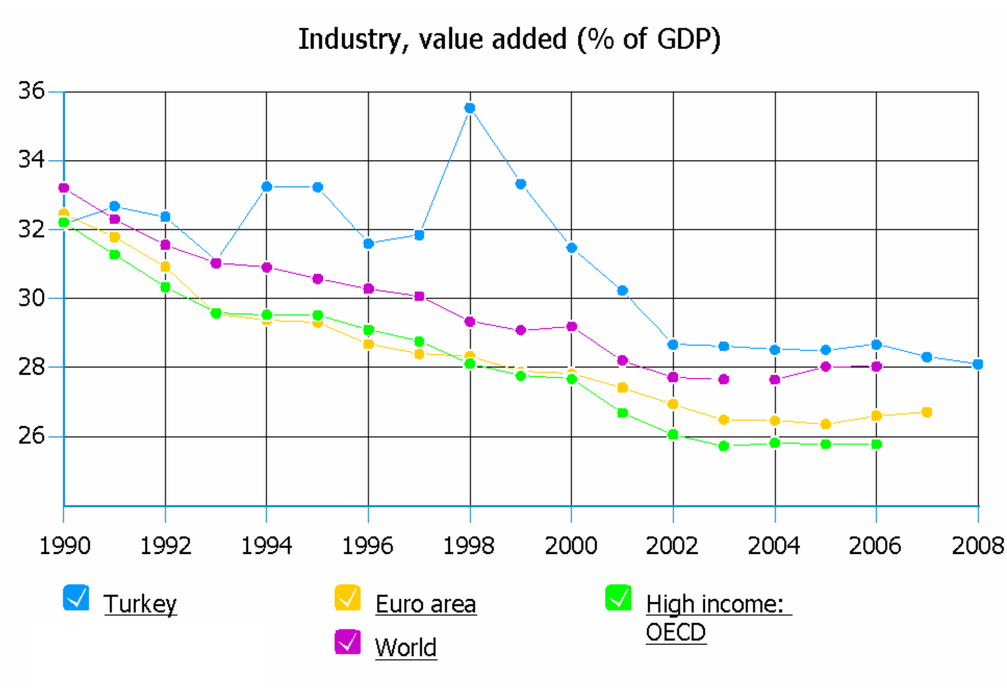

Figure 24: Added value of industry in GDP [216]

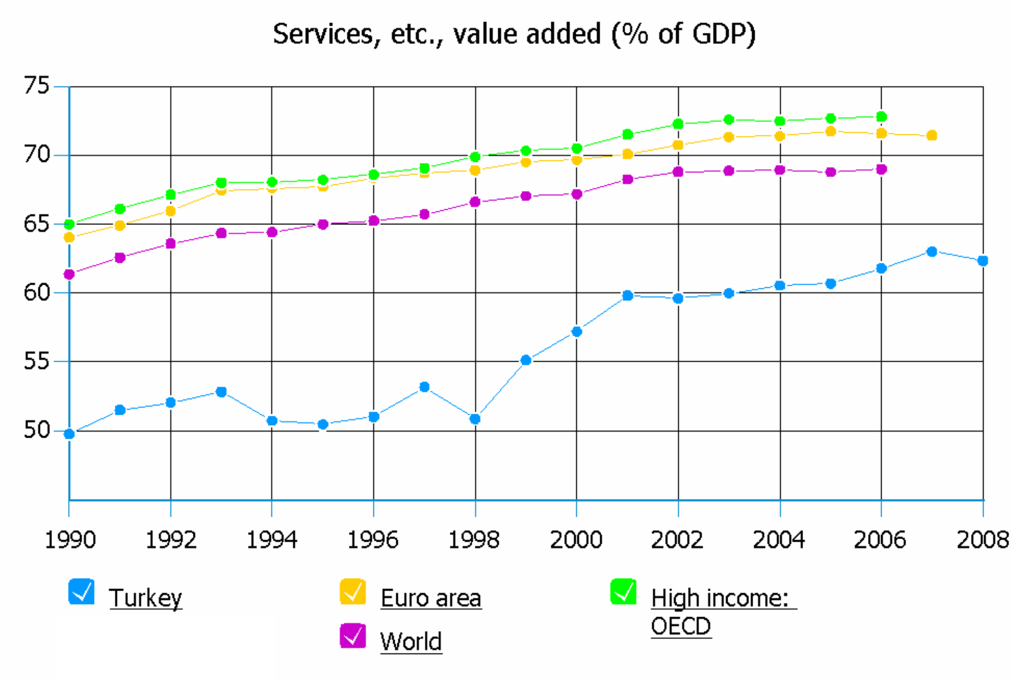

Figure 25: Added value of services in GDP [216]

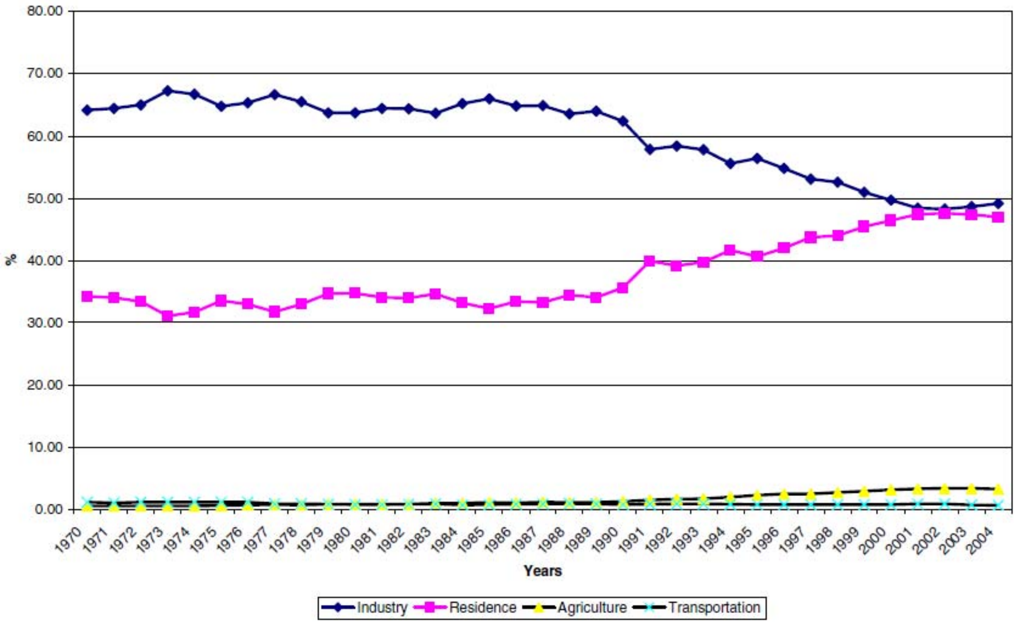

Figure 26: Sectors' electricity energy consumption as a percentage of total consumption between 1970–2004 [218]

Industrial consumption has the biggest share in the Turkey's total electricity usage. However industrial consumption is in a decline trend leaving its share to residential usage **[Figure 26]**. This shows the energy intensity in the industry is decreasing. The sectoral breakdown of energy consumption and primary resource production indicates the growing national imbalances as the domestically supplied share of total energy demand has continuously fallen from 48.1% in 1990 to 27.8% in 2004 **[Figure 27]**. All these reveal a sustained domestic deficit, given the expectations of a very significant rise in final energy demand in the next decade. The Ministry of Energy and Natural Resources (MENR) estimates indicate that total energy demand in Turkey will reach 135,302 thousand tonnes of oil equivalent (TOE) and per capita energy will rise from 1276 kgoe in 2005, to 1663 kgoe in 2013 **[219].** According to another estimate in 2030, total energy consumption will increase to 250 mtoe **[Figure 28] [220]**. These broad shifts underscore that Turkey has not yet stabilized its energy demand, and pressures of being a newly industrialized economy continues to be felt in the future.

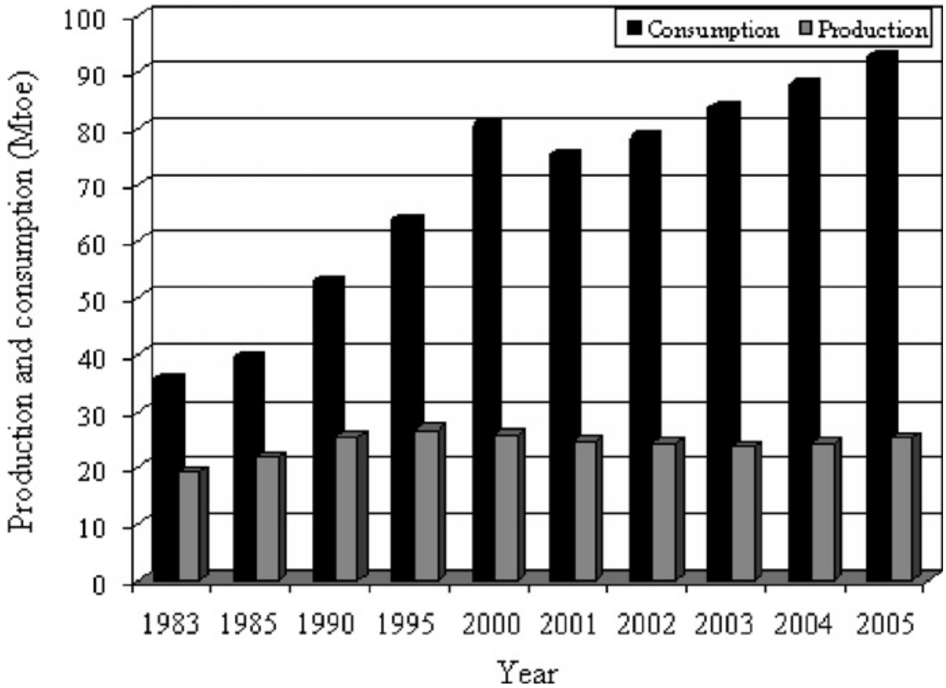

Figure 27: Turkey's primary energy production and consumption during 1983–2005 [221]

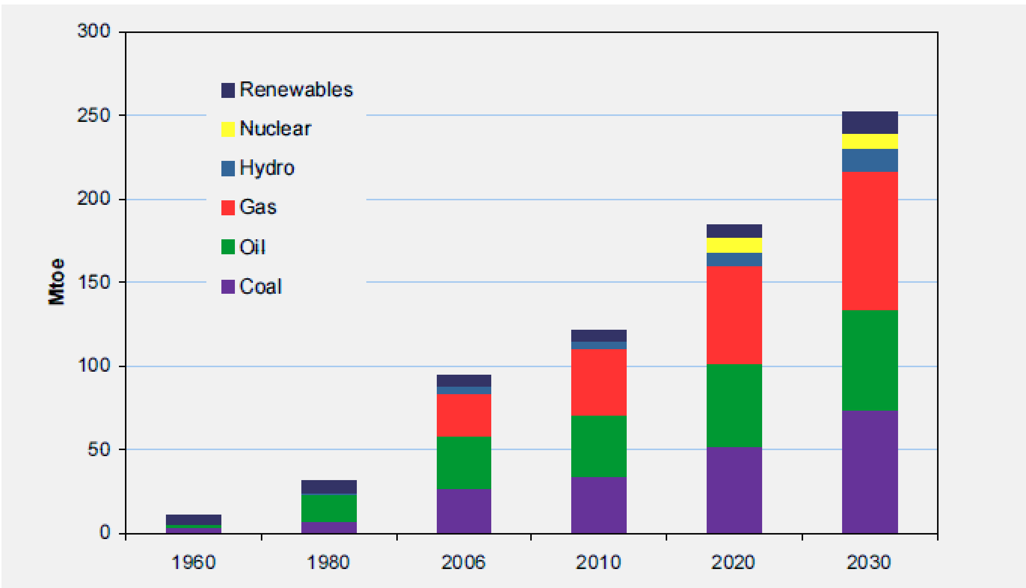

Figure 28: Total final energy consumption 1960-2030 [220]

Because the fact that Turkey's energy consumption has grown considerably since the beginning of the 1980s and on the other side there is no such a rapid increasing trend in energy production; the Turkish government encourages foreign and Turkish private sector investors to implement the energy projects and is working on a new investment model for the construction of new generation plants to create the additional capacity needed. The Turkish energy sector, with its current size of 30 billion US dollars and projected size of 55 billion US dollars by 2015, as well as the fundamental restructuring process it has been going through since 2001, attracts both local and foreign investors. The sector needs an investment amount of approximately 130 billion US dollars by 2020 **[211].**

4.2 Growth & Environment

The relationship between a steady increase in incomes and environmental quality is a matter of discussion for about a few decades. Many reseachers have been investigating if there are any trade-offs between the process of achieving sustainable economic growth rates and reaching to a level of environmental quality. According to some scientists, growing economic activity requires larger inputs of energy and raw material and therefore the amount of waste by-products is getting bigger. By the accumulation of waste and increasing concentration of pollutants in the nature, the carrying capacity of the biosphere will be overwhelmed. Although the incomes are rised, human welfare will be decreased due to the environmental degradation. Furthermore, environmental degradation will eventually cause resource degradation and put economic activity itself at risk. Some scientist go further and claim that in order to stop the environmental degradation, economic growth must cease and the world or a country must make a transition to a steady-state economy. On the other side, there are some people who argue that the fastest road to environmental improvement is along the path of economic growth. They claim that with higher incomes, demand for goods and services that are less material intensive will increase as well as demand for improved environmental quality that leads to the adoption of environmental protection measures and effort for more efficient infrastructure **[222].**

At earlier stages of development, resource depletion and waste generation accelerates due to agrşcultural activities and resource intense industrialization. At later stages of development, a transition begins in the structural composition from resource and energy intense industry towards information and service industry. With the availability of more efficient technologies in this stage, the demand for environmental quality increases. The implied inverted-U relationship between environmental degradation and economic growth came to be known as the "environmental Kuznets curve" **[Figure 29]** by analogy with the income inequality relationship postulated by Kuznets **[222].** The decreasing trend of environmental degradation has been mainly explained in terms of structural changes in the composition of economic output and increased environmental regulation at higher income levels **[223].**

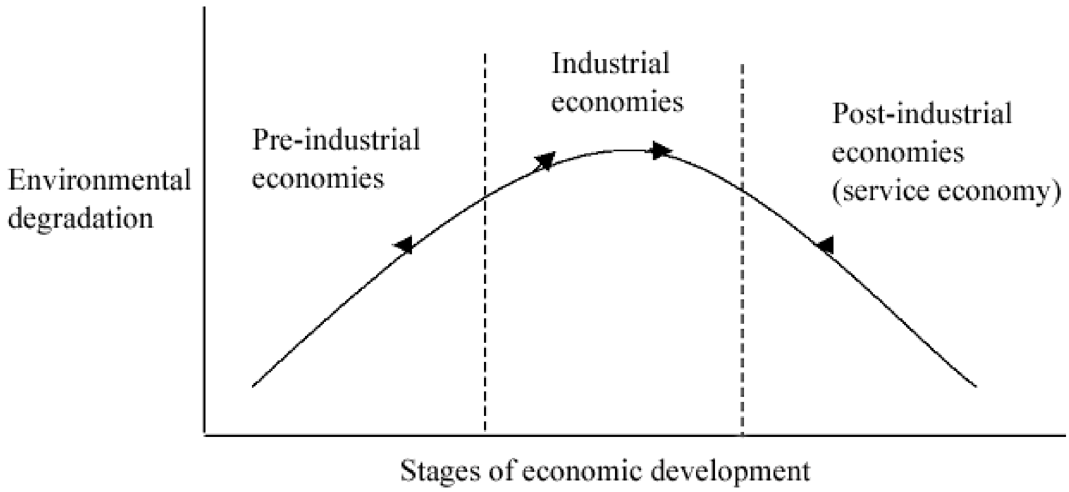

Figure 29: The environmental Kuznets curve: a development-environment relationship [222]

Turkish CO2 emissions per US$ GDP was measured as 0.94 kg in 2002 while the OECD average was 0.44 and the world average was 0.68. As compared to the 1990 values, both the world and the OECD averages on CO2 emissions per US$ GDP were observed to fall, however, for Turkey, a slight increase from 0.89 to 0.94 had been observed. According to the TURKSTAT data, CO2 emissions from fossil burning were 223.4 Gg as of 2004. It is estimated that aggregate CO2 emissions from energy production will reach to 343 Gg by 2010 and to 615 Gg by 2020. According to those data the significant share of CO2 emissions originate from increasing power generation. On a per capita basis, consumption of electricity in Turkey has increased by 6-folds from 1980 to 2005, and is expected to increase to 400 kWh per person by 2010. Gross electricity generation is observed to almost double from 86,247GWh in 1995 to 149,982GWh in 2004. This rapid expansion gives an annual average rate of growth of 7.2% over the mentioned period. **[219]**

Energy intensity, defined as metric ton oil equivalent per real income in purchasing power parities, followed an erratic path until 2000, when it began to decline, but then moved upward again in 2006 **[Figure 30].** The high energy intensity in Turkey compared with that in the EU is mainly attributable to the rapid increase in industrialization and urbanization. With increased production capacity and increased consumption demand, Turkish energy intensities are projected to rise. Carbon intensity, defined as kilograms of CO2 per real income in purchasing power parities, has followed a path similar to that of energy intensity **[Figure 30]**. It increased in value from 0.22 in 1960 to 0.42 in 2006. According to a recent report of Medenergy, it is predicted that energy intensity and carbon intensity in Turkey will remain almost flat for a while and then start declining around 2015. The main reason for this decline is the expected introduction of nuclear power and the reduced share of oil **[220] [Figure 30].**

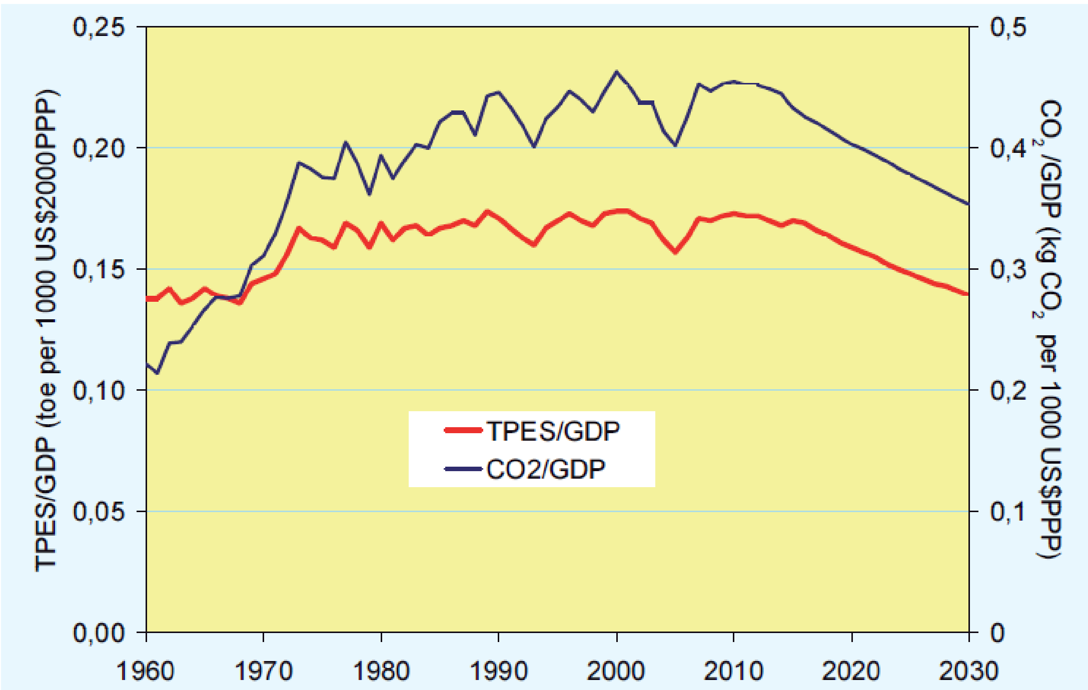

Figure 30: Evolution of energy intensity and carbon intensity in Turkey [220]

It can be said that energy, GDP and environmental issues are strongly coupled with each other. However the character of the relation between those three is still a matter of discussion. Considering both opposite theories about environment and income relation, it can be concluded that for a developing country, in the resource intensive industrialization stage, growth, energy use and environmental degradation move much or less parallel with each other.

CHAPTER 5

STATEMENT OF THE PROBLEM

Turkey has a growing economy and therefore energy demand of the country is increasing rapidly. However, Turkey has inadequate fossil resources which constitute an important share in the total supply. This high level of dependency on imports in fossil resources and insufficient utilization of domestic resources seriously threaten the supply security in Turkey. On the other hand, climate change forces countries to reduce their greenhouse gas emissions mainly caused by fossil fuel usage. Turkey, sooner or later, will probably be responsible for reducing its emissions whether by new international agreements or by EU commitments as a candidate country. It is difficult for countries to satisfy both supply security and environmental concerns. For Turkey, a developing country, economic growth becomes another restricting factor in the energy problem. Therefore, in this thesis, in order to lay the basis for the construction of an appropriate energy strategy for Turkey, the resource potential of Turkey is investigated and, the possible environmental restrictions and the effect of economic growth on the solution of the energy problem is analyzed.

CHAPTER 6

ANALYSIS

In the previous chapters, Turkey's energy problem is mainly examined in consideration with three important parameters. The first parameter is supply security which is directly related with the resource potential and import options of Turkey. The second one is the climate change which is explained in the second chapter, is a recently introduced factor with the ratification of Kyoto Protocol by Turkey. Lastly, relation between economic growth, energy and environment is examined as another factor.

As given in the first chapter of this thesis, energy security remains a major concern for Turkey because of limited domestic energy resources and high level of dependence on imports. Therefore, Turkey has placed high priority on increasing the utilization of domestic energy **[224]**. On the other side Turkey has a rapid growth rate which results in a huge increase in the total energy demand. According to the recent estimates, with the increasing population and the economic growth rate, energy demand will be doubled by the year 2030 **[224]**. Furthermore, as explained in Chapter 2, environmental concerns are about to become legally binding by the new international agreement expected to be signed in 2012 or by the EU commitments on Turkey as a candidate country. For the new commitment period, Turkey is expecting her national special circumstances to be taken in to consideration and negotiating for an appropriate position in the new agreement. Even if this special condition is accepted, Turkey still will have to take the environmental concerns in to consideration. However, based on the evidences shown in the previous chapter, compared with the other OECD countries, it can be said that Turkey has the right to put more importance on supply security and economic growth than environmental issues. Therefore, it can be said that Turkey has to develop an energy strategy considering the priority of supply security and without neglecting the environmental concerns.

At this point, it can be stated that it is better for Turkey to start with emission mitigation methods which does not directly threaten the supply security. One of the most important ways of reducing carbon emissions is forestation. Just by increasing reforestation and stopping deforestation, Turkey could achieve important reduction levels.The Union of Concerned Scientists estimates that U.S. forests absorb between one million and three million metric tons of carbon dioxide each year, perhaps offsetting between 20 percent and 46 percent of the country's greenhouse-gas emissions **[225].** Another important way is to reduce the high energy demand by energy efficiency and conservation. Japan is one of the most successful countries in energy conservation and efficiency applications. After the oil crisis in 1970's, Japan government prepared an Energy Efficiency Law and up to recent especially industrial energy use became unchanged despite the growing output **[3].** Actually, Turkish government has recently started a campaign called EN-VER to build awareness in public for energy conservation and efficiency. Furthermore, an Energy Efficiency Law is prepared and entered into force in 2007 **[227].** However, as can be seen from previous experiences such as the ban on smoking indoors, it can be claimed that wider public attendance can be possible with legal commitments for energy efficiency rather than voluntary efforts. Decreasing electricity transmission losses and illicit uses are other possible ways to reduce the energy demand. By the year 2007, transmission losses and illicit use constituted 19.6% of all power demand of Turkey **[224]**. Obviously, the most important way is to increase the share of renewable resources in the total supply in order for both decreasing energy dependency and reducing emissions. This strategy becomes even more important when it is recalled that utilization of renewable energy resources will be able to contribute in considerable amounts to the total energy supply in the long term period. In the following paragraphs, the energy supply resources of Turkey will be discussed together with the demand of main energy consuming areas and sectors.

As stated in Chapter 1, fossil resources comprise the main part of the primary energy demand of Turkey. However, Turkey has very poor fossil reserves, except lignite. Most of the existing petroleum reserves are old fields which have already seen the peak production levels. Quality of petroleum is really low and meets only 8,7 % of total demand. The share of transportation sector in total energy use and total emissions has been increasing in the past three decades. The worse, transportation sector is almost completely dependent on imported petroleum. Half of the petroleum supply is spent for the transportation. Furthermore, there is no serious alternative for transportation fuel except biofuels. Yet, biofuels are used in small percentages in the total mixture of fuel together with conventional oil products. Biofuels, which are considered to be an alternative fuel, is not expected to have an effective contribution to the total demand in the near future due to some practical limitations. For instance, it is claimed that, even the EU's modest target of 20% reliance on alternative fuels (including biofuels) by 2020 would consume the majority of its cropland **[228].** Turkey, as a developing country has larger agricultural land, residual and labor potential. Hence, in Turkey, biofuels have better potential than Europe in contributing to the total supply in the transportation sector. However, again it is not expected fossil fuels to be completely replaced by biofuels in Turkey and even a considerable contribution of biofuels to the market is only possible with a strong program and a governmental policy supporting and encouraging the investors and informing the rural people about biofuel production and energy farming. On the other side, uncontrolled utilization of farmlands for biofuel production may harm the agricultural activity and food security. A carefully controlled and well-planned biofuel production may be a good opportunity for small farmers and rural development. Besides decreasing dependency, biofuels are also important for reducing the emissions caused by transportation. Biofuels have 40-50% less CO2 emission than petroleum based fuels. Considering all these advantages and disadvantages, it can be said that biofuel will be a considerable alternative for transportation in the near future. In other areas of use, oil may be substituted by other cleaner and domestic resources. However, it seems like share of oil in transportation will be the highest in the recent future. Better solution may be finding ways to reduce the energy used in transportation. Energy use in transportation can be reduced by improving the efficiency of transportation technology, improving the quality of the transportation infrastructure, shifting to less energy intensive transport modes **[229]**. Mass transportation is one of the powerful solutions in urban areas and also railway transportation is a less energy intensive solution especially for long distances. Turkey, unfortunately, moves in the opposite direction. The share of road passenger transport in total passenger transport increased nearly 25 in the time span from 1960 to 2006. The increase in the share of road freight transport in total freight transport is even more dramatic. It went up from only 38% in 1960 to over 90% in 2006, mainly because of the neglect of railways over the last half century. Over the last five and half decades, only 1000 km of railway have been built in Turkey. Today, the length of the main lines is 8697 km, of which 78% is not electrified. Railway electrification average of Europe is nearly 46 % **[230].** Somehow, this sad situation of the railways has not received much attention from policymakers. By the rising incomes and competitive prices, air transportation is increasing its contribution in total oil demand for transportation, which will result in a significant contribution to Turkey's greenhouse gas emission levels in the near future **[224].**

Power generation in Turkey, is mainly dependent on natural gas and coal and the governments aim is to increase the share of natural gas in power generation in the future. Domestic natural gas production is very far away from meeting the increasing demand. Turkey has very limited natural gas reserves. As shown earlier, more than 90% of Turkey's total natural gas demand is supplied by imports. This situation creates an important supply security problem. Therefore, Turkey is trying to build new agreements and pipeline projects with exporter countries and other importers in order to diversify the source of imports. Although it is important for the supply security, source diversification does not reduce the dependency of Turkey to imports. Both natural gas and oil dependency are forcing Turkey to make new explorations especially in off-shore fields. Recent researches in Black Sea have promising results in terms of both natural gas and petroleum reserves. According to the general director of TPAO, if current estimations are correct, Black Sea oil and gas alone will be able to end the Turkey's dependency **[32]**. Turkey should immediately act to solve the political conflicts in the Mediterranean Sea and accelerate the researches in other off-shore regions. From 1934 to 2007, 1416 exploratory wells are drilled in Turkey, which is less than the USA's exploration wells drilled in one year. Considering the increasing demand of natural gas for power generation and oil for transportation, Turkey should be more active in drilling new wells. Natural gas is preferred for power generation also for its respectively less CO2 emissions. However, despite emitting great amounts of greenhouse gases, coal fired power plants will continue to be a strong alternative for electricity generation and industrial use because Turkey still has considerable lignite reserves. The situation for coal is similar in many countries. In most of the future energy projections it is predicted that coal will keep its importance in the next decades due to its low cost and worldwide availability. On the other side countries are looking for methods to reduce the emissions caused by coal. Using clean coal technologies and carbon capture and storage methods are some alternatives for emission mitigation. Turkey has experienced carbon dioxide storage in South Eastern region as an enhanced oil recovery project. Feasibility of other possible oil fields and deep saline aquifers for carbon storage need to be detected if Turkey intends to generate electricity from coal in the future considering her supply security. Clean coal technologies and carbon capture methods still need to be developed. Coal bed methane potential in the West Black Sea Region should be utilized since it is a good opportunity for both reducing methane emissions and meeting the natural gas demand.

Nuclear energy could be a solution for both supply security of power generation and reducing greenhouse emissions caused by coal and gas fired power plants. However, nuclear power is a problematic issue which is still a matter of conflict between the environmental organizations, non-governmental civil communities and governments. Nuclear power lost its popularity after two serious accidents in Three Miles Island and in Chernobyl, Ukraine, which also adversely affected Turkey. Nuclear power should gain public acceptance before it is utilized. Safety, waste management and proliferation are important drawbacks of nuclear power. These possible dangers of nuclear energy are causing a global conflict and therefore a country's nuclear energy production becomes an international issue especially when the country in not a developed country. On the other side, a number of countries have already installed considerable capacities in nuclear power. A good example is France, where nuclear energy constitutes 76% of all electricity generation **[Table 37].** The EU is the first major regional nuclear actor to provide a binding legal framework on nuclear safety. Europe becomes an important model for the rest of the world in establishing and controlling the nuclear safety **[231].** After long efforts for years, Turkey reached to an agreement to develop a nuclear program. Considering the high initial costs and long construction time, nuclear power will probably be able to contribute to the total supply in the 2030's. If possible risks can be carefully controlled and public acceptance is maintained, nuclear power would be the most effective way of reducing the fossil fuel dependency and greenhouse emissions of Turkey.

Renewable resources have a rapidly growing importance for most of the countries planning to reduce greenhouse gas emissions mainly caused by fossil fuels. Being a domestic source for energy, renewables are good opportunities for countries to reduce their dependency on imported resources. Turkey recently realized that it has an important potential of renewable resources. Until the mid-1960s biomass, a renewable energy source, represented more than two-thirds of the total primary energy demand in Turkey, but with the advances in socioeconomic development and industrialization biomass was replaced by modern energy resources **[224]**. Hydroenergy has constituted an important ratio in power generation for more than 30 years. It is the most important domestic resource of Turkey. Although Turkey has a big potential for hydropower, but only 35% of DSIs estimated economic potential has been utilized so far **[128]**. Compared with some European countries, Turkey is not successful in utilization of hydropower up to now. However, Turkey is developing lots of new hydropower plants. Southern Anatolia Project, which is one of the biggest hydro activities of the world, is still continuing. However, due to its environmental and socioeconomic negative effects, large hydropower plant is not a favorable option nowadays. In Turkey, it is planned to build hundreds of new hydropower plants in the near future, however there is a strong reaction against this plan from the NGOs and the people living around that regions. Turkey has a considerable potential for building small hydropower plants. Small hydropower plants can be considered as the most proper way for utilizing the rest of the hydro potential for Turkey. However, the management of water sources is a vital issue and so hydropower development should be carefully planned considering possible drought and environmental risks and public acceptance.

Wind energy has a promising potential in meeting the increasing electricity demand of Turkey. Turkey, having the biggest potential in Europe, has not given importance to wind energy until now. However, after the incentives provided by the new Renewable Energy Law **[232]**, wind energy made a very fast penetration to the power market. Turkey became one of the fastest growing wind markets in all Europe. High initial cost problem seem to be defeated with these incentives and profitable investment conditions provided by the government.

Solar energy is another renewable source requiring high initial costs to be utilized for power generation. Turkey has not installed a considerable on-grid solar power yet. There are a few installations in some universities and solar energy centers. However, Turkey has a significant solar potential. If Turkey could develop and produce her own solar PV technologies, solar power generation will be more profitable. Increasing number of solar research centers in Turkey is promising a solar power development in the future. For both wind and solar energy, imported power systems and equipment constitute the main obstacle for the development. Therefore, solar and wind energy penetration in to the power market becomes dependent on governmental support or imported technology.

On the other side solar energy is successfully utilized for heating purposes in Turkey. Turkey is one of the leading countries in the world in using solar energy for water heating. Turkey is also a solar collector producing country. This makes solar energy completely a domestic source for Turkey. The energy consumption for heating and cooling of buildings in Turkey was about 21.6 mtoe for the year 2005 **[233].** This is more than one third of the total energy consumption. Southern, southeastern and western regions have considerable solar energy potential. Therefore, solar energy can be further utilized for space heating and also cooling in these regions.

Another important renewable resource for meeting the heating demand of Turkey is geothermal energy. It has been a good local solution for years in some regions of Turkey, especially in water and space heating. Turkey has an important potential of geothermal energy and is one of the most active countries in direct applications of geothermal. EIE estimates that if Turkey fully utilizes its geothermal resources, 30% of all heat requirements could be met by geothermal energy. The geothermal resources in Turkey are mostly moderate and low-temperature ones. High temperature geothermal resources capable of supporting direct use projects and power generation are discovered primarily in the Western Anatolia. Geothermal power generation has recently started in Turkey. Other low temperature geothermal resources can be utilized by heat pumps for directs use or binary-cycle systems for power generation. It seems that geothermal energy will play a more important role in meeting the heat demand of Turkey rather than in power generation.

Although all of these statistics present a pessimistic picture, they also indicate areas where achievements are possible. It is possible to say that renewable energy development in Turkey is mainly dependent on governmental policies supporting and encouraging investors. Research and development projects are very important especially for the future of renewable energy in order not be dependent on imported technologies. Renewable energy researches should be encouraged in universities and even in earlier stages of education. Maintaining the public awareness for the importance of the energy conservation, efficiency and considering the public acceptance and environmental risks for the controversial issues such as nuclear energy and hydroelectricity is necessary while building the new energy strategy of Turkey.

CHAPTER 7

CONCLUSIONS

1. As a result of this study, it is possible to say that supply security, climate change and economic growth have many interconnections. Especially, when dealing with the fossil resources utilization, the trade-offs between those parameters should be examined and decision should be build considering the priorities of the country.

2. An idea is, for Turkey economic growth and therefore supply security could be thought as the priority. Analysis show that energy and economic growth are tightly coupled to each other in Turkey unlike the developed OECD countries. Economic growth also causes a rapid increase in greenhouse gas emissions due to increasing energy use.

3. Turkey should try to get the appropriate position in the new commitment period putting forward the reason that Turkey is not as developed as other OECD countries having legally binding reduction targets.

4. Whether assigned an emission target or not Turkey has to consider the climate change and environmental issues and immediately act in order to decrease the greenhouse gas emissions. Even if Turkey achieves to be omitted from the Annex I list of UNFCCC, it will still be responsible of EU's environmental directives as a candidate country. Therefore, it is possible to say that, while building the energy strategy, Turkey should give priority to her growth targets and therefore supply security without neglecting the environmental concerns.

5. Coal is comparatively a secure fossil fuel for Turkey. However, it is one of the major contributors of greenhouse gas emissions. Despite this fact, many countries have plans to continue to use coal in the future. It is difficult for Turkey to reduce the share of coal in the total energy supply before utilizing considerable amounts of renewable or nuclear resources in power generation. The solution may be to reduce the emissions caused by coal by using clean technologies and carbon capture-storage methods. Therefore investigation of possible geological storage fields should be done and research for the feasibility of the technology for clean coal and carbon capture in power plants should be made.

6. Natural gas is cleaner than other fossil resources. However, utilization of imported natural gas in power generation is seriously threatening the supply security of Turkey. For a short term solution, diversifying the sources of import by new pipeline projects is important. This needs serious political and diplomatic efforts. Technically, for a possible natural gas bottleneck, Turkey should immediately activate the geological fields to store secure amounts of natural gas.

7. Petroleum has been seriously replaced in power generation, residential uses with alternative fuels in the world. However, despite the efforts for making and using vehicles with alternative fuels, petroleum is predicted to keep its importance for transportation in the next decades. Turkey is also dependent on imported petroleum for transportation. If estimations about the possible reserves in Black Sea can be confirmed as a result of these ongoing researches, Turkey may get the chance to reduce its dependency for petroleum and natural gas in the next decades. Turkey should increase its drilling activity in both onshore and offshore fields. Diplomatic efforts are needed to start explorations in Mediterranean and Aegean Sea.

8. For decreasing the dependency and emission caused by fossil fuels, maybe it is better trying to reduce the rapidly increasing demand for fossil fuel. Since slowing the economic growth could not be an option, it is possible with energy conservation and efficiency. Especially for petroleum, reducing the energy used in transportation will have a considerable effect. Increasing the share of mass transportation and railways, using cleaner fuel mix (i.e. with biofuels) are some important ways to decrease the demand. Passive solar building design, energy efficient building design and insulation are possible ways to reduce the demand in buildings which constitutes the important part of the total demand. Together with the national campaigns suggesting voluntary attendance for energy conservation and efficiency, there should be also some legal commitments to establish the public awareness in this issue. Furthermore, if transmission losses and illicit uses could be minimized, important amounts of energy can be saved.

9. Forestation, reforestation and avoided deforestation are very effective methods for reducing emissions without threatening the supply security. Stopping deforestation alone may result in an important reduction in greenhouse gas emission. Turkey should find solutions to forest fires and should stop degradation and destruction of forests.

10. Utilizing renewable resources is an effective method for both reducing greenhouse gas emissions and securing the supply. Turkey can be considered rich in terms of renewable energy sources. Power generation from wind, if continues to develop, will have an important role in the future energy supply of Turkey. Both solar and wind power generation needs state support, incentives for development because of high initial costs.

11. Turkey has important solar and geothermal potential. Solar and geothermal energy are especially good alternatives for satisfying the heating and cooling demand of Turkey and they should further be utilized as mush as possible.

12. Hydropower has an important role in the electricity generation of Turkey but only around one third of the economic hydropower potential has been utilized yet. Hundreds of new hydropower plants are projected to be constructed in the next decade, however, unfortunately, this rapid development in not carefully planned. This uncontrolled utilization of water resources may result in serious environmental and social problems.

13. Nuclear energy seems to be one of the most effective solutions for both supply security of power generation and reduction of greenhouse gas emissions. However, public acceptance should be taken in to consideration before building nuclear plants. How safety and waste problems could be minimized should be carefully planned and shared with the public. Maybe the important thing for Turkey is to develop its own secure nuclear technology in order to minimize the dependency on imported energy. Research and Development projects in all energy related areas should be supported and encouraged by the state for long term success.

14. Besides all these useful features of renewable energy resources, most of them can be considered as the parts of a long term solution. By observing the increasing environmental awareness and need for domestic resources, it can be said that, within a few decades time, renewable energy will have an important share in the total supply in many developed countries.

CHAPTER 8

RECOMMENDATIONS

1. Due to the fact that coal has important contribution to greenhouse gas emissions, some conflictual situations may arise when coal, a domestic fossil resource for Turkey, has to be utilized. For supply security reasons domestic resources (i.e. coal) are favorable for meeting the growing energy need. It is not possible to neglect environmental issues however Turkey, as a developing country has right to act in favor of her supply security. Therefore, Turkey should continue to use coal until renewable resources contribute an important share in power generation. Clean coal technologies and carbon capture-storage methods may be partially solutions in order to reduce the greenhouse gas caused by coal. However it is necessary to replace coal gradually with renewable sources or nuclear energy in medium term.

2. Most of the developing countries expect industrialized countries to accept their historical responsibility over climate change and show maximum effort. Developed countries suggest rapid growing economies as China and India to be assigned reduction targets since they have important contribution to the recent emission levels. In this chaos, Turkey should negotiate for the omission from Annex I list, just because of the fact that Turkey is not developed as other OECD countries. This omission will give the chance to be an actor in such mechanisms called Clean Development Mechanism and Carbon Trade which will help Turkey to reduce her emissions.

3. Government has an important role in all these energy issues, whether by supporting or regulating the activities. Energy efficiency and conservation should be maintained both by campaigns suggesting voluntary attendance and in some areas by legal commitments. Railway transportation and mass transportation are two important ways for energy conservation and efficiency that should be promoted by the governmental programs. Renewable energy investments should be encouraged. Solar and wind energy projets need more governmental support since they have serious initial costs.

4. Another important things are the public acceptance and the public awareness. Nuclear and hydropower development have problems due to some environmental and social concerns of the public. Water management is a vital issue. Possible environmental and social impacts have to be detected detaillier and carefully before the plants are utilized. The rest of the Turkey's economic potential should be utilized however it should be kept in mind that uncontrolled hydropower development would lead worse. A secure nuclear development is necessary for Turkey in order to reduce the dependency of the country to imported natural gas and environment-killer coal. However, it is still questionable to produce nuclear electricity with a completely imported technology and investment.

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