COSTS AND BENEFITS OF "THE RETURN OF COAL" CASE CONSIDERING ECONOMIC AND ENVIRONMENTAL CONCERNS IN TURKISH ELECTRICITY MARKET

by

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To Soma,

Where miners became victims of ‘unmerciful growth’

ABSTRACT

COSTS AND BENEFITS OF "THE RETURN OF COAL" CASE CONSIDERING ECONOMIC AND ENVIRONMENTAL CONCERNS IN TURKISH ELECTRICITY MARKET

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M.A. in Public Policy Program, Thesis, 2014

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Key Words: Energy Policy, Coal Policy, Electricity Market, Coal-Fired Power Generation

The main focus of this study is the costs and benefits of return of coal case in Turkish electricity market in terms of economic and environmental aspects. Three chapters mainly answer the questions regarding the study. The first chapter includes a comprehensive explanation of the state of coal both around the globe and in Turkey. Proven reserves, production & consumption values and coal in power generation are analyzed in this chapter. Moreover, the return of coal case for the Turkish electricity market is clearly defined. In the second chapter, economic outcomes of the return of coal are discussed considering the cost effectiveness and a goal of having more predictable market. Certain cases in the Turkish electricity market are used to elucidate issues regarding the economic aspect. Third chapter renders the environmental costs of coal by classifying types of impacts. The cases in Turkey are also introduced in this chapter to grasp the environmental challenges in Turkey. Certain options to mitigate the environmental risks are clearly explained.

ÖZET

EKONOMİK VE ÇEVRESEL BAĞLAMDA TÜRKİYE ELEKTRİK PİYASASI'NDA "KÖMÜRE DÖNÜŞ" VAKASININ FAYDALARI VE MALİYETLERİ

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Türkiye elektrik piyasasında kömüre dönüş vakasının ekonomik ve çevresel açıdan fayda ve maliyetleri, bu çalışmanın ana konusudur. Bu çalışma ile ilgili sorular üç bölümde cevaplanmaya çalışılmıştır. İlk bölüm, kömürün dünyadaki ve Türkiye'deki durumunun kapsamlı açıklamasını içermektedir. Görünür rezervler, üretim & tüketim değerleri ve elektrik üretiminde kömür bu bölümde analiz edilmektedir. Bununla beraber Türkiye elektrik piyasasındaki kömüre dönüş vakası da açıkça tanımlanmaktadır. İkinci bölümde is kömüre dönüş vakasının ekonomik sonuçları, maliyet etkinliği ve öngörülebilir piyasa hedefi göz önüne alınarak tartışılmaktadır. Türkiye elektrik piyasasında yaşanan belirli durumlar, ekonomik açıdan yaşanan sorunları izah etmek için kullanılmaktadır. Üçüncü bölüm, kömürün çevresel maliyetlerini, çevresel etkileri sınıflandırarak açıklamaktadır. Türkiye'deki çevresel zorlukları kavramak adına bu bölümde Türkiye'deki vakalar da sunulmaktadır. Çevresel etkileri azaltmak için belirli seçenekler açıklanmaktadır.

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INTRODUCTION

Along with major fossil fuels such as oil and natural gas, coal has been the main resource of heat and energy since its first exploration. In addition to worldwide proven reserves of 861 billion tonnes[1] coal supplies around 30% of global primary energy needs and global share of coal in power generation is 41%.[2] Moreover, while coal in global primary energy supply increased by 46.1% in 2000 – 2010, it is expected that the same increase rate in 2000 – 2030 will be around 115%.[3] IEA officials stated that coal, which is abundant and geopolitically available, will be here for a long time to grow continuously.[4] It is also expected that coal will retain its global share in power generation at more than 41% in 2030.[5]

In addition to the worldwide statistics, coal has crucial role in electricity generation in Turkey. The average percentage of share of coal in annual power generation is 27.1%, while the same percentage is 24.6% for year 2013, which is the most used resource to generate electricity after natural gas.[6] There are 29 coal-fired power plants currently operational which have an installed capacity of 12,828 MW forms around 19.5% of total installed capacity by April 30, 2014.[7] New plants are also being planned to be operational in the near future. According to the latest coal industry analysis report of Ministry of Energy and Natural Resources (2013), there are 21 plants with 9500 MW installed capacity that are either in process of investment or being planned as a project.

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[1] WEC (World Energy Council), *Survey of Energy Resources 2010*, London, 2010, p.10-12.

[2] WCA (World Coal Association), *Coal Facts 2013*, London, 2013,

[3] IEA (International Energy Agency), *World Energy Outlook 2012*, Paris, 2012.

[4] IEA, 2013: "Global coal demand growth slows slightly, IEA says in latest 5-year outlook" (http://www.iea.org/newsroomandevents/pressreleases/2013/december/name,45994,en.html)

[5] IEA (International Energy Agency), *World Energy Outlook 2012*, Paris, 2012.

[6] TURKSTAT (Turkish Statistical Institute), 2013, http://tuik.gov.tr/UstMenu.do?metod=temelist , accessed on 26.04. 2014.

[7] TEİAŞ (Türkiye Elektrik İletim A.Ş.), 2014, http://www.teias.gov.tr/YukTevziRaporlari.aspx, accessed on 26.04.2014.

Together with the recent statistics indicated above, a strong inclination towards coal in electricity generation has been visible among policy-making institutions, state and market players, which might be called as policies to "return to coal." Ministry of Energy and Natural Resources has a plan of enhancing the share of coal in electricity generation up to 42% until 2023 in order to diminish the negative effects of natural gas due to long – term interstate gas contracts and external dependency.[8] Therefore, in addition to 11 explored coal basins in 2006 – 2014, the governmental institutions have used this strong incentive to explore new coal basins in 4 different regions.[9] Furthermore, Turgay Ciner, president of Ciner Group which contains significant companies in mining and power industry, emphasized that coal reserves in Turkey are sufficient to meet electricity demand and the government should promote pro – coal policies in Turkish electricity market.[10]

On the other hand, ongoing discussions about depending on coal as a primary energy source raise a question mark among environmentalist authorities. The general idea is based on the fact that coal is the fossil fuel which harms the nature most by accelerating global warming. Statistics indicate that coal – based carbon emissions increased by %152 in 2000 – 2010 with a fact that 68% of carbon emissions due to coal consumption after 2009 were relevant with heat and power generation.[11] Greenpeace also points out the negative outcomes of greenhouse gas emissions depending on coal – based power generation, such as drought or population displacement by emphasizing to retain global temperature increase below 2ºC[12].

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[8] "Kömürden elektrik üretimi yatırımlarıyla doğalgaz faturası 14 milyar dolar azalacak", 2014, http://enerjienstitusu.com/2014/04/17/komurden-elektrik-uretimi-yatirimlariyla-dogalgaz-faturasi-14-milyar-dolar-azalacak/, accessed on 10.07.2014.

[9] "Türkiye, bu yıl 4 bölgede yapacağı aramalarla kömür rezervlerini artırmayı amaçlıyor", 2014, http://enerjienstitusu.com/2014/03/03/turkiye-bu-yil-4-bolgede-yapacagi-aramalarla-komur-rezervlerini-artirmayi-amacliyor/, accessed on 10.07.2014.

[10] "Ciner: 'Devlet kömürden elektrik üretimini teşvik etmeli'", 2013, http://enerjienstitusu.com/2013/12/04/ciner-devlet-komurden-elektrik-uretimini-tesvik-etmeli/, accessed on 10.07.2014.

[11] TKİ (Türkiye Kömür İşletmeleri), *Kömür Sektör Raporu (Linyit) 2012*, Ankara, 2013, p. 14-15.

[12] "Coal", 2014, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/, accessed on 23.07.2014.

Many suggestions have been made in order to alleviate these bad effects of carbon emission by many authorities since it had been realized. Supporting the renewables – based power generation projects financially and politically was the most obvious suggestion. The EU Parliament decision of action plan for reducing carbon emissions would be perceived as a suitable example: the parliament voted for taking action in order to reduce carbon emissions by 40% along with a 30% share of renewables in European energy market, which are all by 2030.[13] Moreover, it is presumed that additional base load costs would be reduced to $6/MWh if the share of renewables would increase up to 30% in power generation.[14] On the other hand, renewable sources have their own drawbacks due to the fact that supplying these resources is completely up to the natural conditions. It is up to wind to blow to generate electricity from a wind power plant, for instance, as well as a hydro – power plant, for which generation depends extremely on precipitation. Therefore, renewable sources are seen as a remedy in terms of easing the burden for countries which have high levels of power demand.[15]

Clean Coal Technologies (CCT) as another approach to reduce carbon emissions and increase generating efficiency has also been debated prevalently in recent years. In addition, Carbon Capture and Storage (CCS) technologies that solidify greenhouse gases (GHG), thus decrease the level of emissions, are believed to increase the consumption of coal with a stabilization of carbon emissions, if they would be successfully implemented.[16] However, both operating and constructing these technologies are costly than conventional generating technologies. According to "*The Future of Coal*" (2007), a comprehensive project that was conducted by MIT scholars,

[13] "Parliament backs strong EU stance on 2030 clean energy goals", 2014, http://www.euractiv.com/energy/meps-confirm-ambitious-stance-20-news-533298, accessed on 23.07.2014.

[14] "Enerji Sektöründe Muhafazakarlık", 2014, http://www.yesilekonomi.com/kose-yazilari/ozgur-gurbuz/enerji-sektorunde-muhafazakarlik, accessed on 23.07.2014.

[15] "South Africa: New power generation", *Financial Times*, 2013.

[16] MIT (Massachusetts Institute of Technology), *The Future of Coal*, Boston, 2007 p.14.

the total plant cost ($/kW) of a subcritical pulverized coal (PC) technology[17] with carbon capture costs $950 more than the same option without the carbon capture.[18]

Focusing on the coal type, more than half of coal-fired power plants in Turkey are operated by lignite, which has the lowest efficiency and contains the highest rate of ash (TKI, 2012, p.30). In terms of implementing clean coal technologies, Turkey has a few examples such as Iskenderun Coal Plant, which has been operational since 2003 with 1210 MW installed capacity. This plant have around 41% efficiency rate with nitrogen oxide and sulfur dioxide emission rates which are below the threshold of Turkish standards.[19] However, it is hard to strongly claim that clean coal technologies have dispersed among the electricity market.

The primary objective of thesis is to discuss the costs and benefits of "return of coal" case considering economic and environmental issues, in the light of the developments mentioned above. The main argument stands at a point that "return of coal" case is economically viable however environmentally infeasible for Turkish electricity market. The argument also embraces a course of actions which are proper implementation of clean coal technologies and keeping coal-fired power plants distant from ecologically rich areas will mitigate the environmental risks. The thesis proceeds as follows: the first chapter depicts the state of coal around the globe and Turkey with comprehensive statistics along with comprehensive explanation of the return of coal case. The second chapter evaluates economic outcomes of the return of coal in terms of cost effectiveness and economic impacts on Turkish electricity market. The third chapter clarifies the environmental concerns about the coal-fired power generation in Turkey together with a fruitful discussion of Clean Coal Technologies and potential preventions.

First chapter begins with the definition of coal with its features that determine the quality. The definition is succeeded by introducing coal types along with the international classification of the coal. Considering the latest statistics, then, proven coal

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[17] Subcritical Pulverized Coal technology is a coal – fired power generation method with low pressure steam below 550 °C. This technology refers to an efficiency level of 33 – 37% (MIT, 2007, p.21).

[18] MIT (Massachusetts Institute of Technology), *The Future of Coal*, Boston, 2007, p.19.

[19] G. Ateşok, H. Dinçer, F. Burat, F. Karakaş, M. Özer, *"Çevresel Sürdürülebilirliğe Doğru Kömürün Kullanımı". Türkiye 10. Enerji Kongresi*, İstanbul, 2006, p.27.

reserves, production & consumption rates and the contribution of coal in electricity generation are evaluated globally in terms of geographical regions and countries. The chapter continues by narrowing down the outlook with Turkey: coal deposits are classified with respect to the coal types, chemical features and institutions they belong to. In addition the production & consumption statistics, amounts of imported coal are also analyzed. Depending on resource based power generation values and the development of total installed capacity, the importance of coal in Turkish electricity market is evaluated. The explanation of "return of coal" case is eventually elucidated in the light of developments that point out an inclination to coal in the market.

The second chapter begins with a cost comparison between coal and natural gas for power plants. The unit costs are specified along with the capital costs and the factors affecting the cost formation are discussed. In the light of these explanations, current state of Turkish power market is depicted with its import vulnerability depending on the natural gas. Reasons of the vulnerability are characterized as high import prices, heavy contract liabilities and high levels of external dependency. The ability of coal to diminish the impacts of natural gas is emphasized with respect to production costs, unit costs of power generation and price of imported coal. Furthermore, the market impact of coal is debated compared to the impacts of gas import. First privatization process of the market is comprehensively introduced. Then, certain risks due to domination of natural gas in the market, which would either create or aggravate a potential gas supply crises are rendered, which are capacity constraint of pipelines, an exacerbation of locational asymmetry in terms of installed capacity and externalities. Finally, how the return of coal will alleviate these detrimental impacts is discussed.

The third chapter starts off with the classification of environmental damages caused by coal-fired power generation. In addition to explaining each negative impact, the issue of climate change along with the possible scenarios of global temperature rise is depicted in the context of greenhouse gases emissions. The ecological impacts of coal in Turkey is also discussed with respect to cases underwent recently. In the context of environmental damages, an evaluation if the renewable would be an ultimate solution is discussed comparing to coal. While looking for a potential solution, moreover, Clean Coal Technologies are defined and classified together with the conventional technologies comprehensively. Albeit CCTs are quite effective in terms of reducing GHG emissions, a significance of Carbon Capture & Storage (CCS) is emphasized. A brief cost comparison is made between these technologies also considering CCS and the status of Turkey in terms of implementation of CCT is discussed in the light of recent developments. Finally, alternative solutions for the problems characterized except GHG emissions are evaluated.

Chapter 1

The Return of Coal in Current Outlook

Introduction

Fossil fuels have been the primary source of energy supply indubitably for decades. Even though there are numerous discussions about alternating the energy sources such as implementing projects inclining renewable sources, it is apparent that fossil fuels will not be phased out for the next 20 years at least. What is more, the evaluation is on the direction that the fossil fuels will be consumed more than 12 billion tonnes out of almost 18 billion tonnes of total resource consumption in 2035.[20]

Among the fossil fuels, specifically, coal has a large contribution to satisfy power demand. In addition being used for heat and in iron & steel industries, almost 41% of electricity generation all over the world depends on coal.[21] Although certain countries have been putting an effort to reduce coal utilization in energy supply, coal is said to be here as a fuel for a long time.

In light of these developments mentioned above, there is a strong impression that Turkey has an inclination to rely on coal in electricity generation more. Even though there has not been an announced strict policy, a set of regulations and incentives provide evidence of an increase in coal based power generation, which might be named as "the return of coal" case.

This chapter aims at forming a basis for arguments that will be introduced in the next chapters to clarify the costs and benefits of return of coal case for Turkey. In addition to the evaluation of global outlook with informative explanations, the current state in Turkey in terms of coal utilization is also presented. Then the "Return of Coal" is defined and discussed with respect to regional state.

In the topic of *State of Coal Around the Globe*, first and foremost, the definition of coal is introduced along with features that determine the quality of coal. After the

[20] "BP Energy Outlook 2035", British Petroleum, 2014, p.12.

[21] "Coal & Electricity", WCA, http://www.worldcoal.org/coal/uses-of-coal/coal-electricity/, accessed on 20.06.2014.

international classifications for deciding its rank is explained, coal types within or without the classifications are clarified. Coal reserves dispersed around the globe are comprehensively mentioned according to both coal types and regions where they are located. Countries that have large reserves are highlighted accompanying with relevant data. Production and consumption values are also reviewed and interpreted subject to different researches. Finally the contribution of coal in power generation is evaluated taking all countries into consideration.

State of Coal in Turkey limits the current outlook with Turkey and its processes of power generation. Coal sites are evaluated regarding the institutions they belong to and coal mined in these sites are specified according to its chemical features. Annual production and consumption values are analyzed along with the coal import in the light of given data and few remarks. Then the importance of coal in electricity generation in Turkey is reviewed based on the installed capacity and generation & demand values.

Inclination to contribute electricity generation with coal is discussed under the topic of "'Return of Coal' in the Turkish Electricity Market." Set of official decisions are evaluated together with the statements of government officials, which point out the importance of coal. Then pro – coal incentives of government are elucidated consistent with a welcoming behavior of private sector against coal. Lastly, prioritization of return of coal comparing to alternative incentive in energy sector is explained.

1. State of Coal Around the Globe

a. Characterization of Coal Types

Briefly, coal is defined as an organic fuel type comprising a range of combustible sedimentary rock materials with a specific quality scale.[22] The formation of coal begins with tectonic movements, which have occurred in earth's crust, by burying peat bogs to significant depths in general. Due to the high temperature and pressure, vegetation is transformed into peat having physical and chemical changes; then the peat is transformed into coal.[23] It will be better to introduce the coal types and classification in order to grasp the global outlook.

In addition to having various amounts of sulfur, mercury, ash, moisture and volatile matter, which is considered as a product of thermal decomposition of coal; all types of coal have a stored energy with respect to their carbon content. Moreover, specific features of a coal deposit; such as its ash fusion temperatures, sulfur content, behavior of ash at high temperatures, and its length of time for formation determine the 'organic maturity' level, thus the quality of the deposit.[24] In other words, the quality of coal increases as the carbon content (the energy amount that it may provide) of the coal rises under the effect of pressure and temperature. As the moisture content decreases, the carbon content, thus the energy content increases.

According to International Coal Classification of the Economic Commission for Europe (UN – ECE), coal deposits are broadly divided into two different categories with respect to their calorific values and defined as the following:[25]

- Hard coal: Coal of gross calorific value more than 5700 kcal/kg (23.9 GJ/t) on an ash – free with moist basis in addition to the mean of random reflectance of vitrinite[26]of at least 0.6.

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[22] *Coal Information 2012,* International Energy Agency, 2012, p.11.
[23] *The Coal Resource: A Comprehensive Overview of Coal,* World Coal Institute, 2009, p.2.
[24] James G. Speight, *Coal – Fired Power Generation Handbook*, Scrivener Publishing,2013, p.16.
[25] *Coal Information 2012,* International Energy Agency, 2012, p.11.

- Brown coal: Non – agglomerating coal with a gross calorific value less than 5700 kcal/kg (23.9 GJ/t) containing at least 31% volatile matter on a dry mineral matter free basis.

In addition to the classification of UN – ECE, International Energy Agency[27] comes up with an incrementally different definition of coal types, which have been predicated to the International Coal Classification explained above. In the light of the definition of IEA (keeping the UN – ECE definition of 'hard coal' constant); a coal type which has a gross calorific value of 4165 – 5700 kcal/kg (17.4 – 23.9 GJ/t) with a mean random reflectance of vitrinite less than 0.6 are considered as 'sub – bituminous' coal, while lignite is introduced as a coal type with a gross calorific value less than 4165 kcal/kg (17.4 GJ/t) and the mean random reflectance of vitrinite of 0.6. The figure shown below, which has been retrieved from World Coal Association[28], demonstrates the coal types that are determined due to the international standards, by highlighting variables such as carbon and moisture content:

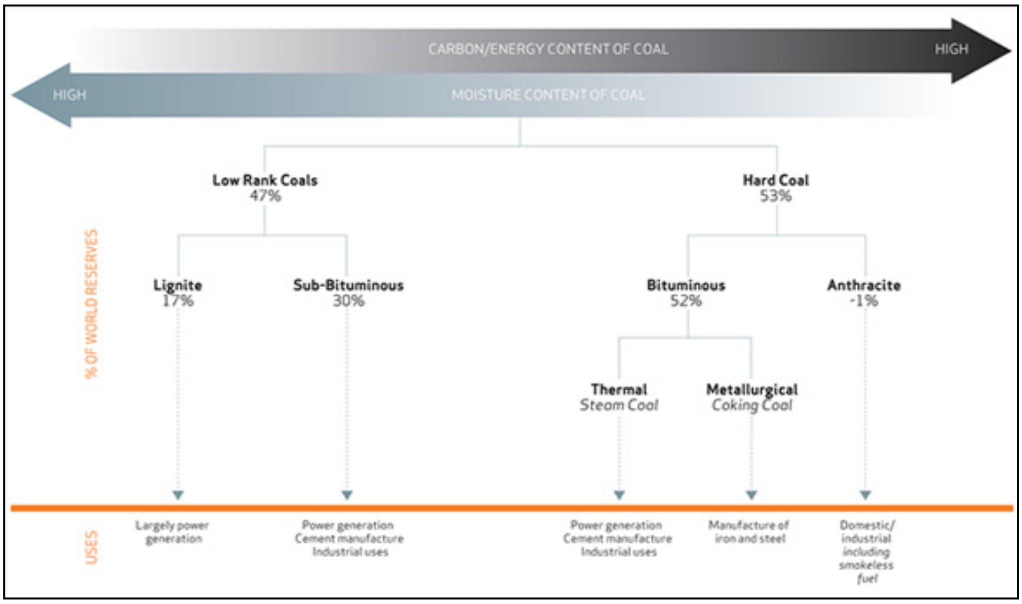

Figure 1.1: Coal types regarding their carbon / energy content and moisture content.

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[26] The study of Vitrinite Reflectance (VR) is used to determine coal rank by measuring the thermal maturity of coal (Brian J. Cardott, *Introduction to Vitrinite Reflectance as a Thermal Maturity Indicator*, presentation at Tulsa Geological Society luncheon, May 8, 2012.2012).

[27] *IEA Coal Data System,* International Energy Agency, 2010, p.10.

[28] World Coal Association, http://www.worldcoal.org/coal/what-is-coal/, accessed on 20.06.2014. Available data on the table that interprets the percentage of world reserves of coal types belongs to year 2012.

Among all of the introduced coal types, lignite has the lowest quality of coal having the lowest level of carbon, around 30 – 35%, and the highest level of moisture (around 20 – 40%).[29] However, percentage of moisture lignite contains might be around 60 – 70 % in rare cases. It has a more earthy appearance together with being softer than the other types.[30] Due to the fact that it is the lowest rank of coal, the lignite provides the least yield of energy with its moist and powdery structure. Heating value of lignite is between 4000 and 8300 Btu per pound and it is mainly used in power generation. Apart from its carbon and moisture content, having high levels of volatile matter (more than 32%) makes lignite to gas emissions which leads to the significant levels of air pollution. Although it might be dried in order to reduce its moisture content (also to diminish the effects of emissions), thus to increase its energy efficiency; this process also requires a specific energy consumption.[31]

One rank up of lignite according to the coal classification corresponds to sub – bitumminous coal, which might be sometimes called as *black lignite* with an appearance differentiates between bright black and dark brown. Its rank is accepted as right in the middle of bituminous coal and lignite because of having less sulfur (mostly under 2%) and heating value (between 8300 and 13000 Btu per pound) along with more moisture (around 10 – 45%) and volatile matter (45% at most) than bituminous coals.[32] Beyond to be used in power generation, sub – bituminous coal is also used for steam power generation and various industrial objectives such as cement production.[33]

Containing more energy content (above 5700 kcal/kg) and heating value (at the level of 11000 – 15500 Btu per pound) than sub – bituminous coal, bituminous coal is accepted as the most common coal type consumed all over the world.[34] Together with having a

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[29] James G. Speight, *Coal – Fired Power Generation Handbook*, Scrivener Publishing,2013, p. 18.

[30] *The Coal Resource: A Comprehensive Overview of Coal*, World Coal Institute, 2009, p.2.

[31] James G. Speight, *Coal – Fired Power Generation Handbook*, Scrivener Publishing,2013, p. 18.

[32] James G. Speight, *Coal – Fired Power Generation Handbook*, Scrivener Publishing 2013, p.18.

[33] Ibid.

[34]Ibid, p.19.

fixed carbon content of around 85%, it also contains moisture up to approximately 17%. This black, smooth and shiny (in some cases) type of coal is prevalently consumed for power generation and specific purposes for iron & steel industry as a fuel.[35]

Apart from the ranked coal types, steam coal (also referred as thermal coal) is considered as a subtype of bituminous coal without assigning any rank. In terms of quality, it has been located between bituminous coal and anthracite. However, it might also be considered as comprising all kinds of sub – bituminous coals.[36] In addition to being consumed for various objectives such as industrial use and locomotive trains with steam as a fuel, steam coal is provided to power plants in order to produce steam for electricity.[37]

In addition to steam coal, which is not ranked with respect to the coal classification explained above, coking coal is defined as a specific type under bituminous coal. The main purpose of producing coking coal is to create coke, an essential matter for iron and steel manufacturing processes.[38] Having a feature of remaining intact in high heat, coking coal is processed in high temperatures to remove volatile matter and relevant impurities. The remaining hot and liquid output solely consists of carbon is solidified and then it turns out a coke.

On the top of ranks among all types of coals, anthracite is the oldest coal geologically with the highest quality. Unlike the other types, anthracite has very little moisture (between 5 – 15%) along with few volatile content (around 5%), which makes this the most qualified hard coal to be composed mainly of carbon (around 80 – 95%).[39] Therefore it produces more heat than other coals having a heating value at the level of 13000 – 15000 Btu per pound.[40] Moreover, it also emits less smoke, which makes it the

[35] Ibid, p.20.

[36] *Coal Information 2012,* International Energy Agency, 2012, part I, p.12.

[37] James G. Speight, *Coal – Fired Power Generation Handbook*, Scrivener Publishing 2013, p.20.

[38] Ibid, p.21.

[39] Ibid, p. 21 – 22.

[40] James G. Speight, *Coal – Fired Power Generation Handbook*, Scrivener Publishing 2013, p.22.

cleanest burning of all coal types. Anthracite is consumed for industrial purposes and residential heating in general.[41]

b. Proven Coal Reserves

Unlike the other fossil fuels such as oil and natural gas, the largest reserves of which are said to be located at the Persian Gulf, one of the most significant feature of coal is the fact that coal reserves all over the world has a more balanced geographical dispersion.[42] Many countries have not been prioritizing the usage of coal due to various reasons and coal reserves of several countries is much more than the rest of the world. However, it would be correct to state that the accessibility of coal is more accessible than the oil or natural gas.

In addition to having the highest confidence category of reserve estimates, the definition of proven reserve is stated as "the economically mineable part of a measured coal resource."[43] The Coal Information report of International Energy Agency (IEA)[44] includes an estimation of German Federal Institute for Geosciences and Natural Resources (BGR), which states that the proved recoverable coal reserves all over the world by the end of 2011 amounts to 1003.8 billion tonnes. Moreover, the distinguished work of IEA also introduces that the same category of reserves was about 636.4 billion tonnes in 1978 according to World Energy Council (WEC), which interprets a 33% increase in reserves during 33 years, comparing to statistics belong to two different institutions.

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[41] *Coal Information 2012,* International Energy Agency, 2012, part I, p.12.

[42] *The Future of Coal,* MIT Press, 2007, p. ix.

[43] Larry Thomas, *Coal Geology*, Larry Thomas, West Sussex: Wiley, 2013, p.187.

[44] *Coal Information 2012,* International Energy Agency, 2012, part II, p.6.

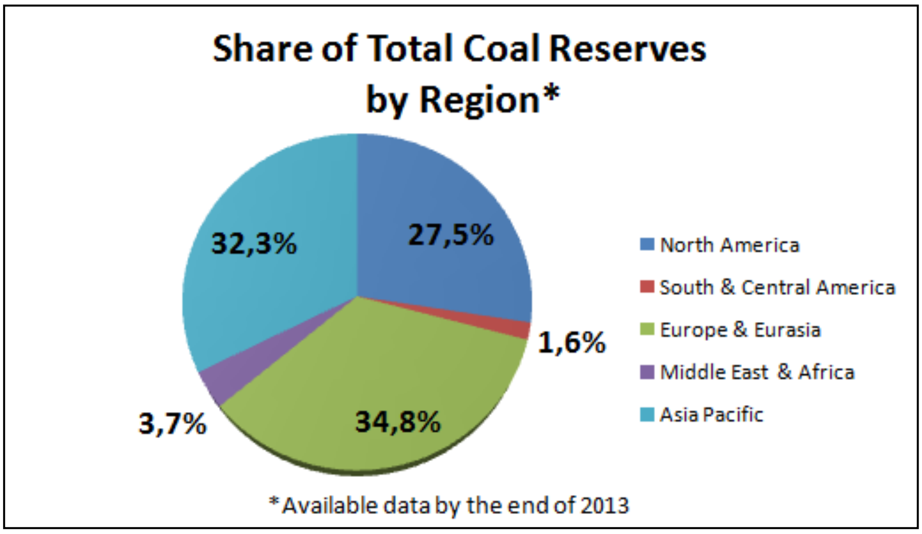

Figure 1.2: Share of Total Coal Reserves by Region (Data retrieved from *"BP Statistical Review of World Energy (2013)"*)

In the comprehensive work with the latest available data published by British Petroleum (BP)[45], proven coal reserves all over the world have increased from 861 billion tonnes to 891.5 billion tonnes between 2012 and 2013, which amounts to an increase by 3.5%. According to the latest data with respect to regions which belongs to year 2013, Europe & Eurasia has the largest coal reserves holding 34.8% of total reserves. The regional distribution of coal reserves is demonstrated on the figure above.

In spite of the fact that coal reserves are widely dispersed all around the globe, it might be perceived that proven reserves have an inclination to conglomerate in countries, which prioritize coal for domestic energy demands or export purposes. The latest numbers of proven reserves indicates that five countries which have the largest coal fields have 72.4% of world reserves[46], while the rest of the world have 27.6%. The United States has the largest reserve with 237.3 billion tonnes, succeeded by Russian Federation and China, which have 157 billion tonnes and 114.5 billion tonnes respectively. The chart which contains the distribution of proven coal reserves with respect to countries is below:

[45] *BP Statistical Review of World Energy (2013)*, 2014, p. 30-34.

[46] Ibid.

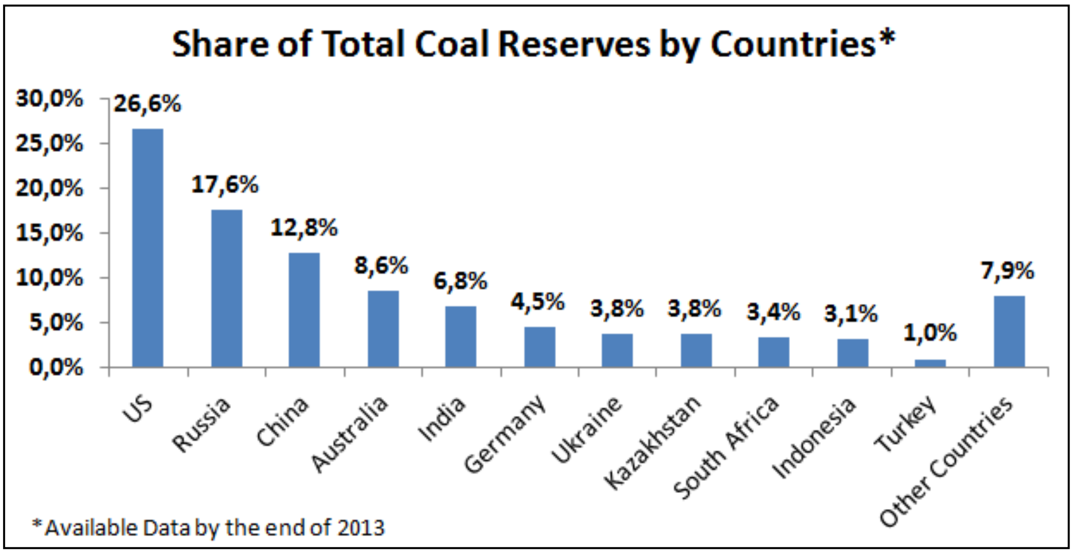

Figure 1.3: Share of Total Coal Reserves by Countries (Data retrieved from *"BP Statistical Review of World Energy (2013)"*)

Comparing year 2013, when the latest data was available, to 2012, worldwide hard coal reserves including anthracite and bituminous coal diminished from approximately 404 billion tonnes to 403 billion tonnes, while the worldwide proven low rank coal reserves including sub – bituminous coal and lignite rose from 456 billion tonnes to 488 billion tonnes, which amounts to 7% increase[47]. Pacific Asian region has the largest hard coal reserves around the globe with 157.8 billion tonnes, while the region of Europe & Eurasia has the largest reserves of low quality coal (sub – bituminous coal & lignite) with 217.9 billion tonnes.

In addition to the regional comparison, United States is at the top of having the largest coal reserves in either hard coals and low – rank coals by the end of 2013. According to the latest available data[48], hard coal reserves which are classified as anthracite & bituminous coal in the United States amount to 108.5 billion tonnes, while the country has 128.8 billion tonnes of sub – bituminous coal & lignite reserves together. Speaking of hard coal reserves China; India, Russia and Australia succeed the United States respectively, having almost same reserve amounts with each other. The figure below demonstrates the top 10 countries with the largest hard coal reserves.

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[47] Ibid.

[48] Ibid.

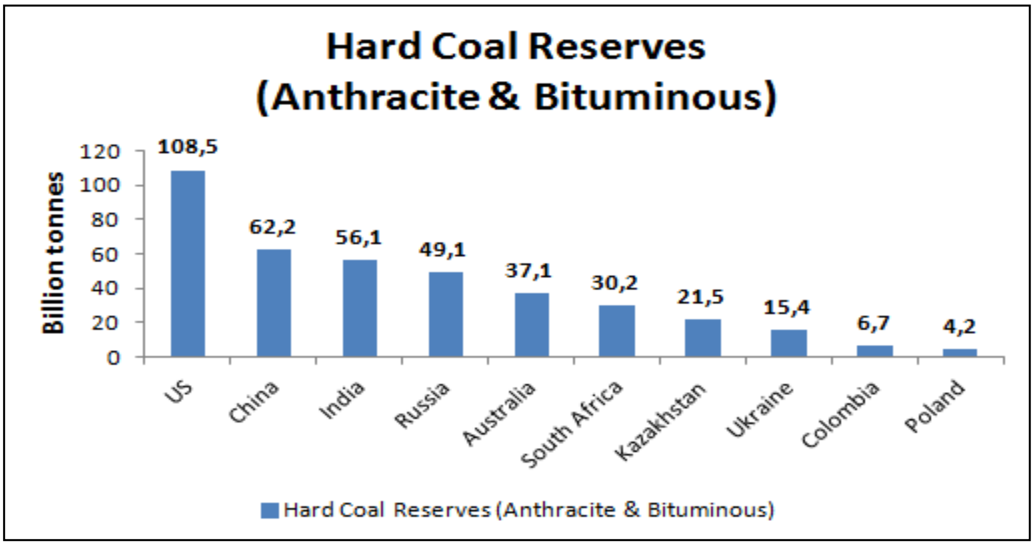

Figure 1.4: Top 10 countries with the largest hard coal reserves (Data retrieved from *BP Statistical Review of World Energy (2013)*)

In terms of low quality coals such as lignite and sub – bituminous coal, Russia follows the United States with a reserve of approximately 108 billion tonnes. Then China, Germany and Australia are ranked in the top five countries which have the largest low – rank coal reserves respectively. Speaking of lignite specifically, on the other hand, Germany has the largest reserves with 40.6 billion tonnes preceding Australia and the United States, which have 37.2 billion tonnes and 30.2 billion tonnes respectively according to the latest available data of year 2012.[49] The figure below demonstrates the top countries with largest reserves regarding the low-rank coal reserves:

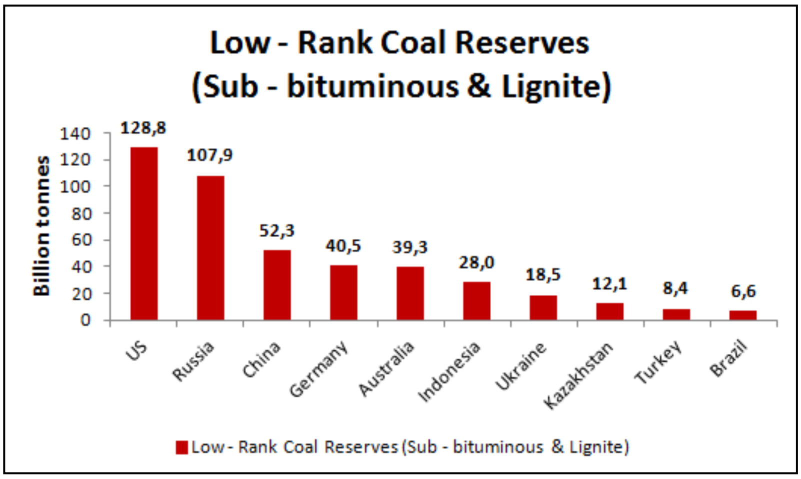

Figure 1.5: Top 10 countries with largest low – rank coal reserves (Data retrieved from *BP Statistical Review of World Energy (2013)*)

[49] *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.13.

c. Production & Consumption Statistics

As an abundant resource which is widely distributed all over the world, it is not too difficult to state that both production and consumption of coal has been increasing, however with a decreasing trend. Despite the fact that there is a remarkable decrease in usage of coal in Europe, coal production & consumption has been growing in Asia, which has led to a continuous increase in production in 2000 – 2012.[50] Moreover, the expectations towards 2035 are in the direction that the global consumption will keep growing due to the continuation of consumption growth in non – OECD countries, although the OECD countries are expected to decrease their coal consumption by 10% between 2012 – 2035[51]. Around 87% of contribution to consumption growth to 2035 in non – OECD countries is expected from China and India, which are forecasted to be the two largest consumers.

total coal produced annually around the world increased by 48.6% in 10 years reaching 7.89 billion tonnes (the largest annual production amount ever) by the end of 2013, according to the latest available data published by British Petroleum[52]. However, the increase in global production has a diminishing momentum for the last few years so that comparing to 2012, the coal production increased by only 0.04%. Member countries of European Union seem to put an effort to decrease annual production, which has a 7% decrease in 2012 – 2013. On the other hand, the increase is continuous in Pacific Asia even though a decreasing trend in growth would be noticed. The annual change in production of Pacific Asia has diminished from 13.9% in 2004 to 1.8% in 2013, which still remains positive.[53] Annual changes in coal production values in terms of regions are demonstrated in the figure below:

[50] Ibid., p.5.

[51] *BP Energy Outlook 2035*, British Petroleum, 2014, p. 69.

[52] *BP Statistical Review of World Energy (2013)*, 2014, p.30 – 34.

[53] Ibid.

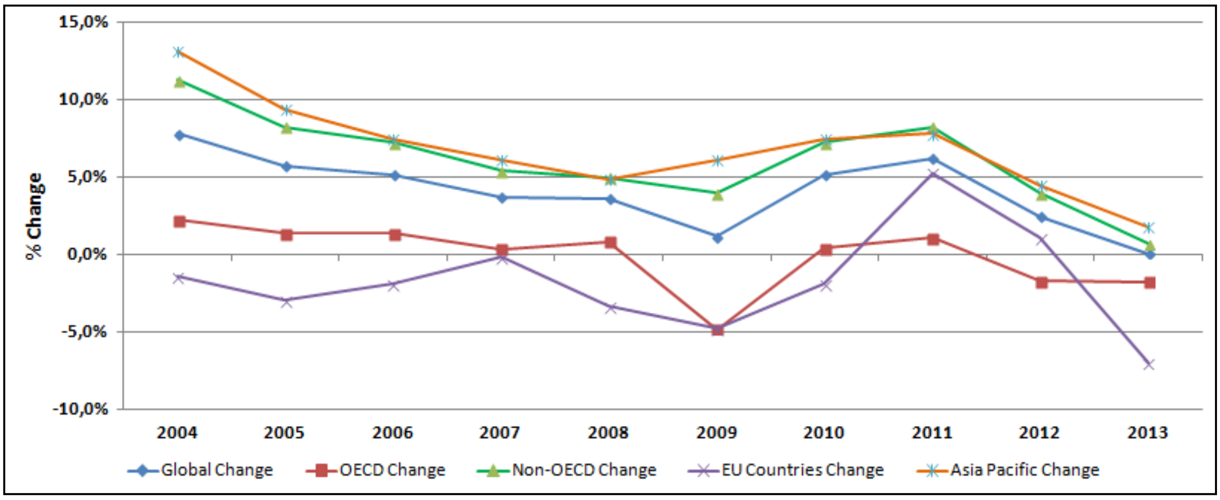

Figure 1.6: Annual Change in Coal Production in terms of Regions ((Data retrieved from *"BP Statistical Review of World Energy (2013)"*)

Pacific Asia has been the region with largest coal production by the end of 2013 (5.33 billion tonnes), where approximately 67.6% of global production took place.[54] Europe & Eurasia has the second rank with 1.22 billion tonnes and the North America following as the third region with the largest coal production. In terms of countries, China is the largest coal producer by far reaching a production value of 3.68 billion tonnes in 2013 (around 46% of total production), which is more than 4 times larger than the annual production of the United States as the second largest producer with 892 million tonnes. India has the third rank with 605 million tonnes preceding Australia and Indonesia, which are the fourth and fifth largest producers with 478 and 421 million tonnes respectively.

The trends of production, which have different characteristics with regards to different regions, are naturally affected by the level of coal demand. It might be observed on the dataset published by British Petroleum[55] that the global coal consumption has grown by around 46.5% with an annual amount of 3.82 Btoe[56] for 2013. On the other hand, it is apparently possible to monitor the similar case for coal production analyzed above: even though the annual consumption values have been increasing in general for 2013 unlike the production, these rates have a decreasing trend compared to 10 years ago. Apart from the European Union countries, which have been putting an effort to

[54] Ibid., (p.30 – 34).

[55] Ibid.,(p.30 – 34).

[56] Btoe = Billion tonnes oil equivalent. 1 toe = 11,630 kWh.

eliminate coal within the scope of long term projects focusing on the renewable projects[57], growth rate in consumption of Pacific Asia region have dropped from 13.6% in 2004 to 3.9% in 2013.

However, this interpretation would not mean that Asian countries are going to abandon from coal in the near future. Consolidated demand of China and India, the two largest coal consumers in Asia, contributed 58.8% of global demand and 81.5% of the demand of non – OECD countries, which increased by 90% in the last ten years.[58]

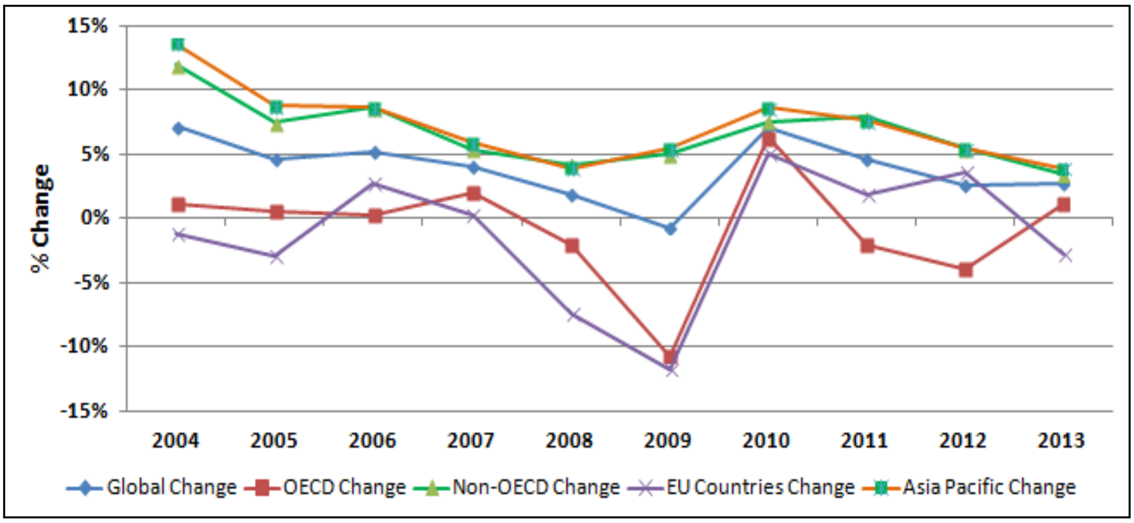

Figure 1.7: Annual Change in Coal Consumption in terms of Regions ((Data retrieved from *BP Statistical Review of World Energy (2013)*)

Moreover, the figure above indicates that non-OECD demand was not affected as the demand of OECD countries during the recession caused by the global crisis took place in 2008 – 2009. In 2009, for instance, demand of non-OECD countries increased by 5%, while the demand of OECD countries decreased by a 10.7%. Share of China and India combined in global and non - OECD coal consumption might be observed on the figure below.[59]

[57] "Parliament backs strong EU stance on 2030 clean energy goals", 2014. (http://www.euractiv.com/energy/meps-confirm-ambitious-stance-20-news-533298) accesed on 01.07.2014.

[58] *BP Statistical Review of World Energy (2013)*, 2014.(p.30 – 34)

[59] Ibid.

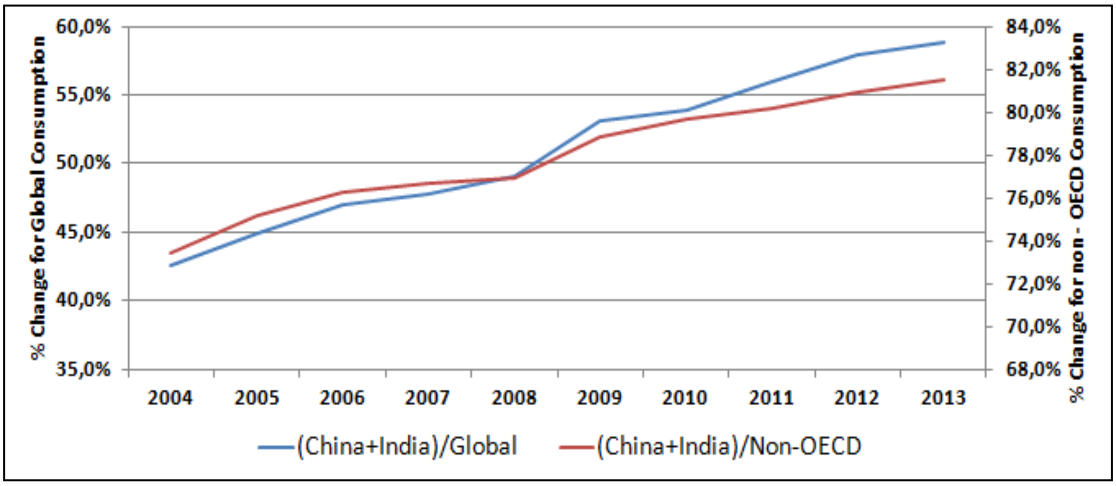

Figure 1.8: Share of China & India combined either in annual global consumption and annual non – OECD consumption for the last ten years

As mentioned above, Pacific Asia is the largest coal consuming region with an amount of 2.69 Btoe in 2013. In terms of consumption per se, Pacific Asia has been at the top rank since 1990.[60] Following the Asia, Europe & Eurasia and North America are the largest consuming regions with 508.7 Mtoe and 488.4 Mtoe respectively. Regarding the countries, China is the largest consumer by utilizing 1.92 Btoe of coal in 2013. The United States and India follow China with 455.7 Mtoe and 324.3 Mtoe respectively. Japan is also a significant consumer (128.6 Mtoe in 2013) along with Russia, which consumed 93.5 Mtoe of coal in 2013.

d. Coal in Power Generation

Apart from heat supply and steel industry, the primary purpose of coal consumption around the world is power generation. Around 40.6% of global electricity demand was satisfied by coal, while the same rate was 37.4% for 1990. Under the assumption that the current outlook in energy sector will persist, there is an expectation that coal will be utilized to generate 41.1% of global electricity demand in 2030.[61]

Regarding the reliance on coal in power generation, the most up-to-date statistics of International Energy Agency[62] indicates that more than 50% of electricity in seven

[60] Ibid.

[61] *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.9.

[62] *The Electricity Information 2012*, International Energy Agency, 2013, p. III.12 – III.15.

countries is generated from coal. South Africa is at the first place by generating 93.2% of power from coal. Poland supplies 87.7% of its power from coal, while the same rate is 80.7% for Kazakhstan. China, as a top producer & consumer of coal, utilizes coal in order to satisfy around 77.8% of its demand and India, the second largest consumer in Pacific Asia, satisfies its 68% of its demand from coal. In terms of rank, Australia stands between China and India with 74.8% of generation from coal.

In terms of hard coal based electricity generation, power generated by five countries, which are the largest hard coal based power producers, would be roughly 75% of electricity generated from hard coal.[63] According to International Energy Agency[64], the United States relies on hard coal most to generate electricity. In 2010, electricity generation in the United States was around 1903 TWh, which amounts to 32.9% of power generation from hard coal around the world. China contributed 22.7% of global demand satisfied by generation from hard coal with around 1313 TWh. Other largest hard coal based power generating countries are India, Japan and South Africa by generating 10.9%, 4.6% and 4.2% of total generation from hard coal respectively.

Speaking of brown coal (or lignite), the outlook is inverted: China dominates the brown coal based power supply by contributing almost 70% of total generation from brown coal.[65] The amount of power generation from brown coal in 2010 was around 1918 TWh, which was more than thirteen times greater than the amount brown coal based generation in Germany, the second largest lignite based power producing country (145 TWh with a 5.3% share in total generation from brown coal in 2010). The United States, Canada and Indonesia have minor roles in that case comparing to China and Germany: their shares on total generation from brown coal are 3.2%, 2.9% and 2.5% respectively. In addition to generation values, China also dominates the world electricity outlook in terms of total installed capacity of coal – fired power plants. By the end of

[63] Ibid.

[64] Ibid.

[65] Ibid.

2010, China holds 470,000 MW of installed capacity, which is the largest value all around the world.[66]

Apart from the actual values comprehensively explained above, making a brief analysis of coal – fired power plant projects which are not currently operational would be useful to clarify how coal policies would evolve in the future. As in many categories, China has been planning to put coal – fired power plants into use more than any other countries. Along with the approval of 16 giant coal–fired power plants by the 12th Five – Year – Plan, an installed capacity of 557,938 MW with 363 plants is planned to be operational in China by July 2012.[67] India is the second country with largest proposed coal – fired power plants with around 519,400 MW installed capacity. After these two countries with the largest coal based power generating facilities, Russia has 48 new projects that amount to 48,000 MW installed capacity. Moreover, there is an interesting detail in the statistics that claim that Turkey succeeds these three countries regarding the proposed coal – fired power plants with 49 new projects, which are planned to have 36,719 MW installed capacity in total.[68] Therefore, depending on the thesis topic, current state of coal in Turkey and its impact on the power market is scrutinized.

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[66] "Chinese Utility Plans", 2012, http://www.mcilvainecompany.com/brochures/chinese_utility_plans_brochure.htm, accessed on 02.07.2014.

[67] *Global Coal Risk Assessment,* World Resources Institute, 2012, p.5 – 6.

[68] Ibid., p.5.

2. State of Coal in Turkey

a. Reserves and Coal Mines

Hard coal reserves are prevalent all over the world, however Turkey has lignite reserves much more abundant than hard coal reserves. Having coal reserves, which amount to 15.4 billion tonnes, 92% of these reserves are formed by lignite (14.1 billion tonnes) as the other 8% is share of hard coal (1.3 billion tonnes).[69]

Turkish Hard Coal Enterprises[70] holds 5 different hard coal deposits, forms the total hard coal reserves of country, and four of these deposits (67% in hard coal reserves) have a coking feature which might be used for coking factories.[71] The only coal site which has non – coking feature is Amasra, so it might be also classified as different from the other four coal sites in terms of calorific value, ash & carbon content and volatile matter. Hard coal deposits of Amasra have more volatile matter and ash together with less carbon content and hence calorific value.

Combining the four sites, which are Armutçuk, Kozlu, Üzülmez and Karadon, the ash content of coal deposits, for instance, varies between 9% and 13%. Coal mined from these sites contains volatile matter at a range of 25 – 34% along with a carbon content level of 47 – 57%. Hence the calorific value of the coal is between 6050 kcal/kg and 7150 kcal/kg.[72] However, coal mined in deposits in Amasra has around 14 – 15% ash content, 32 – 35% volatile matter, 41 – 47% carbon content, which makes its calorific value at the level of 5450 kcal/kg – 6050 kcal/kg.[73]

Speaking of lignite, both governmental institutions and private sector share out the total reserves in Turkey due to the fact that lignite reserves are abundant when compared to hard coal. In addition to the comparably small share of private sector which is around 7.5%, Electricity Generation Co. [74]has approximately 57% of lignite reserves by taking

[69] *2013 Faaliyet Raporu*, Türkiye Kömür İşletmeleri, 2014, p.31.

[70] Türkiye Taşkömürü Kurumu.

[71] *Sektör Raporu*, Türkiye Taşkömürü Kurumu, 2014, p.21.

[72] Ibid., p.22.

[73] Ibid.

[74] Elektrik Üretim Anonim Şirketi (EÜAŞ).

over significant amount of coal deposits from General Directorate of Mineral Research Exploration (GDMRE)[75] and Turkish Coal Enterprises (TCE).[76] The process of taking over the coal sites from the other two institutions has a rationale for Electricity Generation Co. that managing the coal sites by a company, which has a coal based installed capacity of around 6400 MW[77] would bring flexibility bypassing the bureaucratic negotiations among different institutions. Nevertheless, TCE has around 18.3% of total lignite reserves while GDMRE has a share of 18.1%.[78]

In terms of the calorific value (hence the efficiency), lignite sites would be evaluated with respect to the classification of entities as public sector and private sector. Calorific value of coal deposits, which belong to the public sector, varies between 1280 – 3500 kcal/kg, an appropriate range for lignite definition. In case of private sector, the interval of calorific value would be accepted as 1300 – 4900 kcal/kg.[79] However, almost half of the coal sites owned by private companies mine lignite with a calorific value around 4000 kcal/kg. Moreover, the calorific value level of mines owned by private investments would be significantly more than the mines owned by public institutions, if a few private coal sites such as Orta lignite site in Çankırı province (860 – 1000 kcal/kg) is assumed as an outlier.[80]

b. Production & Consumption Statistics

Although there has been a slight decline for the last few years, it would not be wrong to claim that coal production in Turkey has grown since 2004. Total production including hard coal and lignite for year 2012 ended up as 70.4 million tonnes, while the production level was around 45.6 million tonnes, the lowest level, for 2004.[81] In

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[75] Maden Teknik Arama (MTA).

[76] *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.33.

[77] 2012 Annual Report, Electricity Generation Co., 2013, p.27.

[78] *Kömür Sektör Raporu (Linyit)* ,Ministry of Energy & Natural Resources, 2013, p.33.

[79] Cengiz Güneş, "Linyit Kömürü Sahalarının Ekonomiye Kazandırılması" Deloitte, 2012, p.22 – 23.

[80] Ibid., p.23.

[81] http://www.enerji.gov.tr/index.php?dil=tr&sf=webpages&b=y_istatistik&bn=244&hn=244&id=398, accessed on 05.07.2014.

addition to coal demand that will be analyzed further in this topic, a royalty model in mining industry, which might be defined as leasing a coal site with a fixed contract to private sector (introduced in 2004), has also contributed to a 54% increase eight years in production. As a matter of fact, production of raw coal by royalty model for Turkish Coal Enterprises (TCE)[82], has grown from around 2.6 million tonnes in 2005 to 8.2 million tonnes in 2013 with a 215% increase in eight years.[83] Moreover, the value of royalty based coal production in TCE for 2013 forms roughly 26.8% of coal produced in TCE. The effect of royalty model is not limited with lignite. In spite of the decrease in hard coal production, the graph below demonstrates the royalty model based coal production levels for hard coal production published by Turkish Hard Coal Enterprises:[84]

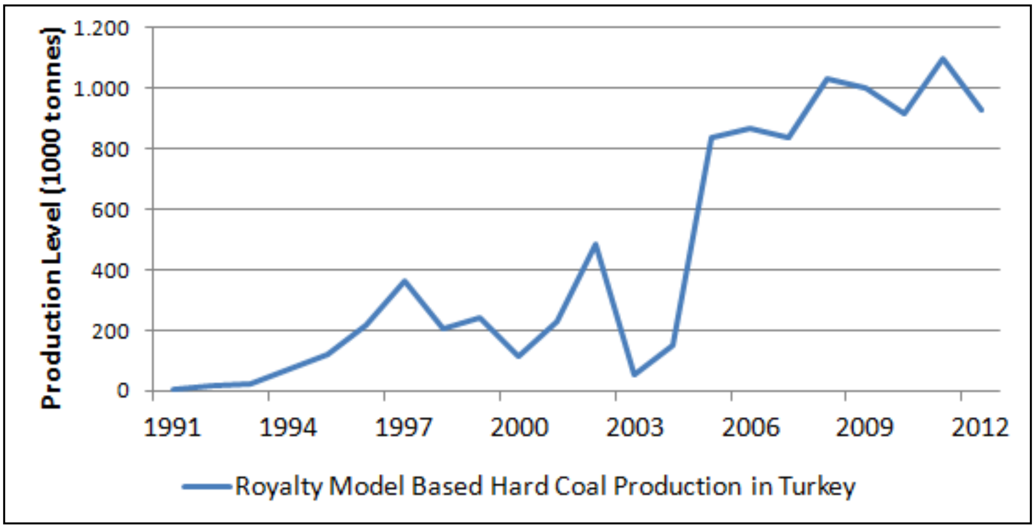

Figure 1.9: Royalty Model Based Hard Coal Production in Turkey

Regarding the long – term natural gas contracts to satisfy energy demand, lignite production in Turkey had begun to drop since 1998 so that it decreased to level of 43.7 million tonnes in 2004.[85] After that time, the lignite production has increased by 56.7%

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[82] Türkiye Kömür İşletmeleri (TKİ).

[83] *2013 Faaliyet Raporu*, Türkiye Kömür İşletmeleri, 2014, p.38.

[84] "Yıllık Taşkömürü Üretimi", http://www.taskomuru.gov.tr/file/uretimler.pdf, accessed on 05.07.2014.

[85] *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.20.

in eight years and ended up as 68.1 million tonnes in 2012.[86] According to 2011 statistics, which has a total lignite production level of 72.5 million tonnes, TCE has a share of 46.1% in total production, while Electricity Generation Co.[87] and private sector has 43.4% and 10.5% respectively.[88]

Regarding hard coal, there is a record that the cumulative production since 1942 is around 225 million tonnes with an annual peak value of raw coal as 8.5 million tonnes in 1974.[89] Neglecting rare growths, however, there has been a continuous decrease since 1974. In 2003 2013, the largest value of hard coal production was 2.87 million tonnes in 2009 and the value of 2013 ended up as 1.91 million tonnes with a 33.4% decrease in four years.[90]

According to the latest dataset which belongs to the year 2012, 99.92 million tonnes of coal in total was consumed in Turkey with a negligible fall compared to the previous year, 68.4 million tonnes of which was lignite production at that year along with the lignite surplus of 2011.[91] Comparing the total consumption of 2012 to the consumption of 2006, it is observed that there is an increase by around 20% along with the increase of lignite consumption, which is by 13.7% in six years.[92] Showing more or less the same characteristics comparing to 2011, 81.7% of lignite consumption in 2012 was made for electricity generation, while 9.7% of lignite was used for households.[93] The remaining 8.6% of lignite was used by industrial purposes.

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[86] "2012 Yılı enerji Dengesi",http://www.enerji.gov.tr/EKLENTI_VIEW/index.php/raporlar/detayGoster/72222, accessed on 05.07.2014.

[87] Elektrik Üretim A.Ş. (EÜAŞ)

[88] *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.20.

[89] *Sektör Raporu*, Türkiye Taşkömürü Kurumu, 2014, p.22.

[90] Ibid., p.23.

[91] "2012 Yılı Genel Enerji Dengesi", http://www.enerji.gov.tr/EKLENTI_VIEW/index.php/raporlar/raporVeriGir/72222/2, accessed on 05.07.2014.

[92] "2012 Yılı Genel Enerji Dengesi", http://www.enerji.gov.tr/EKLENTI_VIEW/index.php/raporlar/raporVeriGir/5480/2, accessed on 05.07.2014.

[93] "2012 Yılı Genel Enerji Dengesi", http://www.enerji.gov.tr/EKLENTI_VIEW/index.php/raporlar/raporVeriGir/72222/2, accessed on 05.07.2014.

In terms of hard coal, consumption is much larger than the domestic production. In 2002 – 2012, the consumption rose by 127.4% and the actual hard coal consumption ended up as 31.4 million tonnes in 2012.[94] Larger volumes of coal consumption and insufficient production naturally require the larger volumes of import. Therefore, coal imports of Turkey have gradually increased since the beginning of 1980s. Volumes of imported coal with hard coal consumption between 2000 and 2012 are demonstrated in the figure below:[95]

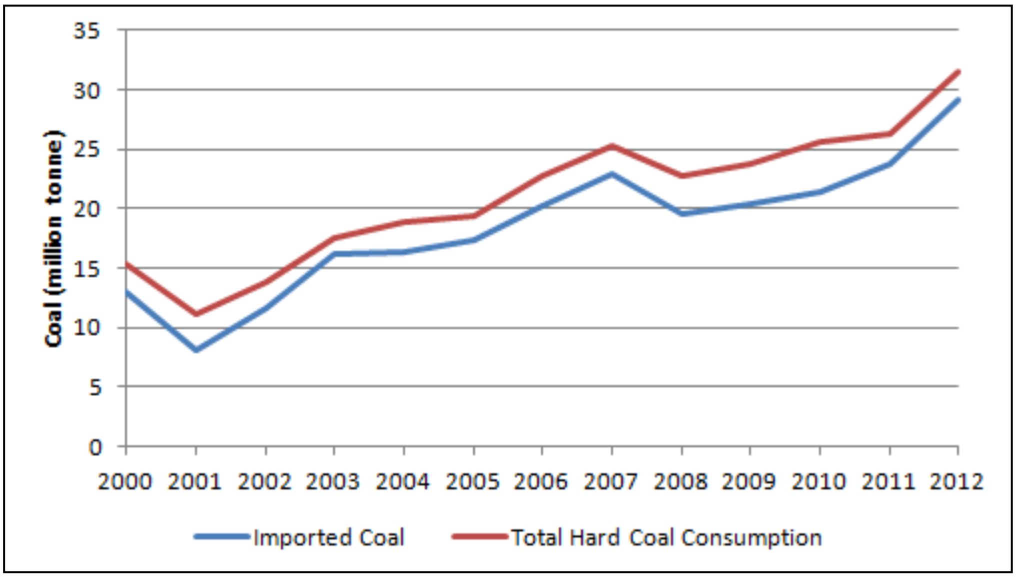

Figure 1.10: Imported Coal and Total Hard Coal Consumption Amounts in 2000 – 2012

Regarding the countries that Turkey imports hard coal from, Russia holds the first place with 33.3% for the year 2012.[96] Colombia is the second largest country in terms of exporting coal to Turkey having a share of 24.5% in total imports. The United States and South Africa have significant shares in imported coal as 14.6% and 11.2% respectively.

Speaking of the current data published last year, year that data available, 38.2% of consumption was for electricity generation, while households used around contributed

94 *Sektör Raporu,* Türkiye Taşkömürü Kurumu, 2014, p.23.

95 Ibid., p.24.

96 *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources., 2013, p.24.

31.5% of consumption.[97] The remaining shares in total consumption belong to coke factories with 17.1% and other industrial purposes with 13.2%.

c. Electricity Generation by Coal in Turkey

Despite several interruptions, the electricity demand in Turkey has always a growing trend along with increasing by 75% in 2003 – 2013.[98] In 2013, the annual power demand ended up as 246,356 GWh growing around 1.7% comparing to previous year.[99] As of year 2014, Electricity Generation Co. forecasts that there will be an annual increase by 5.3% - 6.1% until 2022, when the annual demand will reach 418,590 GWh at the end.[100]

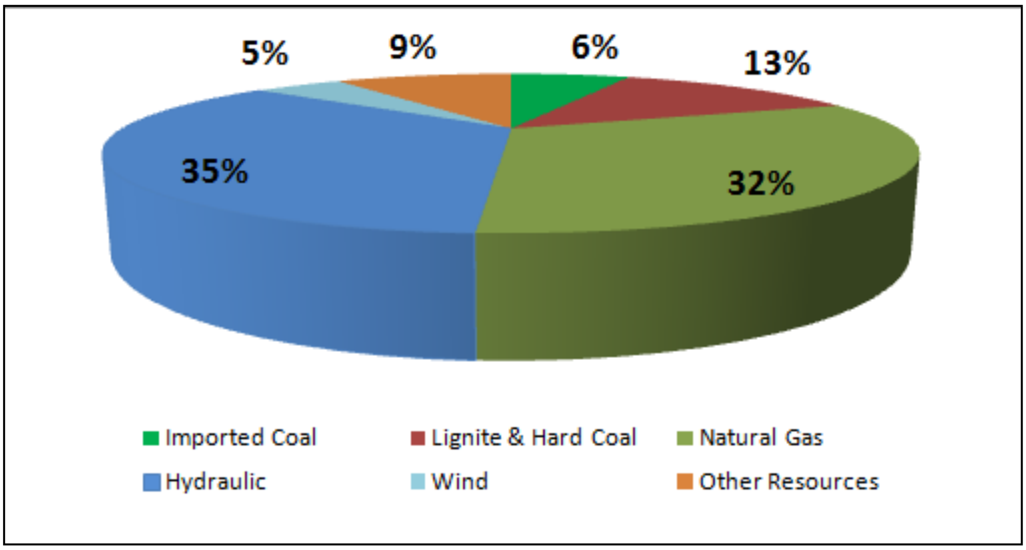

Figure 1.11: Shares of resources in total installed capacity of Turkish electricity market in 2013

The increasing trend of annual demand has consequently increased the installed capacity of power plants in Turkey. The installed capacity has increased by around 80%

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97 "2012 Yılı Genel Enerji Dengesi", http://www.enerji.gov.tr/EKLENTI_VIEW/index.php/raporlar/raporVeriGir/72222/2, accessed on 05.07.2014.

98 *Türkiye Elektrik Enerjisi 5 Yıllık Üretim Kapasite Projeksiyonu*, Türkiye Elektrik İletim A.Ş., 2013, p.6.

99 http://www.teias.gov.tr/YukTevziRaporlari.aspx#, accessed on 06.07.2014.

100 *Türkiye Elektrik Enerjisi 5 Yıllık Üretim Kapasite Projeksiyonu*, Türkiye Elektrik İletim A.Ş., 2013, p.17.

in 2003 – 2013 due to the necessity of satisfying the growing demand.[101] As of June 30th 2014, Turkey has an installed capacity of 66.632 MW, which has also risen by 4% comparing to the beginning of 2013.[102] Combining domestic and imported ones, coal-fired power plants form around 19% of the installed capacity according to the most up-to-date realization.

Speaking of imported coal – fired power plants, six plants[103], currently operational installed capacity of which varies from 190 MW to 1390 MW, form the total installed capacity corresponding to 4262 MW.[104] Apart from the imported coal, all lignite – fired power plants currently online in Turkey except Kangal and Seyitomer thermal plants (total capacity of 1057 MW), which were privatized in 2013[105], are owned by state. However, the government decided to privatize four more coal – fired power plants with a total capacity of 1980 MW[106], three of which are run by lignite.[107]

In addition to demand and the installed capacity, power generation has naturally increased. Annual generation values have increased by approximately 70% between years of 2003 and 2013, when the actual annual generation ended up as 240.154 GWh.[108] Coal has a contribution of 26.3% in total generation Turkey for 2013, nevertheless it is observed that the share of coal in generation has never been less than

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[101] "Elektrik Santrallerinin Toplam Kurulu Gücü, Brüt Üretimi, Net Elektrik Tüketimi", TUİK, http://tuik.gov.tr/PreTablo.do?alt_id=1029, accessed on 05.07.2014.

[102] "Kurulu Güç", Türkiye Elektrik İletişim A.Ş., http://www.teias.gov.tr/YukTevziRaporlari.aspx#, accessed on 05.07.2014.

[103] *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.32.

[104] "Kurulu Güç", Türkiye Elektrik İletişim A.Ş., http://www.teias.gov.tr/YukTevziRaporlari.aspx#, accessed on 05.07.2014.

[105] "Elektrik Üretim A.Ş.ye Ait Elektrik Üretim Santrallerinin Özelleştirme Çalışmaları", Özelleştirme İdaresi Başkanlığı, http://www.oib.gov.tr/portfoy/elek_uretim_santralleri.htm, accessed on 04.07.2014.

[106] *"Kömür Sektör Raporu (Linyit)"* Ministry of Energy & Natural Resources, 2013, p.28.

[107] "İhale Süreci Devam Eden Elektrik Üretim Santralleri" , Özelleştirme İdaresi Başkanlığı, http://www.oib.gov.tr/portfoy/elek_uretim_santralleri.htm, accessed on 04.07.2014.

[108] "2013 Yılı İşletme Faaliyetleri Raporu", Türkiye Elektrik İletişim A.Ş., (http://www.teias.gov.tr/yukdagitim/yillik_menu.htm, accessed on 04.07.2014.

around 23% since 1970.[109] Although coal-based generation does not have a tendency to increase, it retains a share of about 23-30%.

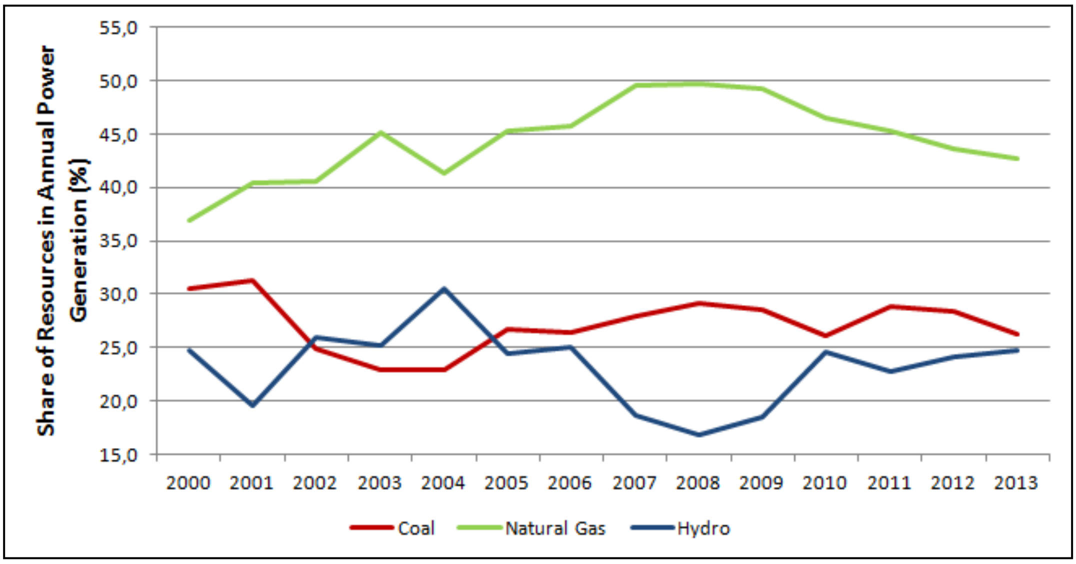

Figure 1.12: Share of Resources in Annual Power Generation in 2000 – 2013.[110]

Beyond the evaluation of resource-based generation, coal consumption in annual generation with respect to coal types have also different trends. While hard coal consumption in power generation more than doubled in the period of 2006 – 2012, lignite consumption had a much more stable trend varying between 50 million tonnes and 65 million tonnes on an annual basis.[111] The reason for the difference between these consumption trends might be explained with the fact that when the hydro – power plants are ready enough to satisfy the demand (e.g. accumulating sufficient level of water in order to generate power), the load dispatching mechanisms have an inclination to decrease the level of generation by thermal resources. Moreover, all of the imported coal-fired power plants have become online in the power grid since the beginning of 2000s, while more than half of lignite-fired power plants built during 1980s.[112] The establishment of plants using imported coal for the last decade has consequently

109 "Elektrik Santrallerinin Toplam Kurulu Gücü, Brüt Üretimi, Net Elektrik Tüketimi", TUİK, http://tuik.gov.tr/PreTablo.do?alt_id=1029, accessed on 05.07.2014.

110 "Enerji Kaynaklarına Göre Elektrik Enerjisi Üretimi ve Payları", TUİK, http://tuik.gov.tr/PreTablo.do?alt_id=1029, accessed on 07.07.2014.

111 "2006 – 2012 Yılı Genel Enerji Dengesi (Orjinal Birimler)", http://www.enerji.gov.tr/index.php?dil=tr&sf=webpages&b=y_istatistik&bn=244&hn=244&id=398, accessed on 07.07.2014.

112 *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.30 – 31.

boosted the usage of imported coal in electricity market and adding this to the hydro – power plants effect mentioned above, led lignite consumption to have a stable trend regardless of having high levels of consumption.

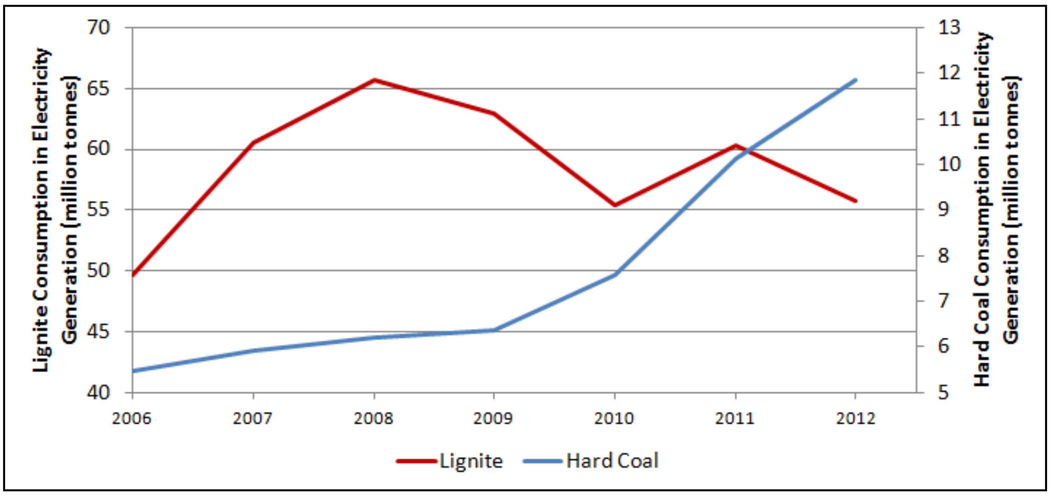

Figure 1.13: Consumption Levels of Lignite & Hard Coal in Electricity Generation in 2006 – 2012.[113]

According to the latest coal industry analysis report of Ministry of Energy and Natural Resources, there are 21 plants with 9500 MW installed capacity that are either in process of investment or being planned as a project.[114] Specifically 11 of these coal-fired power plants with a consolidated installed capacity of 5267.5 MW have already been entitled to get a generation license in order to get involved in the electricity grid.[115] In the light of these developments, it is apparently possible that coal is one of the main resources that Turkish power market has been relying on, although there might be seasonal declines in the usage of coal rarely.

113 "2006 – 2012 Yılı Genel Enerji Dengesi (Orjinal Birimler)", http://www.enerji.gov.tr/index.php?dil=tr&sf=webpages&b=y_istatistik&bn=244&hn=244&id=398, accesses on 25.06.2014.

114 *Kömür Sektör Raporu (Linyit),* Ministry of Energy & Natural Resources, 2013, p.30.

115 "Elektrik Piyasası Üretim Lisansları", Enerji Piyasası Düzenleme Kurulu, http://lisans.epdk.org.tr/epvys-web/faces/pages/lisans/elektrikUretim/elektrikUretimOzetSorgula.xhtml, accessed on 20.06.2014.

3. 'The Return of Coal' in the Turkish Electricity Market

It has been introduced in the previous section that the growing electricity demand in Turkey obviously entails the growing rates of generation and coal is one of the main resources for the expected increase in energy supply. As the necessity of generation has been rising, production levels of coal, along with the production or supply of other resources, has been naturally increasing for years. Beyond the growth of production rates, specifically, a strong inclination towards coal in the electricity generation has been visible for the last few years. Even though it has not been officially declared as a specific coal policy which has been prioritized comparing to other resources, it is not too difficult to grasp that Turkish government has adopted a new policy, called in this thesis as 'the return of coal'.

Ministry of Energy & Natural Resources clarifies the primary goal of Turkish government in terms of coal as complete utilization of all domestic coal mines until 2023 with additional oil searching and drilling operations in the scope of diminishing negative effects of external dependence in energy.[116] The effort of reduction in foreign dependency had actually been on the agenda of both 59th and 60th governments in 2002-2011, however statements about energy supply security and deregulation of the market were quite ambiguous.[117] Since the 61st government (2011), concerns about the current account deficit regarding the external dependence has been emphasized and the main purpose has been determined as increasing the share of domestic resources together with the renewable energy facilities.[118]

Ministry of Energy and Natural Resources has a plan of enhancing the share of coal in electricity generation by up to 42% with a 30% of installed capacity targeted for 2023 in order to diminish the negative effects of natural gas due to long – term interstate gas contracts.[119] Therefore, in addition to 11 explored coal basins in 2006-2014, the

[116] "2013 Faaliyet Raporu, Ministry of Energy and Natural Resources, 2014, p.87 – 88.

[117] Cengiz Güneş, "Linyit Kömürü Sahalarının Ekonomiye Kazandırılması" Deloitte, 2012, p.12.

[118] Ibid.

[119] "Kömürden elektrik üretimi yatırımlarıyla doğalgaz faturası 14 milyar dolar azalacak", 2014 http://enerjienstitusu.com/2014/04/17/komurden-elektrik-uretimi-yatirimlariyla-dogalgaz-faturasi-14-milyar-dolar-azalacak/, accessed on 10.07.2014.

governmental institutions have used this strong incentive to explore new coal basins in 4 different regions aiming at cutting natural gas import costs by $12 billion on an annual basis.[120] Furthermore, the ministry has also announced that 165 new coal sites are going to be opened to searching & drilling operations with tender.[121]

In addition to the statements, the government officials and heads of relevant institutions share pro – coal opinions in the context of domestic advantages of energy supply security. Mustafa Aktaş, incumbent president of Turkish Coal Enterprises, states in his own article that sustainable energy policies and energy supply security form the base of national security and coal should be evaluated as the most indispensible resource than any other fossil fuels in the scope of 2023 vision mentioned above.[122] Moreover, Mücahit Fındıklı, Head of Commission of Industry, Trade, Energy, Natural Resources and IT in Grand National Assembly, states that subsidizing coal would trigger the energy supply to satisfy demand without any dependence; thus the domestic coal – fired power plants should be supported along with nuclear energy.[123] Not only the government officials, but also business authorities discuss about the future of coal with similar remarks. Turgay Ciner, president of the Ciner Group which contains significant companies in mining and power industry, emphasized that coal reserves in Turkey are

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[120] "Türkiye, bu yıl 4 bölgede yapacağı aramalarla kömür rezervlerini artırmayı amaçlıyor", 2014, (http://www.dunya.com/komur-aramaya-tam-gaz-devam-220790h.htm, accessed on 10.07.2014.

[121] "165 maden sahası aramalara açılıyor", 2014, http://enerjigunlugu.net/165-adet-maden-sahasi-aramalara-aciliyor_8946.html#.U71nZPmSySp, accessed on 10.07.2014.

[122] "Türkiye'de Kömür Madenciliği ve Enerjideki Rolü" , 2011, http://bilimakademisi.org/wp-content/uploads/2014/05/T%C3%9CRK%C4%B0YE%E2%80%99DE-K%C3%96M%C3%9CR-MADENC%C4%B0L%C4%B0%C4%9E%C4%B0-VE-ENERJ%C4%B0DEK%C4%B0-ROL%C3%9C.pdf, accessed on 10.07.2014.

[123] "Fındıklı: Kömüre teşvik enerji üretimini etkiler", 2013, http://www.enerjigunlugu.net/findikli:-komure-tesvik-enerji-uretimini-tetikler_2320.html?Pagenum1=118&Pagenum=118&id=2320&yid=#.U71xE_mSySq, accessed on 10.07.2014.

sufficient to meet electricity demand and the government should promote pro – coal policies in Turkish electricity market.[124]

In order to reach long – term objectives of developing coal-based generation, the government introduced a set of incentives. In the context of "regional and industrial support" policies, the government subsidizes the upcoming projects with tax reduction, value added tax reduction, exemption of tariffs and allocation of land together with positive incentives on interest rates.[125] Parallel with the subsidies, the Turkish government has also been facilitating the private investment process. In addition to privatized coal – fired power plants mentioned in "2.c. Electricity Generation by Coal in Turkey", a contract of 10-12 billion dollars was signed with the United Arab Emirates for Afşin Elbistan coal site, the expected production relying on which is 85 million tonnes of coal annually, within the scope of 2023 vision that has a necessity of 42 billion dollars of investment.[126] The incentive for new investments also draws an attention of new market players. Various investors applied for license of new coal-fired power plant projects, a total installed capacity more than 11,000 MW in 2013.[127]

Apart from the return of coal case, incentives for renewable energy are also included in government's long-term energy objective. What is more, government's program called Mechanism of Supporting Renewable Energy Sources[128], which enables the renewable power plants to sell the generated electricity to government without facing any market risk, might be evaluated as a policy more protective than a set of policies called return of coal in this thesis. However, it is quite hard to approve that renewable facilities are reliable enough to satisfy high portions of Turkish electricity demand by phasing out the fossil fuels. Adverse natural conditions such as draughts, would affect the generation

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[124] "Ciner: 'Devlet kömürden elektrik üretimini teşvik etmeli'", 2013, http://enerjienstitusu.com/2013/12/04/ciner-devlet-komurden-elektrik-uretimini-tesvik-etmeli/, accessed on 10.07.2014.

[125] "2009/15099 – Yatırımlarda Devlet Yardımları Hakkında Karar", 2009, http://www.resmigazete.gov.tr/eskiler/2009/07/20090716-5.html, accessed on 10.07.2014.

[126] "Elektrik üretiminde ibre kömüre kayıyor", 2014, http://www.dunya.com/elektrik-uretiminde-ibre-komure-kayiyor-227478h.htm, accessed on 10.07.2014.

[127] "Yatırımcılardan Kömür Santrallerine Yoğun İlgi", 2013, http://www.enerjigunlugu.net/yatirimcilardan-komur-santrallerine-yogun-ilgi_3764.html#.U72Ay_mSySq, accessed on 10.07.2014.

[128] Yenilenebilir Enerji Kaynakları Destekleme Mekanizması (YEKDEM)

rates together with the efficiencies of hydro power plants. Due to the draught that took place during the first 3 months in 2014, for instance, generation values in hydro power plants had a significant fall, which was offset by coal – fired power plants with an increase by around 4% in generation.[129] It is up to wind to blow to generate electricity from a wind power plant, for instance, as well as a hydro – power plant, for which generation depends extremely on precipitation. Therefore, renewable sources are seen as a remedy in terms of easing the burden for countries which have high levels of power demand.[130]

[129] "Kuraklık HES'leri vurunca termik santrallere yüklendik", 2014, http://www.hurriyet.com.tr/ekonomi/26427542.asp, accessed on 10.07.2014.

[130] "South Africa: New power generation", 2013, *Financial Times,* p.3.

Conclusion

Among the fossil fuels, coal has an importance in terms of energy supply and it is classified in international standards according to its physical and chemical features. Roughly, it might be said that coal has two types, which are hard coal with high calorific value and high carbon content (hence the efficiency) and brown coal with the features vice versa. Coal reserves are more homogeneously dispersed all over the world, which might be counted as an advantage, than the other fossil fuel reserves such as oil reserves, which tends to consolidate in a specific region. However, few countries with the largest reserves still dominate the global reserves of both coal types. Although the United States has the largest coal reserves in both types, China dominates the both global production and consumption. Besides China and India, two countries relying on coal significantly, contribute to global growth of coal in both production and consumption in spite of the fact that Europe has been reducing the usage of coal. Moreover, specifically for coal-fired power generation, Asian countries are the largest power producers from lignite as the region, where hard coal is used the most for power generation is North America. What is more, the Asian countries have been planning to increase share of coal in electricity generation by building more coal – fired power plants. High levels of power demand with respect to high population lead specifically China and India to rely on coal more, while Europe is able to set strict targets to focus on renewable sources.

Lignite reserves are apparently much more abundant than hard coal reserves in Turkey. While the hard coal reserves completely belong to the state, the lignite reserves are shared out among various governmental institutions and private companies. Each coal deposit has different chemical features in terms of carbon content, calorific values and other substances. On the other hand, it is possible to state that lignite sites owned by private sector have the higher quality than the sites owned by public sector.

Production and consumption of coal have generally increased for the last decade and royalty model in state-owned coal mines have facilitated to increase production rates in order to satisfy demand. Although Turkey has enough lignite mines to meet the demand, the same thing could not be approved for the hard coal. Therefore, Turkey has been importing a significant amount of hard coal at a growing trend. Both lignite and hard coal are primarily used to generate electricity apart from heat and industrial purposes.

Specifically for power generation, growing electricity demand naturally makes any related variable grow such as the total installed capacity and amount of generated electricity. Among the other power resources, coal has an important share both in the installed capacity and daily & annual amount of generation. Furthermore, number of licensed coal-fired power plant projects are remarkable, which obviously indicates that coal will persist to be the one of main resources of electricity in Turkey.

The growth of coal based electricity generation has a rationale for Turkey regarding the alleviation of negative effects of external dependency. It is argued that as the state and market would go towards domestic resources for energy supply, Turkey might be less dependent on import of energy resources, which would be an advantage in terms of current account deficit reduction. Although the government has not proclaimed a specific policy, a set of statements and incentives for private sector indicates the inclination to coal, which is defined as 'the return to coal'. In addition to the explanations within the scope of Turkey's 2023 vision, strong evidences such as remarks of government officials along with strong incentives determined by decree laws form a basis for the return of coal. Moreover, these developments have made investors much more eager to get involved in power generation with various projects, specifically with coal-fired power plants. Even though there are incentives for development of renewable energy sources in the near future, an idea that the renewable might contribute to meet the much larger portion of demand is not realistic due to the natural uncertainties. Therefore, the return of coal comes to the fore among the other set of policies introduced by the Turkish state.

Chapter 2

An Economic Debate of the Return of Coal

Introduction

Coal is relatively abundant in terms of reserves in Turkey compared to other fossil fuels that have the highest share in electricity generation. Although hard coal has been imported at significant levels, lignite reserves in Turkey are quite able to make the market rely on coal. However, around a half of power demand is satisfied by utilizing natural gas, all of which is imported with certain risks.

This chapter aims at an economic evaluation of the return of coal case. As long as natural gas is predominantly used for power generation carrying certain risks, the economic aspects of the return of coal case are discussed with respect to these threats. Generation levels of hydro power plants depend heavily on natural conditions; therefore these plants are not taken into consideration.

This chapter underlines the geopolitical importance of the return of coal case by pointing out vulnerable position of natural gas in terms of a long–term strategy. On the other hand, the geopolitical debate is not clearly specified, because the economic and geopolitical aspects are quite interlaced such that the economic advantages naturally leads to a much stronger geopolitical position.

The evaluation starts with a discussion of cost effectiveness. Focusing on power generation, a comparison regarding the total costs including investment, operation & maintenance and unit fuel cost is made. Then the unit costs are specified, which depicts that coal is much cheaper than natural gas. In light of these discussions, current Turkish outlook is explained.

Turkey is almost completely dependent on external resources in terms of natural gas, which clearly creates vulnerability. The vulnerability is caused by three disadvantages, which are high unit prices of import, heavy contract obligations and an extreme external dependency in the gas supply. Coal as a much less costly option is emphasized to have an ability to certainly diminish the impacts of threats carried by gas. Therefore, first, production cost of coal and import cost of gas are compared with each other.

Afterwards, the unit costs of electricity generation depending on both coal and natural gas are discussed. Imported coal is also taken into consideration. Along with the costs and prices for power generation stated in this chapter, imported coal is underlined to be still a better option than too much reliance on natural gas

The return of coal case significantly contributes to maintain a predictable electricity market by minimizing the risk of price fluctuations. Apart from the cost effectiveness, the second economic aspect this chapter focuses on is the impact of coal on the power market. First of all, privatization process and current dynamics of Turkish electricity market are introduced.. Then, certain risks depending on natural gas domination, which triggered several instances of energy crises in Turkey, are identified. Capacity constraint of imported gas is the first one among these risks, while locational asymmetry of installed capacity is the second threat which may cause a crisis. External problems such as technical issues depending on exporter countries are the last type of threat for the market.

Hydro power plants (HPP) are perceived as a mechanism to intervene the market prices in case of crisis. Having a negligible unit cost, offers from HPPs are able to repress the high prices downwards. On the other hand, disadvantages of HPPs are explained: a drought would block the generation capacity at least to a certain extent.

All of risks having negative impact on the market might be overcome by a more extensive use of coal, which is comprehensively explained. Eventually, the return of coal case is stated as a possible solution to certain issues relevant with economy.

1. Coal as a Cost Effective Strategy

Fossil fuels have been hauling Turkish electricity market for years in terms of meeting the demand as comprehensively discussed in the previous chapter. In spite of remarkable efforts put by Turkish government, which aims at promoting renewable sources – based plants in generation, share of fossil fuels has never dropped below 64% since 2000.[131] The case is valid not only for Turkey, but also for various other countries, which emphasize the importance of renewable sources more. Germany, for instance, declared a strict policy to phase out nuclear energy by increasing the share of renewable based generation.[132] Share of coal to satisfy the demand in Germany, however, ended up as 45.5% in 2013 increasing by 1.5%, while the share of renewable sources grew by less than 1% between 2012 and 2013 ending up as 23.4%. Renewable facilities such as wind power plants or solar power plants depend heavily on climate conditions. Even though an installed capacity of renewable sources surpasses the generation capacity based on fossil fuels, it is impossible to expect a wind power plant to generate electricity continuously due to the fact that wind may not blow. Therefore, there is a categorical difference between fossil fuels and renewable sources in terms of availability to power generation. Thus, comparing the fossil fuels inter se provides a much more reliable economic evaluation for energy supply. These fuels are primarily coal and natural gas for the Turkish power market.

The latest studies simply indicate that either production or import costs of coal are relatively cheaper than other fossil fuels. Although the costs of electricity (including setup and investment cost) depending on different fuels have a tendency to be close to each other, coal seems to be the most feasible choice economically in the long run. Specifically for the comparison between coal and natural gas, total annual costs including fuel, construction, operations & maintenance converge to each other at the first sight. Investment costs of coal-fired power plants are generally double the investment costs of natural gas based power plants for 300 MW and 800 MW

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[131] "Enerji Kaynaklarına Göre Elektrik Enerjisi Üretimi ve Payları", TUİK, http://tuik.gov.tr/PreTablo.do?alt_id=1029, accessed on 07.07.2014.
[132] "Germany's clean energy drive fails to curb 'dirty' coal power", 07.01.2014, http://www.dw.de/germanys-clean-energy-drive-fails-to-curb-dirty-coal-power/a-17345796, accessed on 12.07.2014.

capacity.[133] However, even though the annualized cost of a conventional coal-fired power plant is said to be around $63/MWh (in 2008 $), while the same cost for a natural gas plant is approximately $62/MWh the unit fuel cost of coal is roughly three times less than the fuel cost of natural gas.[134]

Coal has a competitive advantage comparing to natural gas in terms of unit fuel costs. In the United States, the cost of steam coal to generate electricity ended up as $2.37 per million Btu for March 2014, while the same cost for natural gas was $6 per million Btu.[135] Moreover, forecasts also tell that coal will be remarkably cheaper than the natural gas in the long run. In period 2014 – 2024, the maximum cost of steam coal production for Greenfield projects all over the world is not expected to exceed around $90/tonne.[136] The forecasted cost trends of coal and natural gas in power generation between 2020 and 2040 are demonstrated in the figure below:

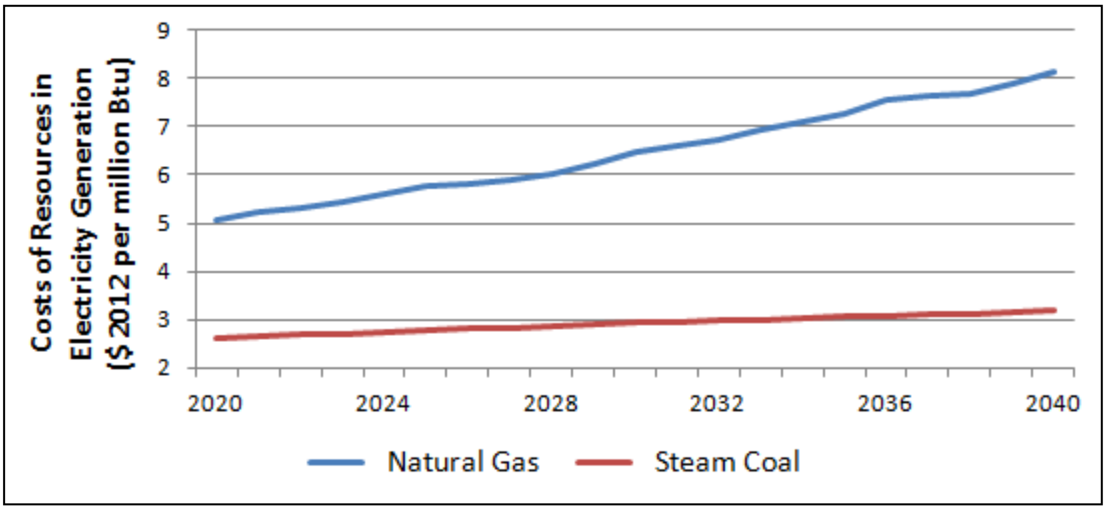

Figure 2.1: Forecasted unit costs of steam coal and natural gas in electricity generation in 2020 – 2040.[137]

[133] Nejat Tamzok, Selçuk Yılmaz, Çetin Koçak, "Afşin Elbistan Linyit Rezervlerinin Elektrik Üretimi Bakımından Değeri ve İzlenmesi Gereken Politikalar", 2009, p.8, http://enerjienstitusu.com/medya/afsin.elbistan.linyit.rezerv.elektrik.uretim.deger_.politika.cetin_.kocak_.pdf

[134] Stan Kaplan, "Power Plants: Characteristics and Cost" CRS Report for Congress, 2008, p.39.

[135] EIA, Electricity Data Browser http://www.eia.gov/electricity/data/browser/#/topic/15?agg=2,0,1&fuel=vtvo&geo=g&sec=g&freq=M&start=200801&end=201404&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0 , 2014, accessed on 10.07.2014.

[136] "World Energy Investment Outlook" IEA Press:2014, p. 83.

[137] "Electricity Supply, Disposition, Prices and Emissions" EIA, 2014, http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014&subject=0-

Having high levels of costs, natural gas means financial vulnerability for Turkey, too. In addition to being 75% of Turkish primary energy resource, a little more than 98% of the natural gas annually consumed in Turkey is imported.[138] 83% of annual import is done via pipelines and Russian Federation has the lion share of supplying around 58% of total import.[139] Iran and Azerbaijan are other countries exporting natural gas to Turkey via pipelines, having 18% and 7% share of total import respectively. The import costs from these countries are significantly high as monitored in the figure below:

Country	2012 (price $/1000m^3$)	2013 (price $/1000m^3$)	Discount % in 2013
Russia (Western Line)	446	429	3.81
Russia (Blue Stream)	445	428	3.82
Azerbaijan	354	349	1.41
Iran	530	507	4.34

Figure 2.2: Natural Gas Prices via Pipeline for Turkey and Annual Discounts.[140]

Natural gas is a costly option because of not only its excessive import costs, but also the forms of contracts signed between the exporting countries. Although private companies are involved in Turkish gas market, the government predominantly controls the market with its company named Petroleum Pipeline Corporation (PPC)[141]. More than 92% of gas import via pipeline is carried out by PPC, which also has a share of 91% in total wholesale trade in Turkish gas market.[142] Type of contracts signed between PPC on behalf of Turkish government and the exporting countries is defined as 'take-or-pay' (ToP) contracts, which incur an extra cost as fine to an importing country in case of not intaking a certain amount of gas committed before. Specifically, take-or-pay obligations lead to a negative financial costs mostly due to demand uncertainty. In 2008 – 2009, PPC also had to pay for unused quantity in accordance with its take-or-pay commitment because of decline in gas consumption due to the economic crisis and high hydro-based

AEO2014&table=8-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a accessed on 10.07.2014.

[138] "Doğalgaz Piyasası Sektör Raporu" Ministry of Energy & Natural Resources, 2013, p.30.

[139] Ibid., p.23.

[140] "Natural Gas in the Turkish Domestic Energy Market" The Oxford Institute for Energy Studies, 2014, p.29

[141] Boru Hatları İle Petrol Taşıma Anonim Şirketi (BOTAŞ).

[142] "Doğalgaz Piyasası Sektör Raporu" Ministry of Energy & Natural Resources, 2013, p.24 & 33.

power generation values which make gas-based generation unnecessary.[143] Therefore, Turkey paid a take-or-pay fine of $5 billion, half of which was paid to Russia.[144] Apart from the demand uncertainty, Turkey also paid ToP fines due to problems of infrastructure. After the announcement that take-or-pay bill of Turkey in 2012 was around $1.6 billion, Turkey also paid $343 million to Azerbaijan due to technical inabilities to take gas via pipelines.[145]

Natural gas has been a primary issue of geopolitical debates on Turkey since its share gained importance on energy supply. Apart from ToP contracts and excessive intake costs of gas, high level of external dependency in order to meet the high demand due to heat and power generation have turned the natural gas into a geopolitical vulnerability. What is more, three countries in Caspian region play a major role (around 83%) in gas trade of Turkey and this fact apparently deepens the vulnerability. Turkey has persistently been announcing its objective as prevention of the unrestrained progress of external dependency in terms of energy supply, as depicted in " 'The Return of Coal' in Turkish Electricity Market" section in the first chapter of this thesis.

The return of coal case gains importance right at this very specific point. On the one hand, natural gas causes huge import bills along with ToP obligations that might lead to cost increases for electricity market, which is an import -oriented strategy extremely. On the other hand, coal reserves of Turkey are abundant so that coal is available to generate electricity at a much lower cost than natural gas. In other words, more investments and incentives for coal to get the lion's share of power generation in Turkey are quite cost effective strategies to alleviate the negative effects of gas import such as high and volatile prices together with long-term detrimental contracts. Focusing on the Afşin Elbistan coal field, which is accepted as one of the largest coal reserves in Turkey, one study pointed out the unit costs of domestically supplied coal types is far cheaper than predominantly imported natural gas. Even though these coal types are ranked among the lowest quality, the difference between the costs is still apparent.

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[143] "Natural Gas in the Turkish Domestic Energy Market" The Oxford Institute for Energy Studies, 2014, p.28.

[144] "Untangling Turkey's Gas Pricing Knot", 2014, http://www.naturalgaseurope.com/high-turkish-energy-imports-iran-russia accessed on 13.07. 2013.

[145] "Ucuz gazı çekemedik 343 milyon $ ceza ödedik!", 2014, http://www.gazetevatan.com/ucuz-gazi-cekemedik-343-milyon---ceza-odedik--603534-ekonomi/ accessed on 13.07.2014.

Findings provided by the study indicate that a tonne of coal mined from Afşin Elbistan coal field is three and a half times less costly than imported natural gas with the same calorific amount.[146] Therefore, the study implies the coal production to supply for a 1000 MW of power plant is highly likely to save Turkey from an obligation to pay a $300 million per year bill for natural gas import.[147]

The contrasting cost structure of coal and natural gas is reflected in the Turkish electricity market. It is hard for Turkey to tell that neither institutions nor the market players are transparent enough to monitor the actual costs. In fact, private companies naturally choose to keep these data discreet in order to avoid any risks of competition. However, I had an opportunity to be informed about the costs[148] of power plants by a senior analyst at an energy consulting company with a quite large portfolio. The analyst who demands confidentiality about his identity clarified that depending on the supplier and location, unit costs of power plants have certain ranges. Among the market players, public or private, the minimum cost of a natural gas plant is around 130 TL/MWh, but vast majority of these plants have a cost of 180 TL/MWh. The unit costs regress to the level of 50 – 70 TL/MWh for lignite-fired power plants; however the cost might rise to 90 – 100 TL/MWh in very few cases. In addition to lignite, imported coal plants generate electricity at around 90 TL/MWh, which is also cheap enough comparing to the natural gas.

Importing coal and expanding an installed capacity depending on the imported coal is not as financially harmful as relying largely on natural gas. There is a huge gap between transportation costs, which directly affect the import price formation and coal stands as more feasible option. Moreover, imported coal has an advantage in terms of not having heavy obligations unlike the gas contracts. Although an inclination to lignite is more economically viable, imported coal plants generate power at a relatively lower cost than gas-fired power plants as well. The figure below demonstrates the price trend of imported coal for power generation:

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[146] Nejat Tamzok, Selçuk Yılmaz, Çetin Koçak, "Afşin Elbistan Linyit Rezervlerinin Elektrik Üretimi Bakımından Değeri ve İzlenmesi Gereken Politikalar", 2009, p.6, http://enerjienstitusu.com/medya/afsin.elbistan.linyit.rezerv.elektrik.uretim.deger_.politika.cetin_.kocak_.pdf, accessed on 13.07. 2014.
[147] Ibid.
[148] These costs does not include initial investment costs of a power plant, such as the cost of construction.

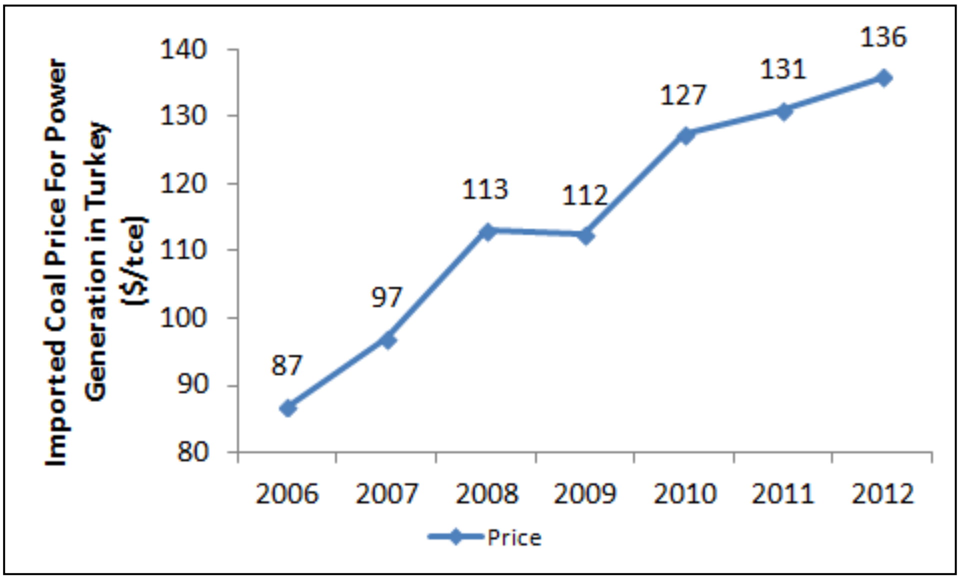

Figure 2.3: Imported Coal Prices for Power Generation in Turkey in 2006 – 2012 ($/tce[149]).[150]

In the light of Turkish power generation dynamics, coal comes to the forefront comparing to natural gas. Economic aspect has a share for coal to shine out among the other fossil fuels indubitably. In addition to produce coal in domestic sites at a low cost, reliance on imported coal is also more financially advantageous considering transportation. These clear benefits, give a chance to alleviate the negative effects of long-term liabilities depending on the natural gas import. Thus, less gas import will contribute the objectives of government to eliminate external dependency in energy security, which will certainly strengthen the geopolitical status of Turkey. On the other hand, evaluation based on the cost effectiveness is not solely enough to comprehend the return of coal case. Impacts on power market of coal are quite crucial to grasp the possible gains in economy and geopolitics.

[149] Tonne coal equivalent.
[150] "Taşkömürü Sektör Raporu" Türkiye Taşkömürü Kurumu, 2014, p.32.

2. Market Impact of Coal

a. Electricity Market in Turkey

It is fruitful to understand the Turkish power market itself in order to grasp the impacts of coal on the market. There were slight efforts for private participation during 1980s such as enacting a law (Law No. 3096) in 1984 to enable private investors to get involved in the power market with various business models.[151] However, the actual progress of deregulation of the market begun with Law No. 4628, named as "Electricity Market Law" that segregated the generation, transmission and distribution phases of electricity supply under three different institutions.[152] As of 2004, Balancing and Settlement Regulations[153] was determined in order to optimize the generation schedule and facilitate the power grid.[154] During the implementation of this system, prices of base load electricity was stable and constant for a long time, while generation costs were increasing as a challenging fact for producers[155]. After a transition process in order to optimize the newly – emerging market, a new system is determined called as "Day Ahead Market"[156] was launched in 2009.

In the regulation document, the Day Ahead Market (DAM) is described as a retail power market operated by a system administrator, which aims at managing sales & procurement process of generation and demand a day ahead.[157] The system operator, which is called as Market Financial Settlement Center[158] (MFSC), gets the generation & demand schedule together with the generation prices for the next day from producers & consumers. Therefore, base load power price for the next day is determined on an hourly basis with respect to offers of sales and procurement. Power pricing mechanism

[151] Erkan Erdoğdu, "Regulatory Reform in Turkish Energy Industry: An analysis" Munich Personal RePEc Archive, 2004, p.4.
[152] "Elektrik Piyasası Kanunu", 2001, http://www.tbmm.gov.tr/kanunlar/k4628.html accessed on 15.07.2014.
[153] Dengeleme ve Uzlaştırma Yönetmeliği.
[154] "Dengeleme ve Uzlaştırma Yönetmeliğinin İlk Hali", 2004, http://www.epdk.org.tr/index.php/elektrik-piyasasi/mevzuat?id=36 accessed on 15.07.2014.
[155] "Türkiye Elektrik Piyasası'nda Elektrik Ticareti", Accenture, 2013, p.5.
[156] Gün Öncesi Piyasası.
[157] "Elektrik Piyasası Dengeleme ve Uzlaştırma Yönetmeliği", 2009, http://www.epdk.org.tr/index.php/elektrik-piyasasi/mevzuat?id=36 accessed on 15.07.2014.
[158] Piyasa Mali Uzlaştırma Merkezi (PMUM).

is conducted according to a model called “Merit Order.”[159] The Merit Order model is processed as ordering the cheapest offer of generation to the most expensive one until the forecasted demand for the next day is matched. Then the base load price of electricity, also called as System Day Ahead Price[160] or Market Exchange Price[161], is determined for 24 hours.

The most unpredictable part of the power market is the fact that demand is uncertain. Although the demand is met by matching the sales and procurement via Day Ahead Market, it is impossible to know the hourly demand of the next day. In addition to the Day Ahead Market, therefore, Balancing Power Market[162] has also been introduced. The Balancing Power Market is defined as an organized retail electricity market which aims at offsetting the supply and demand by evaluating the generation & procurement offers within the day.[163] If demand is not matched with generation plan approved by the system operator in the context of Day Ahead Market (a day ago), offers from producers for the Balancing Power Market are considered by the operator. After the evaluation process, the operator determines the price and generation quantity for each chosen producer in each hour. In case of excessive supply determined a day ago, the operator sends orders to the chosen producers not to produce at a certain price and the balance in the market is provided. Although the generation prices depend on each power plant, the hourly averages of these prices, called as System Marginal Price[164], are monitored together with the Market Exchange Price. A sample demonstration of both Day Ahead Market prices and Balancing Power Market prices for a certain day is shown in the figure below:

[159] “Türkiye Elektrik Piyasası’nda Elektrik Ticareti”, Accenture, 2013, p.5.
[160] Sistem Gün Öncesi Fiyatı (SGÖF).
[161] Piyasa Takas Fiyatı (PTF).
[162] Dengeleme Güç Piyasası (DGP).
[163] “Elektrik Piyasası Dengeleme ve Uzlaştırma Yönetmeliği”, 2009, http://www.epdk.org.tr/index.php/elektrik-piyasasi/mevzuat?id=36 accessed on 15.07.2014.
[164] Sistem Marjinal Fiyatı (SMF).

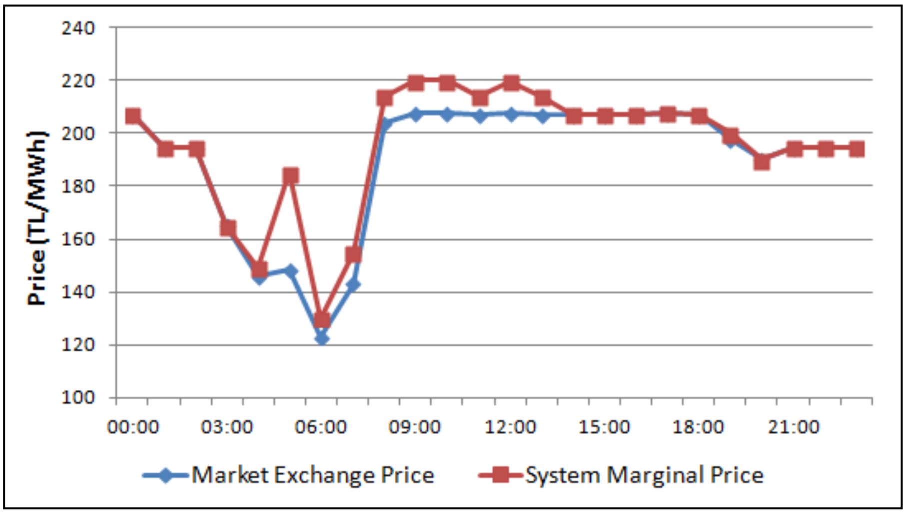

Figure 2.4: Hourly Market Exchange Prices and System Marginal Prices for July 16, 2014.[165]

There are many factors directly affecting the price formation after the privatization of electricity market. As it is depicted on the framework above, power producers offer to generate electricity at a certain price for each time interval. The settlement center determines an hourly price depending on all offers. Generation costs based on various fuels and sources is apparently one of these factors. Apart from the cost issues, the electricity market is influenced by the factors, which is beneficial to be discussed along with the return of coal case.

b. A Solution For a Predictable Market: Coal

The predictability of power market is quite important as well as the cost effectiveness for both producers and retailers. An uncertain trend of price would extremely harm the market players at each phase. An abrupt rise in prices, for instance, creates a costly situation for retailers, while producers take a financial bath in case of suddenly decreased prices. Moreover, fluctuation in the actual prices complicates the process of accurate forecasting of the market for all players. Therefore, all players simply demand a predictable market, which is developing with stability, for a win-win case.

The dynamics of price formation obviously underlies a stable power market with a predictable price trend, because the prices are determined by the interaction between predicted demand and the daily offers made by market players. One of the factors on price formation is cost scheme of a producer as mentioned above. Cost of base load

[165] "Genel Raporlar" PMUM, 2014, https://rapor.pmum.gov.tr/rapor/xhtml/ptfSmfListeleme.xhtml accessed on 17.07.2014.

electricity for a certain plant is a major factor in both generation schedule and the offered price to system administrator. In terms of fuels, renewable sources apparently do not have any unit costs. If wind blows or sun rises, renewable based power plants generate electricity without a unit fuel cost. On the other hand, fossil fuels such as coal, fuel oil or natural gas have significant levels of unit costs of procurement for a plant, as stated before in this chapter.

Cost aspect is certainly not the only element influencing the price formation. Beyond forming the price, several factors have a serious impact on the fluctuation of market, which is observed occasionally. Since the most of these points that create instability in the market are relevant with reliance on natural gas, a discussion comparing the return of coal case to these risks of natural gas in the price formation is significantly fruitful. Besides, as depicted before, natural gas has already been creating a general vulnerability in Turkish energy outlook with high levels of import and consumption. Therefore, the reliability of coal is evaluated with respect to various adverse effects of natural gas on the market.

Capacity constraint of gas import under certain circumstances extremely jeopardizes the stability of power market. In case of high demand depending on cold weather conditions or extreme consumption of electricity, gas import might be insufficient for energy supply due to reaching the maximum capacity of intake. Although there is a chance to switch a different fuel for generation, shortage of gas would mean higher offers from producers, thus higher prices. That is what happened in Turkish electricity market during the gas crisis took place in December, 2013. Temperature values decreased by around 8°C in month December comparing to previous month and the decreases continued within the month.[166] Change in weather conditions directly affected power demand by making the demand profile rise by 6% compared to the same period in 2012.[167] This case caused the increase in gas import so that gas intake reached to its maximum level via pipelines.[168] An analyst from the electricity market confirmed that

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166 "Türkiye İçin Hava Durumu", 2014, http://www.accuweather.com/tr/tr/turkey-weather accessed on 17.07. 2014.

167 "Günlük İşletme Raporları ve Alınabilir Güç" TEİAŞ, 2014, http://www.teias.gov.tr/yukdagitim/YukTevziRaporlari.htm accessed on 17.07. 2014.

168 "Soğuyan Havayla Uçan Talebi Kapasite Nasıl Karşılayacak?", *Hürriyet*, 2014, http://hurarsiv.hurriyet.com.tr/goster/haber.aspx?id=25337514&tarih=2013-12-12 accessed on 17.07.2014.

PPC has sent an order to both public and private gas plants to decrease the gas intake by 50%, which led to the fact that an installed capacity of around 5500 MW could not be operational or generated at a very limited capacity. Therefore, daily generation values of gas-fired power plants decreased from 364 GWh to 228 GWh.[169] In terms of energy supply, blackouts up to several hours happened in 10 provinces including some districts in Ankara, the capital.[170] Therefore, the crisis naturally affected the price formation. When the maximum hourly base load Day Ahead Market price in a day was at a level of 190 – 200 TL/MWh, as of December 7, the first day of crisis, it rose up to 650 TL/MWh.[171] In terms of Balancing Power Market prices, there was a more dramatic change: the maximum hourly prices rose from the level of 205 – 210 TL/MWh up to 1100 TL/MWh due to impact of gas crisis.[172] The figure below clearly demonstrates trends of Day Ahead Prices and daily natural gas based generation values for December, 2013:

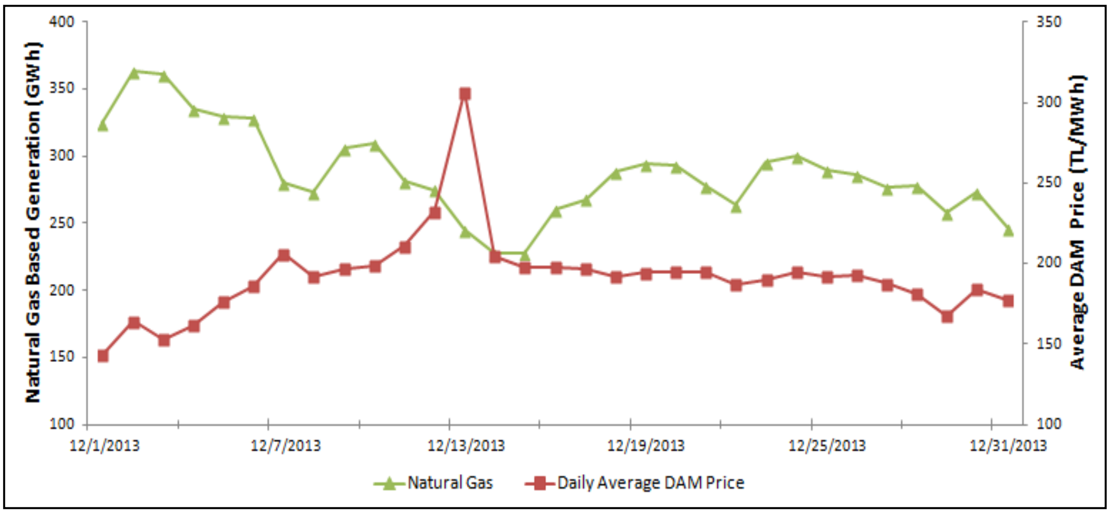

Figure 2.5: Average Daily Day Ahead Market Prices & Natural Gas Based Generation Values in December 2013.[173]

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[169] "Günlük İşletme Raporları ve Alınabilir Güç" TEİAŞ, 2014, http://www.teias.gov.tr/yukdagitim/YukTevziRaporlari.htm accessed on 17.07. 2014.
[170] "Doğalgaz Krizi Nedeniyle Köylerde Elektrik Kesintisi", 2013, http://www.aktifhaber.com/dogalgaz-krizi-nedeniyle-koylerde-elektrik-kesintisi-901856h.htm accessed on 17.07.2014.
[171] "PTF ve SMF Listeleme", 2014, https://rapor.pmum.gov.tr/rapor/xhtml/ptfSmfListeleme.xhtml accessed on 17.07. 2014.
[172] Ibid.
[173] "PTF ve SMF Listeleme", 2014, https://rapor.pmum.gov.tr/rapor/xhtml/ptfSmfListeleme.xhtml accessed on 17.07. 2014 and "Günlük İşletme Raporları ve Alınabilir Güç" TEİAŞ, 2014, http://www.teias.gov.tr/yukdagitim/YukTevziRaporlari.htm, accessed on 17.07. 2014.

Heterogeneous distribution of total installed capacity based on various fuels creates a remarkable threat to a power market with predictable prices. In terms of the installed capacity, a locational asymmetry between regions leads to generation amounts varying with respect to each region. A certain region would have an opportunity to generate electricity more than a region which has a fewer generation capacity. Therefore, if the demand of a region could not be met due to a fewer capacity, the generated electricity needs to be transmitted from a region with higher production values to the lower one. However, amount of power to be transmitted is subject to the maximum capacity of transmission lines between the regions. If demand shortage of a certain region is larger than the maximum capacity of the transmission line, it is inevitable to encounter with blackouts in this region. In terms of market stability, the blackouts, regardless of their impacts, correspond to higher base load market prices because of the lack of supply. Although the issue of locational asymmetry has already been a major problem for years, gas supply vulnerability has been exacerbating the problem significantly.

Thrace region, part of country in European side, suffered from this locational asymmetry threat during the December gas crisis explained above. The region predominantly comprises gas-fired power plants, which form more than 90% of the total installed capacity.[174] In addition, the larger part of Istanbul, the largest city of Turkey, is in this region with holding the highest demand. Combining the Asian and European side, Istanbul contributes to country's demand by consuming around 15% of total.[175] More than 10% of the contribution to total peak load comes from the region.[176] In the light of an outlook with high demand, extreme reliance on natural gas made the region vulnerable against the gas supply crisis in December 2013. Most of the power plants could not work with full utilization due to inability to procure gas at usual level. Demand was quite high that it increased by 6% comparing to December 2012.[177] The gap between supply and demand could not be closed enough via transmission lines, which carries power to the region. Analyst from the power market stated that the

[174] EMRA (Energy Market Regulatory Authority), 2014 http://lisans.epdk.org.tr/epvys-web/faces/pages/lisans/elektrikUretim/elektrikUretimOzetSorgula.xhtml, accessed on 17.07. 2014.
[175] "İstanbul'un 'elektriği' 8 ülkeyi geride bıraktı", 16.03.2014, http://www.hurriyet.com.tr/ekonomi/enerji/26018739.asp, accessed on 17.07. 2014.
[176] "2013 – 2022 Yılları Türkiye İletim Sistemi Bölgesel Talep Tahmin ve Şebeke Analiz Çalışması" TEİAŞ, 2013, p.17.
[177] "Günlük İşletme Raporları ve Alınabilir Güç" TEİAŞ, 2014, http://www.teias.gov.tr/yukdagitim/YukTevziRaporlari.htm, accessed on 17.07.2014.

maximum transmission capacity of grid was less than the gap. Although power plants in Aegean dispatch region could cover up the lack of demand in Thrace, the capacity constraint of the line disabled this option. Thus, short – time and frequent blackouts happened, which also affected Istanbul significantly.[178] The analyst also underlined that the area specific supply problem caused a huge leap in price offers so that a power plant in Thrace were able to generate electricity at 2000 TL/MWh in Balancing Power Market.

External factors depending on various issues have an impact on the electricity market obviously. Importing almost all of gas, around 50% of which is used to generate electricity, Turkey feels the impact of external problems with respect to energy supply. Two months after the December gas crisis, market prices fluctuated again during February 2014. A senior analyst in the market explained that Baku – Tbilisi – Erzurum pipeline, which carries imported gas from Azerbaijan to Turkey, had an outage at Sencegal station located in Baku. Therefore the pipeline was not operational for 2 days. Moreover, cold weather conditions in Iran influenced the pressure of pipeline between Iran and Turkey. Regarding the decreasing pressure, which blocks the pipeline to work at full utilization, Iran could not offtake a sufficient level of gas to Turkey for several days. Accordingly, PPC was constrained to send an order to gas-fired power plants to reduce the gas intake by 50%. Therefore, gas supply problem turned into similar case with the December crisis: Gas-fired plants were not able to generate at required capacity or they could not work. Although there was not any gap between supply and demand for a specific region like the case in December, which had caused numerous short – term blackouts, the market was affected because of the problem. Hourly Day Ahead Market price during the problem increased up to 499 TL/MWh; while it was 190-200 TL/MWh.[179]

The source from the energy markets emphasized that the actual hourly price of 499 TL/MWh was because of an order of government to public power plants with dual-fuel to switch to secondary fuel, which is fuel oil. In case of gas-fired power plants could not be operational at a specific hour, these plants either could not bid any offer or they did

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[178] "İstanbul'da elektrik kesintisi!", 2013, http://www.istanbulajansi.com/haber/7929/Istanbulda-elektrik-kesintisi.html#.U9OVd_mSySo, accessed on 17.07.2014.

[179] "PTF ve SMF Listeleme", 2014, https://rapor.pmum.gov.tr/rapor/xhtml/ptfSmfListeleme.xhtml accessed on 17.07.2014.

not choose to. The dual-fueled power plants bid offers at that hour relying on fuel oil, which has the highest generation cost among fossil fuels, in order to meet demand. Thus, in terms of covering up the cost at least, offers from fuel-oil are quite high. Naturally, high hourly Day Ahead Market prices also made the daily average to rise dramatically. The daily average of DAM prices for the first 5 days of February (just before the gas supply problem) was 158.2 TL/MWh. When the problem arose, daily average price increased up to 217 TL/MWh and continued to end up at 195-210 TL/MWh until the end of the problem.[180]

Installed capacity of hydro power plants is one of the main power resources along with natural gas and coal. In addition, there is an extremely negligible unit cost of generation in hydraulic resources as mentioned in the beginning of this topic. Therefore, the hydro power plants have a feature of decreasing the market prices in general. Specifically, effect of hydraulic resources is much more visible on the hourly maximum Day Ahead Market price, which tends to increase abruptly during extraordinary incidents. The analyst who informed about electricity market explained that in case of price fluctuation, the hydro power plants are usually perceived as a tool to intervene the prices in order to provide stability. Using the hydraulic resources in seasons with sufficient level of precipitation would have an opportunity cost due to a risk of inability to use these resources in seasons without the precipitation. Therefore generation values from HPPs have a seasonal trend, which usually increase during March – August in each year.

Speaking of December crisis, the government was quite precautious about using hydraulic resources in the reservoirs of public plants, because of inclination to retain the resources to use in seasons without precipitation. However, the government did not intend to encounter with the same fluctuation of December during February. When the gas crisis returned as of February 6, generation of HPPs immediately increased and held constant in high levels comparing to previous period. Thus, the maximum hourly Day Ahead Market prices were not allowed to exceed 210 TL/MWh except the first day of crisis, maximum hourly price of when is 499 TL/MWh.[181] The figure below indicates the daily average DAM prices, the maximum hourly DAM prices and daily hydro – based generation values during the crisis in February 2014:

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[180] Ibid.
[181] Ibid.

Date	Generation from HPPs (GWh)	Maximum Hourly DAM Price (TL/MWh)	Average DAM Price (TL/MWh)
2/3/2014	114	191	152
2/4/2014	157	199	166
2/5/2014	169	207	188
2/6/2014	196	499	217
2/7/2014	229	210	209
2/8/2014	199	210	208
2/9/2014	133	206	199
2/10/2014	199	210	202
2/11/2014	206	210	206
2/12/2014	181	209	204
2/13/2014	168	205	195
2/14/2014	168	205	183
2/15/2014	135	200	170
2/16/2014	98	185	147
2/17/2014	114	193	157

Figure 2.6: Generation from HPPs, Maximum Hourly DAM Prices and Average DAM Prices during the gas supply problem in February 2014.[182]

The most apparent vulnerability for HPPs is the fact that renewable resources depend extremely on natural conditions. As emphasized before in this chapter, for instance, it is up to wind to blow for power generation from a wind turbine. The same case also applies to the hydro power plants: if precipitation is not happened at a desired level, reservoirs of HPPs might not be at a sufficient level of power generation. Correspondingly, Turkey has been experiencing the possible risk of drought since the beginning of 2014. Reservoirs could not be fed enough with the precipitation during the last winter and this case went on during spring. Therefore, HPPs in Turkey could not have the sufficient level of water in order to meet high portion of demand.[183] The drought risk impacted many of dams in Turkey significantly that some of these dams in

[182] Ibid. and "Günlük İşletme Raporları ve Alınabilir Güç", TEİAŞ, 2014, http://www.teias.gov.tr/yukdagitim/YukTevziRaporlari.htm, accessed on 17.07.2014.
[183] "Kuraklığın HES'lere ve doğalgaz ithaline etkisi", 31.05.2014, http://www.dunya.com/kurakligin-heslere-ve-dogalgaz-ithaline-etkisi-229380h.htm, accessed on 18.07.2014.

Istanbul have run dry completely.[184] Inability of HPPs to generate electricity naturally leads to an increase in fossil fuel-fired power generation.

The relationship between various resources used for power generation creates certain issues negatively affecting Turkish electricity market. The country predominantly relies on natural gas, which has a remarkable vulnerability against crises. Hydro power plants are able to prevent the negative effects of gas, however the option of renewables carry a risk of drought. On top of these facts, the return of coal case is quite able to phase out threats depending on both natural gas and HPPs. Having abundant lignite reserves, Turkey does not have any difficulties in terms of providing coal for power plants. More coal sites and more lignite production for power generation means an elimination of capacity constraint depending on gas import to a large extent. Moreover, the return of coal case includes more coal-fired power plant projects in the country, which corresponds to a more balanced distribution of total installed capacity. If the proposed projects are also dispersed in order to maintain the regional balance, a necessity to rely extremely on either a single fuel or transmission lines to a certain region is successfully removed. In other words, more coal-fired power plant projects in Thrace region significantly alleviate the impacts of a possible crisis both caused by the shortage of gas and exacerbated by the maximum capacity of transmission lines. Furthermore, it is quite apparent that an inclination to coal prevents a great deal of risks regarding externalities. An impact of any external factor which becomes an obstacle for Turkey to import gas would be possible to ignore to an important degree, if coal production is promoted enough. If a technical complication happens to pipelines, which might lead to a crisis in Turkish electricity market, for instance, a sufficient level of coal based power generation is clearly able to cover up demand and prevent any price fluctuation in the electricity market. The alleviation of negative impacts with respect to gas certainly removes the risks of HPPs regarding opportunity costs of generation and drought. As the dependence on coal is fairly enough to eliminate threats of gas import, need for hydro based generation in order to repress the prices downwards is clearly reduced. Low levels of hydraulic resources in reservoirs, thus, cease to be a threat to a certain extent. A possible return of coal case, eventually, would alleviate the risks caused by other fuels economically.

[184] "İstanbul'un barajları alarm veriyor", 19.07.2014, http://www.milliyet.com.tr/istanbul-un-barajlari-alarm-veriyor-gundem-1914083/ accessed on 20.07.2014.

Conclusion

Natural gas is predominantly utilized to generate electricity in Turkey; therefore it is more accurate to compare coal with the natural gas in terms of economic and geopolitical evaluation of the return of coal case. As long as renewable based power generation is extremely up to the natural conditions, the renewables have not taken into consideration in the discussion.

The most notable notion of economic evaluation is cost effectiveness. The total costs of coal and natural gas seem to be close for power plants at the first sight. Including the incentives determined with respect to long – run projections, however, coal is realized as a more feasible option. The rationale behind this fact is caused by the unit costs of production: price of coal per unit is around two and a half times less than the price of natural gas. Moreover, the long – term price forecasts point out that the price of natural gas will increase much faster in the next decades.

Natural gas means a high degree of vulnerability for Turkey. Almost all of the gas is imported and more than 80% of gas import is made by three countries via pipelines. In addition to high unit costs, the gas contracts are quite a heavy liability because of take-or-pay obligations. The ToP obligations entail to pay the price of gas committed, even though the gas import is not made at the committed level due to low demand. Turkey has paid a great deal of ToP fines to the main exporters for years. Furthermore, external dependence on the gas supply naturally creates a geopolitical risk, which contradicts the long – term objectives of Turkish government.

The return of coal case is quite sufficient to diminish negative impacts of gas import. First, the production of coal is much less costlier than the gas import. Second, there is not such heavy obligation such as take-or-pay contracts. Third, an inclination to coal relaxes a constraint of gas – oriented external dependency by reducing the necessity in power generation. What more, the unit cost of coal is for power generation, either lignite or imported coal, is relatively cheaper than the cost of gas according to market information.

Coal-oriented power generation policies are able to reach a more predictable electricity market in Turkey, comparing to natural gas. Privatization process of the Turkish power market has continued for two decades and a price mechanism based on offers from producers is established. Day Ahead Market prices represents base load power prices determined a day ago, while Balancing Market prices corresponds to the base load prices determined by the offers in order to offset meet demand. In this regulated market, heavy reliance on natural gas in power generation has three risks that lead to remarkable crises as salient price fluctuations. Capacity constraint of gas import is the first risk. In case of high electricity demand, the natural gas might not be imported at a desired level because of the maximum capacity constraint of pipelines. Fall in supply naturally increases the prices suddenly. Secondly, capacity constraint could be a threat for a case of locational asymmetry in terms of installed capacity of a certain region. If there is a gas supply problem and a region has an installed capacity consists of gas-fired power plants predominantly, another region might need to cover up the gap between supply and demand by transmission lines. If the gap is larger than the maximum capacity of transmission lines, blackouts might happen. Thus, market prices would fluctuate. External problems with respect to exporter countries are regarded as the third risk. A technical problem, for instance, would prevent to offtake a certain amount of gas to the importing country, which might cause the shortage of gas. Impact of this case would extremely increase the prices.

Hydro power plants are generally used to control market prices in case of crises caused by gas import. Generation from hydraulic resources have an effect of reducing the prices due to having a negligible unit cost. On the other hand, the generation amount from HPPs depends extremely on natural conditions. If sufficient level of water is not provided by precipitation, HPPs could not be operational as desired. Therefore, they fail to alleviate the negative impacts of the crises.

The return of coal case removes all risks belong to both gas import and hydro based power generation. If coal production is incentivized, an option of importing the gas less arises. Decrease in gas import means that power market feels the impacts of capacity constraints of pipelines and external problems much less than before. Furthermore, more projects on coal-fired power plants considering equal distribution among regions are able enough to eliminate the risk of locational asymmetry. Diminishing these impacts on the market corresponds to the fact that HPPs will not have to work at full capacity during critical periods; therefore the possible risk of drought with respect to the HPPs might be removed. Eventually, vicious circle in Turkish energy market might be transformed into a virtuous circle with the return of coal case.

Chapter 3

Environmental Concerns for the Return of Coal Case

Introduction

The return of coal case have economic advantages in terms of cost effectiveness and providing a more stable electricity market as explained in Chapter 2. This situation also make coal a reliable resource in power generation relatively considering geopolitical concerns, because utilization of domestic coal reserves apparently decrease the level of external dependency in gas import. However, coal poses a great deal of risk in terms of environmental issues such as climate change, water and air pollution.

The main objective of this chapter is to clarify the specific threats with respect to coal-fired electricity generation together with the potential preventions to diminish the negative impacts. First the environmental costs of coal are distinguished: types of environmental damages caused by coal-fired power generation are comprehensively explained. The threat of climate change depending on greenhouse gasses (GHG) emissions is depicted through increasing carbon dioxide emissions around the world and possible scenarios of global temperature rise. Then the negative impacts of coal caused by combustion wastes and mining related operations are explained along with its outcome of water pollution. Moreover, the factors affecting the environment in Turkey are mentioned according to specific cases. Certain incidents, which occured due to coal production and coal-fired power generation, are stated such as the effects of coal dust, combustion wastes of power plants and water polluting matters. The renewable energy sources are strongly recommended as a potential remedy by environmentalists due to these cases; therefore possibility of the renewables to be an ultimate solution is discussed. As a result of the discussion, renewables are not seen as a potential source to phase out coal in power generation for the next decades. Therefore the importance of Clean Coal Technologies (CCT) is emphasized.

Clean Coal Technologies are quite significant to reduce GHG emissions and increase generating efficiency of power plants. Therefore, the CCTs and conventional technologies are distinguished with respect to their methods and technical features. Emission rates and generating efficiency percentages of these technologies are also stated. In addition, the importance of Carbon Capture & Storage (CCS) technologies to achieve the goal of halving the carbon emissions by 2050 is mentioned. Studies on the cost structure of CCTs and CCS systems are scarce, therefore the costs of different technologies with and without CCS retrofit is analyzed according to comprehensive study introduced by MIT, called "The Future of Coal". In the light of this important work, both costs of electricity and total investment costs are evaluated. Furthermore, potential implementation of CCTs in Turkish power market is discussed. Recent developments in R&D phase are explained along with general remarks on CCT of environmentalists. Although it is hard to evaluate options in light of poor cost information, the most suitable CCT option to implement in Turkey is discussed regarding the coal type.

Alternative solutions to negative environmental impacts except GHG emissions are discussed. Suggestions to prevent coal dust, water pollution and mining related outcomes are included in this discussion. On the other hand, private investment plans for coal with minimum environmental concerns are strongly emphasized as the most important problem among the environmental issues. Government intervention in order to regulate these plans is considered as insufficient by giving an example about Soma mine disaster, which led to casualties of 301 miners. Finally possible courses of actions to diminish the detrimental effects of these cases, thus coal, are stated.

1. Impacts of Coal-Fired Power Generation on Environment

a. Environmental Costs of Coal

The recent statistics indicate that coal will persist to be a primary fuel in energy supply and it will preserve its position in power generation. This fact depends on abundance and its balanced geographical dispersion. Focusing on these attributes, however, the costs of coal for environment are not taken into account. In general, coal has been perceived as a main threat for both the environment and communities all over the world due to its various impacts, which will lead to irreparable damages.[185]

i. Emissions of Greenhouse Gases (GHGs)

The major environmental impact of coal-fired power generation is as emission of greenhouse gases (GHGs). Depending on elements comprised by definition of GHGs, such as carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxide (NOx), mercury (Hg) and particulate matter (PM), the emission of GHGs have different detrimental impacts on the environment.[186]

Carbon dioxide (CO2) emissions are accepted as the primary GHG emissions through human activities among the other greenhouse gases emitted by coal.[187] As the global energy demand increases, the carbon dioxide emission values also rise by significant annual rates. Although various sectors such as transportation and industrial purposes significantly contribute the CO2 emissions, electricity generation and heat holds the lion's share in total emission all over the world by 41%.[188] Specifically, more than 70%

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185 "Coal", http://www.greenpeace.org/international/en/campaigns/climate-change/coal/, 2012, accessed on 23.07.2014.

186 "Coal Power Plants", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Coal-Power-Plants/ accessed on 23.07.2014.

187 "Overview of Greenhouse Gases", 2012, http://www.epa.gov/climatechange/ghgemissions/gases/co2.html accessed on 26.07.2014.

188 "21st Century Coal: Advanced Technology and Global Energy Solution", IEA, 2013, p.16.

of the emissions in electricity sector comes from the usage of coal.[189] It is also stated that the most 25 carbon dioxide emitting power plants all over the world are fueled by coal.[190] Figure 2 presented below clearly demonstrates that share of coal in CO2 emissions in total energy consumption had a rising profile in 2000 – 2011. What is more, Greenpeace emphasizes that if current plans for coal-fired power plants will be applied, coal will contribute to the CO2 emissions by 60% until 2030.[191]

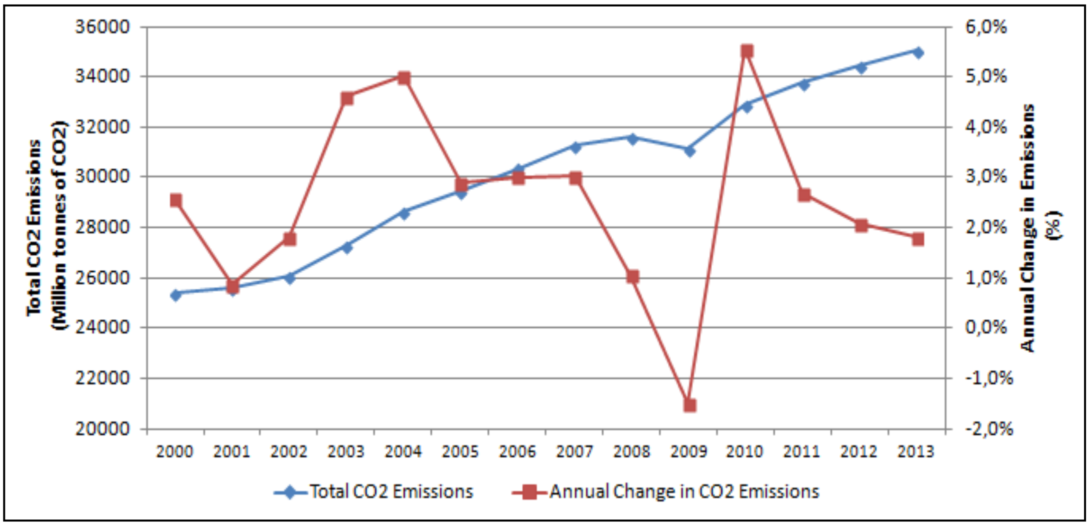

Figure 3.1: Total World CO2 Emissions and Annual Changes of the Emission Values in 2000 – 2013.[192]

[189] "The Case Against Coal", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/The-case-against-coal/, accessed on 23.07.2014.

[190] "Coal Power Plants", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Coal-Power-Plants/ accessed on 23.07. 2014.

[191] "The true cost of coal", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/the-true-cost-of-coal/ accessed on 23.07.2014.

[192] "BP Statistical Review of World Energy (2013)" British Petroleum, 2014, http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html, accessed on 23.07.2014.

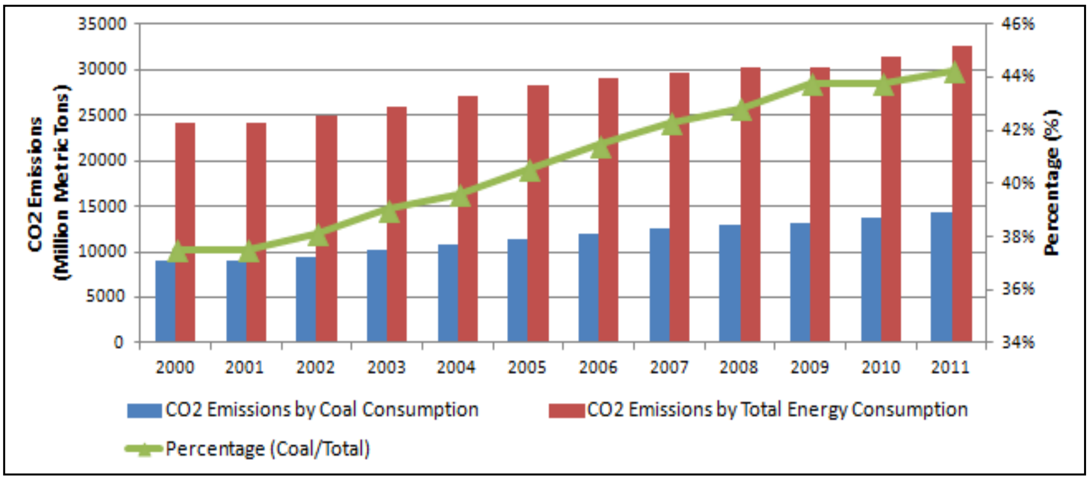

Figure 3.2: Share of Coal in CO2 Emissions by Total Energy Consumption in 2000 – 2011.[193]

The steady rise of carbon dioxide emissions is regarded as a serious threat to the environment because of having a primary effect on the exacerbation of climate change, defined as the greatest environmental challenge.[194] The climate change is underlined to cause widespread drought and flooding due to rising sea levels and global temperature rise must be confined to 2ºC at most.[195] International Energy Agency depicts a possible 2ºC scenario by 2050 is possible with an illustrative energy pathway, otherwise a 6ºC will be valid in case of no specific action in terms of new policies.[196] The figure below indicates annual CO2 emissions under certain global temperature rise scenarios by 2050:

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193 "International Energy Statistics", 2012, http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=90&pid=1&aid=8&cid=ww,&syid=2000&eyid=2011&unit=MMTCD, accessed on 23.07. 2014.

194 "The Case Against Coal", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/The-case-against-coal/, accessed on 23.07.2014.

195 "Coal", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/, accessed on 23.07.2014.

196 "21st Century Coal: Advanced Technology and Global Energy Solution" IEA, 2013, p.13.

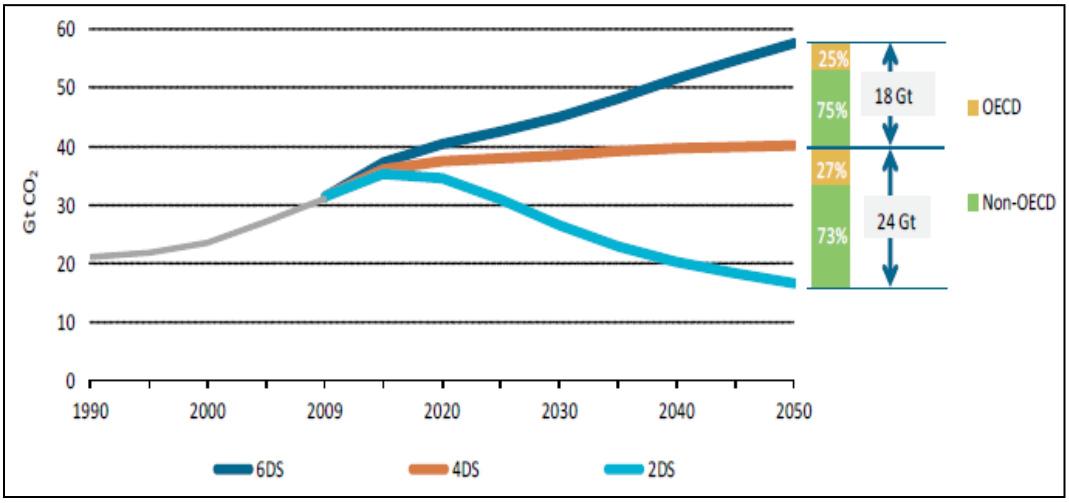

Figure 3.3: World Energy-Related Annual CO2 Emissions.[197]

Carbon dioxide emissions come to the forefront in terms of having an impact on climate change. Apart from the CO2 emissions, gas emissions by the other GHGs have also certain negative effects on enviroment. Sulfur dioxide (SO2) and nitrogen oxide (NOx) are capable of interacting with water, oxygen and other chemicals to cause acid rain, which damages the forests along with creatures living in aquatic habitat.[198] Moreover, nitrogen oxide emissions directly trigger the harmful ground level ozone (smog), which leads to emerge chronic respiratory diseases such as asthma, emphysema and various relevant infections.[199] Particulate matter (PM) emissions also contribute to the air pollution with NOx by boosting the level of cardiovascular and respiratory illnesses.[200] The total cost of asthma in Europe based on NOx and PM emissions was calculated as €17.7 billion per year.[201] In addition, mercury emissions from coal power plants contribute to water pollution mostly. Along with having an impact on health conditions of people of all ages, mercury settles into water by emission and form a highly toxic

[197] Ibid., p.15.

[198] "Coal Power Plants", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Coal-Power-Plants/, accessed on 23.07.2014.

[199] "Coal in a Climate Change", *Natural Resources Defense Council*, 2007, p.13.

[200] "The Unpaid Health Bill: How Coal Power Plants Make Us Sick", *Health and Environment Alliance*, 2013, p.14-16.

[201] Ibid., p.14.

form that leads to contamination of fishes. This case creates a case to make animals and creatures living underwater, which are fed with fishes, die.[202]

ii. Water Pollution

Water pollution has been identified as one of the detrimental effects of coal-fired power plants on environment. Power plants located on watersheds have an impact of affecting every aspect of lakes and rivers in terms of health and productivity. Primarily, discharging water could increase the water temperatures quite enough to threaten aquatic ecosystems vulnerable to a temperature shock. Operations of the plants could alter water flows and levels, which is harmful enough to damage plants and animal communities. Furthermore, cooling water intakes because of the power plants might lead to impingement of fish species that results damage to fish populations and decrease the possibility of economic fishing activities.[203]

iii. Combustion Waste

Combustion operations of coal-fired power plants produce large amounts of waste along with electricity generation. Along with ash, various types of solid and liquid wastes such as lead, cadmium, mercury and arsenic are disposed by the power plants. An annual coal combustion waste of the United States alone is calculated roughly as 130 million tonnes.[204] The waste as a toxic output might be used for industrial purposes such as for cement industry. In terms of avoiding the negative impacts, moreover, the waste matter is generally restrained to a certain area with a method of surface impoundment. However, the surface impoundment is perceived as a risky operation in terms of environmental effects of the waste. The waste is impounded at a slurry liquid state on the surface, therefore there is a threat that the toxic waste has a high potential to leach and contact with water and groundwater.[205] In this case, it is extremely possible for the

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202 "Mercury", 2012, http://www.epa.gov/mercury/about.htm, accessed on 23.07.2014.

203 "Coal in a Climate Change", *Natural Resources Defense Council*, 2007, p.14-15.

204 "Power Plant Waste", 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Power-plant-waste/ accessed on 23.07.2014.

205 "Coal in a Climate Change", *Natural Resources Defense Council*, 2007, p.15.

toxic matter to contaminate drinking water, accumulate in livestock and crops.[206] In addition to negative impacts of the waste, Natural Resources Defense Council states that the contamination level that belongs to coal combustion waste is proportional with proximity of coal combustion waste site to a certain aquatic habitat.[207] Along with the necessary preventive barriers, the NRDC underlines sufficient achievement of disposal activities depends on the distance between toxic chemicals and groundwater that is connected to nearby surface waters.[208]

iv. Mining Related Environmental Effects

Coal mining and production might be regarded as a separate phase in terms of meeting electricity demand. However, both form and level of damage that the mining processes have on the environment clearly converges to the negative impacts of coal-fired power generation. One of the most visible impacts of coal mining is an impact on natural habitats. Certain biologically and naturally diversified regions were ruined with cutting hundreds of trees in order to operate surface mining activities.[209] These cases resulted to a fragmentation of habitats and even though these certain regions were reclaimed as grasslands, neither ecological nor soil quality could be the same like before.

Mining operations usually pose a risk of emergence a reaction called Acid Mine Drainage (AMD), defined as “metal-rich water formed from chemical reaction between water and rocks containing sulphur-bearing minerals”.[210] In each type of mining, sulphur-bearing minerals interact with precipitation and groundwater, and then form an acidic leachate, which carries the toxic matter into the groundwater. Thus the water becomes degraded together with being less habitable, unfit for recreational purposes.[211]

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206 “Power Plant Waste”, 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Power-plant-waste/, accessed on July 23, 2014.

207 “Coal in a Climate Change”, *Natural Resources Defense Council*, 2007, p.15.

208 Ibid.

209 Ibid., p.7.

210 “The Coal Resource: Comprehensive Overview of Coal”, *World Coal Institute*, 2009, p.28.

211 “Coal in a Climate Change”, *Natural Resources Defense Council*, 2007, p.8.

Terrestrial damage and water pollution with respect to AMD are two important negative results of coal mining. What is more, the mining also contributes a great deal to air pollution. Depending on the features of coal, methane, which is stated as 20 times as powerful as greenhouse gases in terms of emissions, is able to harm the atmosphere during the mining operations.[212] It is more likely to see methane content in coal in underground mines due to the fact that "deeper coal seams have higher methane content".[213] Furthermore, methane is an extremely explosive matter, so underground mines use large – scale ventilation systems in order to escape the harmful emissions in mine. However, the mines might release methane into the air at very low concentrations.[214]

b. Impacts of Coal on Environment in Turkey

Various detrimental consequences of coal-fired power generation on environment has been showing themselves all over the world. Turkey has also been feeling the negative environmental impacts more and more, as power generation has been rising. In 2009, carbon dioxide emissions from power plants increased by 52% while electricity generation rose by 28.7% compared to 2004.[215] Moreover, top five power plants contributing to CO2 emissions the most in Turkey are all coal-fired power plants and the sum of their contribution constituted %29 of total emissions from power generation of Turkey in 2009.[216] In spite of fluctuation in annual change rates, total CO2 emissions also rose in the last decade generally, demonstration of which is presented in the figure below:

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[212] Mining Impacts, 2012, http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Mining-impacts/#a3, accessed on 23.07.2014.

[213] "Coal in a Climate Change", *Natural Resources Defense Council*, 2007, p.9.

[214] "The Coal Resource: Comprehensive Overview of Coal", *World Coal Institute*, 2009, p.28.

[215] Turkey CARMA, http://carma.org/region/detail/298795, accessed on 24.07.2014.

[216] Ibid.

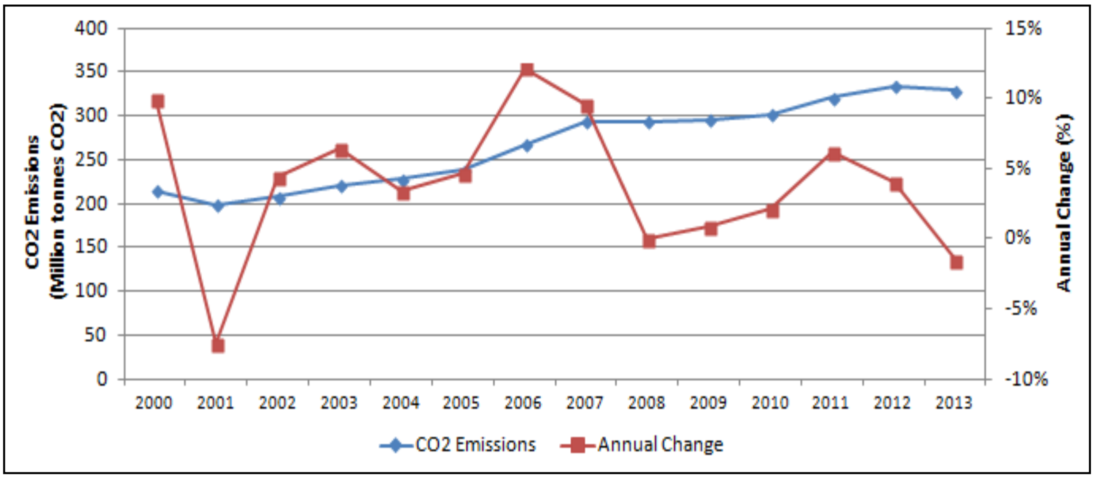

Figure 3.4: Total CO2 Emissions in Turkey and Annual Change in Emission Values in 2000 – 2013.[217]

Emissions of GHGs pose a remarkable threat for Turkey more and more. Apart from the emissions, there are various environmental challenges due to coal-fired power generation that Turkey has been facing. Disposal of toxic waste nearby a coal power plant might cause air pollution for a certain region. People of Tufanbeyli region in Adana, for instance, stated their unrest because of toxic wastes and water disposed from a coal power plant still under construction.[218] In addition to having fertile lands for farming activities, they were concerned of this case due to a stinky smell from the waste spread around the region and possible water pollution.

Low health conditions were encountered in regions where coal power plants are located. Çatalağzı region toughly experienced the negative effects of coal in terms of health problems of residents along with the water pollution cases. Cancer rates in town have been rising, while around 20% of children are born suffering from chronic respiratory illness with underdeveloped lungs.[219] Apart from the health conditions, water contamination of the local tributary depending on leaking ash was observed. The main

217 "BP Statistical Review of World Energy (2013)" British Petroleum, 2014, http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html , accessed on 23.07. 2014.

218 "Tufanbeyli'nin köyleri EnerjiSA'ya isyan ediyor", 2014, http://www.adanamedya.com/tufanbeylinin-koyleri-enerjisaya-isyan-ediyor-56141h.htm accessed on 25.07. 2014.

219 "Black Clouds Looming", CEE Bankwatch Network, 2013, p.11.

reason of these cases was determined that the coal power plants in that region release a great deal of heavy metals and radioactive ash.[220]

Coal power plants indubitably enhance the level of detrimental impacts on environment. On the other hand, harmful effects might also be caused by various phases of mining facilities in Turkey. Coal storage facilities in Kurtpınarı, a village in Adana province, has caused an environmental hazard for the region since their first establishment in 2011.[221] Residents of the village explained that people have difficulties to drink water even after the cleaning process and breathe due to coal dust hung in the air and contaminated surface water. Fertility of farms has decreased because of the fact that farms are encased in coal dust, which also has made animals in the farms sick.[222] On the other hand, private companies operating the storage facilities do not take any responsibility for dispersed coal dust. One official from these companies stated the facilities are operated in EU standards and the residents are in a rent seeking behavior rather than being concerned for the environment. [223]

Turkey has been facing the negative effects of coal, regardless of causing by a coal-fired power plant or a certain mining related process. However, the main problem exacerbating the negative effects is understood as irreconcilable attitude of investors of coal. Case happened in Amasra is a remarkable example that investors usually do not act with any environmental concern: A coal power plant was planned to be constructed nearby cultural site in Amasra. The project poses an environmental risk because coal deposits of the plants are located beneath the aquifer zone, which is a threat for the region's water reservoir serving one hundred thousand people per day.[224] Moreover the thermal plant cooling system is planned to use sea water and this case would negatively affect the fishing activities in Amasra, defined as a coast zone for fish reproduction area.[225] This case would contribute to diminish in touristic – oriented expansion of Amasra due to low quality of fisheries and agricultural products affected by the coal

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220 Ibid.

221 "Tarlalara Kömür Tozu Yağıyor", 2014, http://www.aljazeera.com.tr/al-jazeera-ozel/tarlalara-komur-tozu-yagiyor, accessed on 25.07.2014.

222 Ibid.

223 Ibid.

224 "Black Clouds Looming", CEE Bankwatch Network, 2013, p.9.

225 Ibid., p.10.

power plant project. Despite the negative environmental impacts, congressmen of Bartın province, where Amasra is located, claimed that investing company of the project personally requested rights of exploration in the aquifer zone.[226] Although the project was refused for three times before because of touristic expansion concerns by Ministry of Environment and Urban Planning, the incumbent minister made the following statement: "I have to think about the future of whole country. There are valuable coal deposits below ground in there, which is necessary to be utilized for Turkey".[227]

[226] "CHP Bartın Milletvekili Rıza Yalçınkaya: Hema Kavşak Suyu'nu İstiyor", 2010, http://www.bartinhalkgazetesi.com/Haber.php?id=3871, accessed on 25.07. 2014.

[227] "Üç Kez Reddedildikten Sonra Onaylanan Amasra'ya Termik Santral Projesi Askıda", 2014, http://t24.com.tr/haber/uc-kez-reddedildikten-sonra-onaylanan-amasraya-termik-santral-projesi-askida,265958, accessed on 29.07. 2014.

2. Clean Coal Technologies as a Prominent Remedy

Potential outcomes of climate change for the next decades have made many countries incline to new advanced technologies. In terms of achieving a 2ºC scenario by 2050 as a common ground, increasing conversion efficiency in coal-fired power generation and reducing carbon emissions have gained importance.[228] Thus, coal, which does not seem to fade out in the near future, has an option to pollute less during power generation, while investments for renewable sources persist in the meantime. These new advanced technologies are defined as Clean Coal Technologies (CCT), which aim at rising the percentage of generation efficiency and cutting the carbon emission to a certain extent.

a. Categorizing Conventional Technologies & CCT

Clean Coal Technologies of coal-fired power plants are differentiated with respect to certain methods, their generating efficiency and carbon capturing levels. In terms of generation principle, International Energy Agency (IEA)[229] and the comprehensive study of Massachusetts Institute of Technology (MIT)[230] classify the current power generation systems into three main types:

- **Pulverized Coal & Circulating Fluid Bed Combustion (Air Blown Generation Technologies):** In pulverized coal combustion, coal is completely pulverized and air blown into the furnace for rapid combustion, thus generation. As a conventional method of power generation, the PC system is the most prevalent technology among the coal power plants around the world with three sub-types introduced below:
  - **Subcritical PC System:** A generating method by having a steam pressure and temperature below the critical point of the water, which are 22 MPa and 550ºC respectively. The generating efficiency of this technology varies between 33% and 37%. Emissions of particulate

228 "Technology Roadmap: High-Efficiency, Low-Emissions Coal-Fired Power Generation" IEA, 2012, p. 12.

229 "21st Century Coal: Advanced Technology and Global Energy Solution" IEA, 2013, p.28-34 and "Technology Roadmap: High-Efficiency, Low-Emissions Coal-Fired Power Generation" IEA, 2012, p. 21-23.

230 "The Future of Coal" MIT Press, 2007, p.17-43.

matter, SO_2 and NO_x are controlled by reducing these emissions by 99.9%, 99+% and 90% respectively.

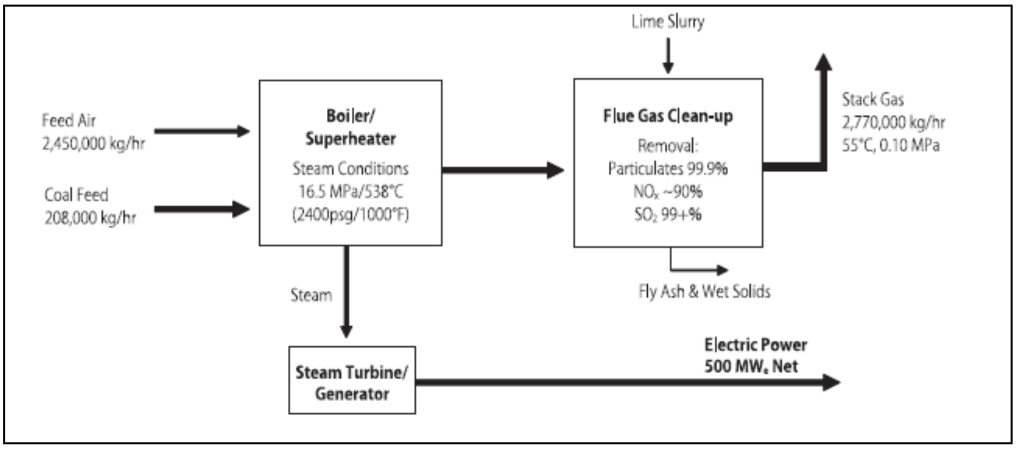

Figure 3.5: Subcritical PC Unit for 500 MW coal-fired power plants. [231]

- **Supercritical PC System:** Unlike subcritical PC, this boiling technology generate at a pressure and temperature at 24.3 MPa and 565ºC. Along with the latest developments, supercritical PC systems are able to reach an efficiency level of 42 – 43%., In addition to emissions of GHGs such as particulate matter, SO_2 and NO_x, supercritical PC systems emit around 10% CO_2 less compared to the subcritical units.
- **Ultra-Supercritical PC System:** Having the highest generating efficiency, which is around 45%, ultra-supercritical PC units operate at around 32 MPa steam pressure and 600ºC temperature[232]. The most prominent feature of this system is it requires around 21% less coal than a subcritical PC unit to generate electricity at a given amount. This corresponds to the fact that carbon emissions in ultra-supercritical units are around 21% less than subcritical units.
- **Circulating Fluid Bed (CFB) Combustion:** Although CFB units do not belong to the classification of PC units, they are evaluated as a variety of PC combustion. Unlike PC methods, coal is burned at a relatively bigger form like it is crushed. Both coal and limestone feed the bed, which operates at comparably low temperatures, about 427ºC. Slurry fluid in the bed among various fluid materials in addition to coal. Due to

[231] Ibid., p.20.
[232] Steam temperature values might change with respect to region and plant.

generation at low temperature values, CFB units are able to capture NOx and SO2. It has a generating efficiency around 34%. The most significant feature of CFB combustion is an ability to use wide range of coal types with low heating values or high ash coals.

- **Integrated Gasification Combined Cycles (IGCC):** In IGCC power plants, coal and other carbon-based fuels are gasified to be burned by using a gas turbine. The main advantage of this process is an allowance to use both solid and liquid fuels, which results to an increase in environment-friendly generation performance. The resultant output of generation process is syngas, which consists of carbon monoxide, carbon dioxide, hydrogen, water, methane and other relevant elements. After the syngas is condensed, it may be used to fire gas turbines. The coal is oxidized at a temperature value between 1340ºC and 1400ºC. The overall generating efficiency of IGCC power plants is at a level of 38 – 41%.

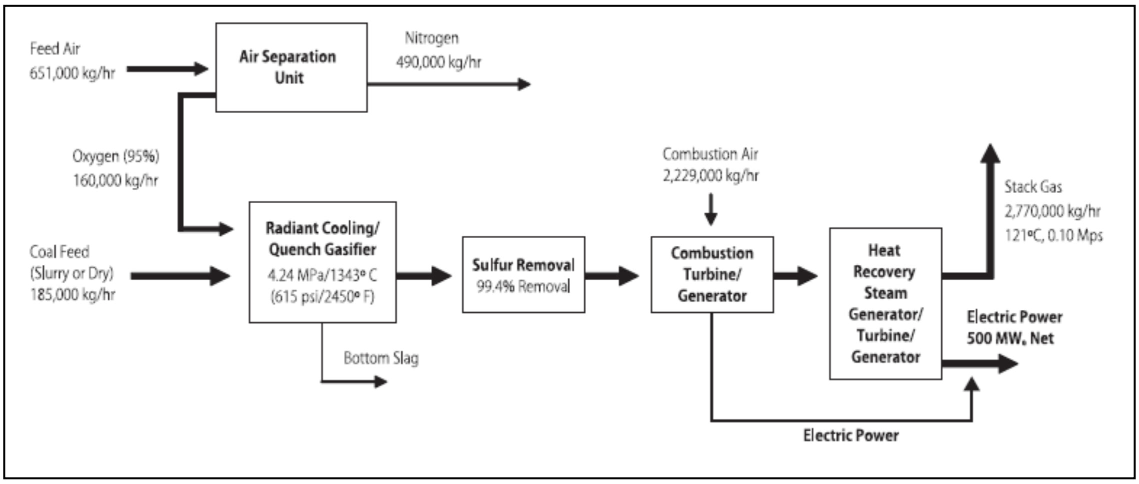

Figure 3.6: An IGCC Unit of 500 MW.[233]

- **Oxy-Fuel Combustion System:** The oxy-combustion units per se might be regarded as identical with PC systems in terms of many features: steam cycles and fuel handling systems are quite similar. The main difference is these systems operate coal combustion with oxygen by separating from air. Air separation unit removes nitrogen to produce a stream of oxygen to combust, then oxy boiler combusts coal with oxygen. Eventually carbon dioxide as by product is compressed and sent to geological storage site. There has not been any

[233] Ibid., p.33.

commercial experience of this technology and developments have still been continuing. Having a generating efficiency of around 30%, oxy-fuel units are not perceived as a feasible option to generate electricity except carbon capture.

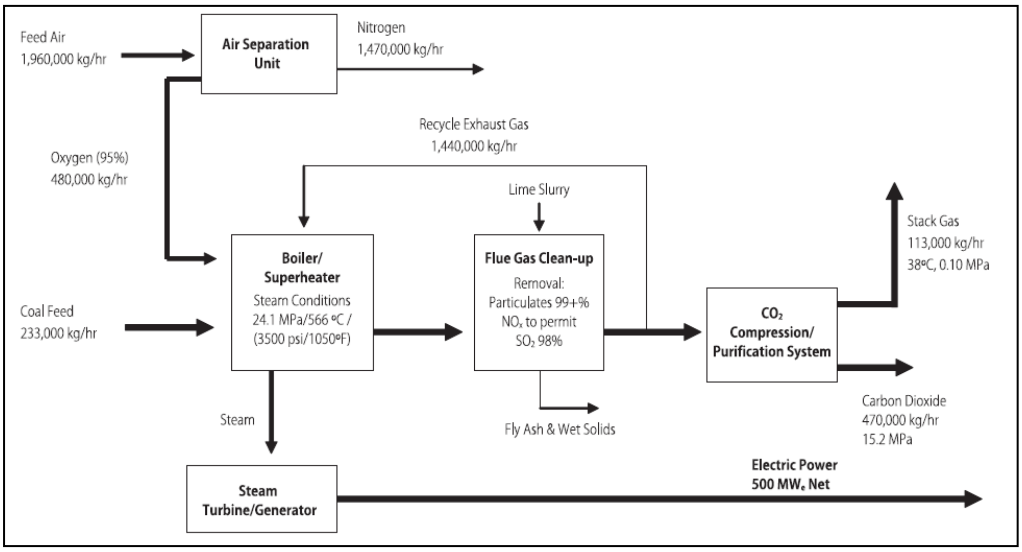

Figure 3.7: Oxy-Fuel Generating Unit of 500 MW.[234]

Clean coal technologies have gained importance in terms of reducing GHG emissions along with enhancing generating efficiency. However, they are not sufficient to succeed a 2ºC global temperature rise scenario by 2050 alone. As a worst case scenario, Carbon Capture and Storage systems, regarded as the only technology to cut carbon dioxide emissions by 80-90%, should be retrofitted to the power plants.[235] The main disadvantage of CCS (except cost structure which is explained in the next section) is reducing plant efficiency by 7 to 10 percentage points.[236] Nevertheless, it has a great deal of contribution to cut the carbon emissions in terms of alleviating the negative environmental impacts.

[234] Ibid., p.31.

[235] "Technology Roadmap: High-Efficiency, Low-Emissions Coal-Fired Power Generation" IEA, 2012, p. 19.

[236] Ibid.

b. Cost Evaluation of CCT considering Carbon Capture & Storage (CCS)

Studies on cost structure of clean coal technologies along with Carbon Capture & Storage systems are scarce; therefore few works enable to get acquainted with the cost effectiveness scheme. The latest work of MIT called "The Future of Coal" is an extremely important contribution to grasp the costs at each level. The comprehensive table demonstrating performances and economics of choices among PC systems under certain assumptions is in the figure below:

	SUBCRITICAL PC		SUPERCRITICAL PC		ULTRA-SUPERCRITICAL PC		SUBCRITICAL CFB[6]	
	W/O CAPTURE	W/ CAPTURE	W/O CAPTURE	W/ CAPTURE	W/O CAPTURE	W/ CAPTURE	W/O CAPTURE	W/ CAPTURE
PERFORMANCE								
Heat rate (1), Btu/kW_e-h	9,950	13,600	8,870	11,700	7,880	10,000	9,810	13,400
Generating efficiency (HHV)	34.3%	25.1%	38.5%	29.3%	43.3%	34.1%	34.8%	25.5%
Coal feed, kg/h	208,000	284,000	185,000	243,000	164,000	209,000	297,000	406,000
CO_2 emitted, kg/h	466,000	63,600	415,000	54,500	369,000	46,800	517,000	70,700
CO_2 captured at 90%, kg/h (2)	0	573,000	0	491,000	0	422,000	0	36,000
CO_2 emitted, g/kW_e-h	931	127	830	109	738	94	1030	141
COSTS								
Total Plant Cost, $/$kW_e$ (3)	1,280	2,230	1,330	2,140	1,360	2,090	1,330	2,270
Inv. Charge, ¢/kW_e-h @ 15.1% (4)	2.60	4.52	2.70	4.34	2.76	4.24	2.70	4.60
Fuel, ¢/kW_e-h @ $1.50/MMBtu	1.49	2.04	1.33	1.75	1.18	1.50	0.98	1.34
O&M, ¢/kW_e-h	0.75	1.60	0.75	1.60	0.75	1.60	1.00	1.85
COE, ¢/kW_e-h	**4.84**	**8.16**	**4.78**	**7.69**	**4.69**	**7.34**	**4.68**	**7.79**
Cost of CO_2 avoided[5] vs. same technology w/o capture, $/tonne	41.3		40.4		41.1		39.7	
Cost of CO_2 avoided[5] vs. supercritical w/o capture, $/tonne	48.2		40.4		34.8		42.8	

Basis: 500 MW_e net output. Illinois # 6 coal (61.2% wt C, HHV = 25,350 kJ/kg), 85% capacity factor

(1) efficiency = 3414 Btu/kW_e-h/(heat rate);
(2) 90% removal used for all capture cases
(3) Based on design studies and estimates done between 2000 & 2004, a period of cost stability, updated to 2005$ using CPI inflation rate. 2007 cost would be higher because of recent rapid increases in engineering and construction costs, up 25 to 30% since 2004.
(4) Annual carrying charge of 15.1% from EPRI-TAG methodology for a U.S. utility investing in U.S. capital markets; based on 55% debt @ 6.5%, 45% equity @ 11.5%, 38% tax rate, 2% inflation rate, 3 year construction period, 20 year book life, applied to total plant cost to calculate investment charge
(5) Does not include costs associated with transportation and injection/storage
(6) CFB burning lignite with HHV = 17,400 kJ/kg and costing $1.00/million Btu

Figure 3.8: Representative Performance and Economics for Air-Blown PC Generating Technologies.[237]

Generation systems with CCS naturally increase the cost as it might be observed in the figure. In addition, cost of electricity per kWh also rises among PC units as generating

[237] "The Future of Coal" MIT Press, 2007, p.19.

efficiency decreases. A proportion might be seen between the carbon dioxide emissions and the costs of electricity in options without CCS: as the cost rises, emission value also rises because of the quality of technology. The remarkable point is CCS costs at least $3/kWh for each combustion systems, however it is quite successful to cut the emissions by at least 80%.

Ultra-supercritical PC option shines out in terms of costs, emissions and generating efficiency. Although it has the highest total plant cost without carbon capture, the availability to retrofit the ultra-supercritical systems with CCS seems more feasible. Among the choices, USC units have fewer emissions, less costs of electricity and less total plant cost after a potential CCS retrofit. On the other hand, under certain assumptions, IGCC or Oxy-Fuel technologies are at least as advantageous as USC system in terms of cost structure as well as performance measures, which is demonstrated in the figure below:

	SUPERCRITICAL PC		SC PC-OXY	IGCC	
	W/O CAPTURE	W/ CAPTURE	W/CAPTURE	W/O CAPTUREQ	W/CAPTURE
PERFORMANCE					
Heat rate (1), Btu/kW$_e$-h	8,868	11,652	11,157	8,891	10,942
Generating efficiency (HHV)	38.5%	29.3%	30.6%	38.4%	31.2%
Coal feed, kg/h	184,894	242,950	232,628	185,376	28,155
CO_2 emitted, kg/h	414,903	54,518	52,202	415,983	51,198
CO_2 captured at 90%, kg/h (2)	0	490,662	469,817	0	460,782
CO_2 emitted, g/kW$_e$-h (2)	830	109	104	832	102
COSTS					
Total Plant Cost (3), $/kW$_e$	1,330	2,140	1,900	1,430	1,890
Inv. Charge, ¢/kW$_e$-h @ 15.1% (4)	2.70	4.34	3.85	2.90	3.83
Fuel, ¢/kW$_e$-h @ $1.50/MMBtu	1.33	1.75	1.67	1.33	1.64
O&M, ¢/kW$_e$-h	0.75	1.60	1.45	0.90	1.05
COE, ¢/kW$_e$-h	**4.78**	**7.69**	**6.98**	**5.13**	**6.52**
Cost of CO_2 avoided vs. same technology w/o capture (5), $/tonne		**40.4**	**30.3**		**19.3**
Cost of CO_2 avoided vs. supercritical technology w/o capture (5), $/tonne		**40.4**	**30.3**		**24.0**

Basis: *500 MW$_e$ plant net output, Illinois # 6 coal (61.2 wt % C, HHV = 25,350 kJ/kg), & 85% capacity factor; for oxy-fuel SC PC CO_2 for sequestration is high purity; for IGCC, GE radiant cooled gasifier for no-capture case and GE full-quench gasifier for capture case.*
(1) efficiency = (3414 Btu/kW$_e$-h)/(heat rate)
(2) 90% removal used for all capture cases
(3) Based on design studies done between 2000 & 2004, a period of cost stability, updated to 2005$ using CPI inflation rate. Refers to the Nth plant where N is less than 10. 2007 cost would be higher because of recent rapid increases of engineering and construction costs, up to 30% since 2004.
(4) Annual carrying charge of 15.1% from EPRI-TAG methodology, based on 55% debt @ 6.5%, 45% equity @ 11.5%, 39.2% tax rate, 2% inflation rate, 3 year construction period, 20 year book life, applied to total plant cost to calculate investment charge
(5) Does not include costs associated with transportation and injection/storage

Figure 3.9: Representative Performance and Economics for Oxy-Fuel Pulverized Coal and IGCC Power Generation Technologies, Compared with Supercritical PC.[238]

[238] Ibid., p.30.

IGCC and Oxy-Fuel technologies have a tendency to be less costly considering these options with CCS. Total plant cost of IGCC rises by $460/kW due to retrofitting CCS, while the same case results to a $730/kW for a USC system. Albeit the cost of electricity in both IGCC and Oxy-Fuel options without CO2 capture are higher than USC, the tables indicate that adding CCS make IGCC the cheapest option among these three choices.

c. Focusing on CCT Implementation in Turkey

Projects for applicability of clean coal technologies are in process and both academic and governmental institutions have been striving to research new methods of power generation, which aims at increasing efficiency along with reducing emissions, compatible with Turkish electricity outlook. Turkish Coal Enterprises (TCE) & MAM Energy Institute of TÜBİTAK[239], for instance, have been developing an IGCC project by constructing and operating pilot power plants in order to observe the applicability of IGCC technologies for lignite reserves.[240] Moreover, a similar project called OPTIMASH, which aims at gasifying lignite with high ash content in order to reach the plausible efficiency and emissions threshold by establishing a 1 MW pilot power plant to be observed.[241]

Studies on CCT carried out by different institutions indicate that clean coal will have a potential for the future in Turkey as a country with abundant coal reserves. On the other hand, developments for clean coal are encountered with environmental oppositions. Greenpeace, for instance, defines the clean coal technologies will be available to operate at least by 2020, when is too late to prevent the significant amounts of emissions, at high costs.[242] However, beyond the ongoing developments, few coal-fired power plants with CCT have operated in Turkey. İÇDAŞ Company, which has an installed coal-fired capacity of 1605 MW, has been generating electricity around 14 TWh per annum with 2 supercritical PC and a Circulating Fluid Bed (CFB) technology.[243] In addition to

[239] The Scientific and Technological Research Council of Turkey.

[240] "Kömür Sektör Raporu (Linyit)", Türkiye Kömür İşletmeleri, 2013, p.55.

[241] M. Gökalp Ersoy, "Türkiye Linyitlerinin Elektrik Üretimi Amaçlı Değerlendirilmesine Teknolojik Bir Seçenek: "OPTIMASH" Projesi", 2012, p.3.

[242] Energy (R)evolution, Greenpeace International, 2012, p. 61.

[243] http://www.icdas.com.tr/pages/3723/429/f/tr-TR/Enerji.aspx accessed on 27.07.2014.

acquiring high performance in terms of SO2, NOx and mercury emissions, the CFB unit has a monitoring system, which shows the emissions of dust, SO2, NOx and CO way below the critical values.[244]

Researches for cost structure of CCT and carbon capturing technologies in Turkey are not visible enough; therefore it is quite hard to state a preference depending on the cost effectiveness. However, the costs of clean coal technologies together with carbon capturing retrofits are relatively high investment costs in spite of their ability to cut the environmental costs.[245] Comparing to the technologies according to coal types, on the other hand, an inclination IGCC-oriented development projects for lignite with high ash and dust content in Turkey appears as a feasible option because of availability to be retrofitted with CCS at relatively lower cost and lower emissions monitored in the previous section. As long as CFB units are suitable enough for high-ash coals, they might also be taken into account for Turkish lignite.[246] Specifically for hard coal, USC units might be considered as an appropriate option due to their high generating efficiency at high steam pressure and temperature.

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[244] http://www.icdas.com.tr/pages/5750/4741/f/tr-TR/iCDAs_Akiskan_Yatakli_Santral_Baca_Gazi_Olcum_Degerleri.aspx, accessed on 27.07. 2014.

[245] Şengüder, İ. "Kömür-Enerji-Çevre Üçgeninde 'Linyit SWOT Analizi'" MTA, p.4-5.

[246] "The Future of Coal" MIT Press, 2007, p.22.

3. Remarks for Alternative Solutions

Alleviation of GHG emissions caused by an inevitable case of "the return of coal" might be potentially achieved with Clean Carbon Technologies (CCT) and Carbon Capture & Storage (CCS) systems. In terms of other environmental threats for Turkey, such as combustion wastes, water pollution and coal dusts, there are alternative solutions as both methods and systems. Combustion wastes, for instance, might be prevented to leach by using a concrete wallboard made from the wastes or these wastes might be sold to as a raw material for certain industrial purposes such as cement or construction after a recycling process.[247] This alternative would also mitigate risks of water pollution caused by the wastes, a prevalent case in Turkey. Various preventive actions in mining process such as spraying water on roads, conveyors and having a land as a buffer zone between the mine and nearby place could reduce the effects of coal dust at a significant level.[248] Apart from the potential solutions to be addressed, however, the much bigger question mark as an obstacle remains as a main threat to achieve to prevent negative effects: aggressive strategies in coal-fired power plant projects, such as putting effort to locate a thermal plant right in the middle of a certain natural habitat, are regarded as the most threatening aspect of environmental hazard.

Negative environmental impacts of coal-fired power plants on Turkey are mostly a result of private investment projects with least environmental concerns. In addition to cases clearly explained in "1.b. Impacts of Coal on Environment in Turkey", happenings for Karabiga thermal plant point out the main obstacle: the project had an installed capacity of around 415 MW and the power station is planned to be established in Çan region in Çanakkale province.[249] However, the main source of income of the region is agricultural activities with fertile lands, which might be under threat by a new coal-fired power plant. Ministry of Environment and Urban Planning evaluated the project in the context of Environmental Impact Assessment (EIA)[250] report and

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[247] "Coal in a Climate Change", *Natural Resources Defense Council*, 2007, p.15-16.

[248] "The Coal Resource: Comprehensive Overview of Coal", World Coal Institute, 2009, p.28.

[249] "Çanakkale Çan'da ikinci termik santral için ÇED süreci başladı", 2014, http://yesilgazete.org/blog/2014/02/18/ozel-haber-canakkale-canda-ikinci-termik-santral-icin-ced-sureci-basladi/ accessed on 28.07. 2014.

[250] Çevre Etki Değerlendirme raporu.

determined the project is appropriate regarding environmental concerns. On the other hand, Provincial Court of Çanakkale province cancelled the execution of the process with respect to negative impacts on agricultural lands, residential districts and aquatic environment.[251] Then the investors of the projects divided the application of EIA report into four parts like four different investments in order to proceed fast bypassing the court, which also rejected the four different EIA applications due to violation of legislation.[252] The remarkable action in this case is the ministry, as a governmental institution, approves the EIA process of the project with risks more than once.

Private investors do not have sufficient concerns for environment in terms of locating a coal-fired power plant project nearby a terrestrial habitat. What is more, government might not be claimed as having a precautious attitude against aggressive strategies of private sector. It is possible to observe the negligent attitude of the governmental bodies in different examples, but the most recent case is quite remarkable, which is directly linked to Soma mining disaster, the greatest mining accident in the late history caused deaths of 301 workers in May, 2014.[253] The company operating the mine by royalty system has been considered as the responsible entity of the accident because of not making the necessary provisions, such as constructing rescue chambers in the mine, against a potential accident.[254] Furthermore, president of the company was proud of cutting the production costs by more than 80% a year before the accident.[255] Albeit the company has got such a shady image in terms of cost minimization strategies and caring well-being of the workers, Energy Markets Regulatory Authority (EMRA)[256] granted

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[251] "Karabiga termik santrali için iptal kararı", 2014, http://www.radikal.com.tr/cevre/karabiga_termik_santrali_icin_iptal_karari-1178174 accessed on 28.07. 2014.

[252] "Karabiga'da Kömürlü Termik Santrale Durdurma", 2014, http://www.bianet.org/bianet/toplum/155912-karabiga-da-komurlu-termik-santrale-durdurma accessed on 28.07.2014.

[253] "Soma faciası: Ölü sayısı 301, kurtarma çalışmaları sona erdi", 2014, http://www.bbc.co.uk/turkce/haberler/2014/05/140516_soma_toplama.shtml, accessed on 28.07. 2014.

[254] "Soma Holding'den 'yaşam odası' itirafı", 2014, http://www.milliyet.com.tr/soma-holding-yonetim-kurulu/siyaset/detay/1883363/default.htm, accessed on 28.07. 2014.

[255] "Soma Holding, kömürün maliyetini 135 dolardan 24 dolara indirmiş", 2014, http://www.zaman.com.tr/ekonomi_soma-holding-komurun-maliyetini-135-dolardan-24-dolara-indirmis_2217816.html, accessed on 28.07. 2014.

[256] Enerji Piyasaları Düzenleme Kurulu (EPDK).

the company's separate application for coal-fired power plant along with mining facilities in Amasya province.[257] Furthermore, in spite of Soma disaster, the incumbent government refused the legislative proposal of opposition about necessitation of rescue chambers in mining facilities.[258]

Turkey has been facing different environmental impacts of coal-fired power plants; however the main obstacle which facilitates the negative effects to occur is investments with minimum environmental and societal concerns. In addition to diversification of technical solutions against the impacts, the environmental risk mitigation entails an increased level of executability of the environmental regulations. Besides, an emphasized policy about keeping coal power plant projects and mining facilities away from residential, terrestrial and aquatic habitats will alleviate the negative impacts without a doubt.

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[257] "Soma Holding'e bu defa termik santral izni", 2014, http://www.zaman.com.tr/ekonomi_soma-holdinge-bu-defa-termik-santral-izni_2234964.html, accessed on 02.08. 2014.

[258] "AK Parti'den madenlerde 'yaşam odası' zorunluluğuna ret", 2014, http://www.radikal.com.tr/turkiye/ak_partiden_madenlerde_yasam_odasi_zorunlulugun a_ret-1201218, accessed on 28.07. 2014.

Conclusion

The inevitable position of coal in Turkish electricity market has economic benefits as comprehensively mentioned in Chapter 2. On the other hand, coal is one of the most polluting fossil fuels with severe environmental effects. Greenhouse gas emissions have come to the forefront among these effects recently. In addition to various effects of emissions of nitrogen oxide, sulfur dioxide mercury and particulate matter, carbon dioxide (CO2) emissions threaten the environment by triggering climate change with an increase in global temperature rise. The necessity of keeping the rise at most 2ºC to avoid climate change entails to reduce CO2 emissions by 50% until 2050.[259] Apart from the emissions, coal-fired power generation cause water pollution by discharging water, which has an effect of breaking the balance of aquatic habitats. Combustion wastes from coal-fired power plants also pollute water and affect health of livestock. Albeit being a different phase from power generation, mining related processes have serious impacts on the environment. In case of surface mining, firstly, natural habitats might be damaged by cutting trees to open up a mining field. Secondly, water might be polluted by Acid Mine Drainage (AMD), a reaction resulting acidic and toxic matter in groundwater. Thirdly, mine release a great amount of methane, a gas 20 times more powerful than a GHG.

'The return of coal' will bring nothing than negative impacts to Turkey regarding environmental issues. GHG emissions in Turkey have been increasing with a significant contribution of coal-fired power generation. Moreover, disposal of toxic wastes from the power plants hinder farming and fishing activities to a certain extent. High ash levels nearby the power plants exacerbate the frequency of respiratory illnesses for a certain region. In addition, coal dust due to mining facilities effect the quality of air along with agricultural lands and livestock. Environmentalist organizations emphasize to switch the renewable energy sources in power generation and phase out coal in the near future in order to prevent these negative effects. On one hand, the renewables are quite applicable considering the regional outlook. On the other hand, they are not a type of sources that could be relied solely on. The first reason is uncertainty and unpredictability of these sources as an obstacle to meet demand increasing annually. The second argument is explained as feasible fields for renewable sources to generate

[259] "Technology Roadmap: High-Efficiency, Low-Emissions Coal-Fired Power Generation", IEA, 2012, p. 12.

electricity with a sufficient efficiency are not homogenously dispersed, which is a challenge for power grid to meet the regional demand. Therefore, it is more appropriate for the renewables to be promoted with regional projects rather than relying extremely on them in Turkey.

Clean coal technologies gain importance in case of “the return of coal” regarding the environmental concerns with respect to the necessity of reducing GHG emissions along with increasing generating efficiency. Considering both conventional and clean coal technologies, there are three main types of coal-fired power generation varying according to methods and systems, which are Pulverized Coal & Circulating Fluid Bed Combustion systems, Integrated Gasification Combined Cycle and Oxy-Fuel Combustion systems. In PC units, as the most prevalent technique of power generation, coal is pulverized and blown by air for combustion. Sub-types of PC systems vary with respect to steam temperatures and pressures during operation. Circulating Fluid Bed technology is accepted as another type of PC, however the operation is made by relatively lower temperatures with various fuels other than coal. IGCC technology is considered as a new clean coal technology, which aims at gasifying coal to make use of gas turbines. Oxy-fuel combustion system is based on combustion of coal with oxygen separated from air. However, this system has not been commercialized yet. Although these technologies are quite beneficial for both generating efficiency and cutting the emissions, Carbon Capture & Storage (CCS) systems are required to achieve the goal of keeping global temperature rise at 2ºC by 2050. Therefore, a cost comparison between these technologies should take retrofits of CCS into account.

It is hard to reach a solid study about cost comparison between different CCTs also considering CSS in current literature. Therefore, the cost analysis has been made according the most reliable study done by Massachusetts Institute of Technology (MIT). It is deduced that IGCC option is quite beneficial among the other options in terms of high generating efficiency, low levels of emissions and advantageous cost structure in case of CCS retrofit. In comparison among the PC units, ultra-supercritical units have the same advantages with IGCC.

Turkey has been conducting researches for CCT development and adaptation to domestic coal reserves. Among the studies done by predominantly governmental institutions, there is a slight inclination to IGCC technologies. On the other hand, there is an opinion stated by environmentalists that CCTs will not be able to operational until 2020, when is too late to prevent negative impacts of emissions. However, apart from the development works conducted, there are few coal-fired power plants implementing CCT successfully. One of these plants belongs to İÇDAŞ Company, for instance, are able to control GHGs, the emissions of which are way below the critical points. There is not any study found specifically for the cost structure of CCT in Turkey, however implementing CCTs are known as a costly option. Considering coal types consumed for power generation in Turkey, on the other hand, IGCC and Circulating Fluid Bed technologies would be appropriate for Turkish lignite with high ash content, while Ultra-Supercritical systems might be evaluated for hard coal.

There are several environmental challenges that Turkey has been encountering except GHG emissions. Each problem mentioned case by case in "1.b. Impacts of Coal on Environment in Turkey" has a technical solution that mitigates the risks. However the most important obstacle to protect environment from coal is aggressive investment strategies of private sector, even determined to bypass the governmental processes with various methods such as dividing application into several different pieces in order not to be realized by the authorities. Moreover, the government is not as precautious as it has to be in these cases so that the company allegedly responsible for Soma disaster, the most catastrophic mining accident for the last few decades, could be able to get a license for a coal-fired power plant located right at a natural environment. In the light of these incidents, the government should take more strict actions in order to prevent aggressive strategies of private companies that might harm the environment. In other words, to keep the coal-fired power plants distant from environmental regions, residential areas and aquatic habitats will be a quite solid course of action for Turkey in return of coal case.

CONCLUSION

This study has elucidated the return of coal case characterizing its potential economic gains and environmental costs for Turkish power market. The main aim has been a clarification of the possible effects of coal on both the costs and stability of electricity market. The objective has also been as putting an emphasis on negative environmental impacts of coal-fired power generation, which are based on various reasons such as greenhouse gas emissions, combustion wastes and mining related outcomes. Moreover, the study has underlined that the bigger issue which aggravates the negative impacts is a lack of government supervision against profit maximization strategies of private investors with minimum environmental concerns.

In light of these points, main argument of the study has been formed as follows: the return of coal is a feasible case considering economic aspects for the Turkish electricity market. Regardless of its types, coal has a more cost effective structure than other fossil fuels and an inclination to coal is able to maintain a more predictable power market by risk mitigation depending on gas export. On the other hand, coal as a fuel has severely negative environmental impacts that might significantly harm certain habitats along with accelerating climate change. Moreover, environmentally inappropriate power plant projects approved by Turkish government have been making the case worse. Therefore, the main argument simply points out two preventions in terms of diminishing environmental damages: promotion of Clean Coal Technologies (CCT) and strict government policies to restrain establishment of coal-fired power plants at environmentally vulnerable areas.

The first chapter of thesis has contained a definition coal. It is roughly classified as brown coal (lignite) and hard coal according to calorific value determined by international classification standards. The main advantage of coal is its more homogenous dispersion around the world compared to other fossil fuels; however few countries have been dominating both reserves and production & consumption activities. Specifically, China and India are considered as the largest players and they are also expected to retain these positions for several decades, including coal-fired power generation. Turkey has lignite reserves abundantly; therefore both public and private companies share the reserves while hard coal reserves completely belong to the state. Production & consumption values have increased for the last decade and lignite production is able to meet demand while hard coal has to be imported. In terms of electricity generation, coal has a significant share in both total installed capacity and daily & annual generation values. Its significance seems to grow due to remarkable number of licensed coal-fired power plant projects. The growth has a reason considering an effort of government to reduce the external dependency in energy import. Albeit there is not a proclaimed policy, an inclination to coal of both government and the market is visible, which might be called as "the return of coal".

The second chapter has made an economic comparison between coal and natural gas because of the domination of the gas in Turkish electricity market. Comparing generally the cost performance of these two fossil fuels, coal is realized as a more effective option in the long run, although the total plant costs of both fuels are close. Almost all of natural gas consumed in Turkey has been imported for years. Therefore, three factors that make the natural gas an economic & geopolitical vulnerability for the Turkish power market are high import costs, heavy contract liabilities and high levels of external dependency. The return of coal case is quite able to alleviate the negative impacts causing the vulnerability in terms of lower production costs and lower costs of electricity generation. Apart from the cost effectiveness, the return of coal case contributes to establish a more predictable power market by minimizing the risk of price fluctuation, compared to natural gas. After the privatization process of the power market, price mechanism is based on the offers of producers. In that outlook, a heavy dependence on gas import in power generation carries three risks that might lead to massive crises with remarkable price fluctuations: capacity constraint of pipeline for gas import, exacerbation of challenge of locational asymmetry of installed capacity and externalities depending on being an importer country. If coal-fired power plant projects are promoted, compared to natural gas power plants, coal as a domestic fuel will certainly alleviate the negative effects of these three problems.

The third chapter has clarified the environmental damages caused by coal-fired power plants. Emissions of Greenhouse Gases (GHG) come to the forefront because of triggering the climate change. If carbon dioxide emissions will not be halved by 2050, the global temperature rise will be more than 2°C that will lead to flooding and drought. Apart from the emissions, negative impacts such as water pollution, coal combustion wastes and mining related impacts, which are water pollution, air pollution and ruining terrestrial habitats, have been comprehensively explained. The negative environmental impacts of coal in Turkey have been characterized case by case experienced recently, which are air pollution, water pollution and coal dust along with the combustion wastes. The renewables have been evaluated as a potential solution; however the unpredictability hinders them to be relied solely on. Therefore, Clean Coal Technologies to increase generating efficiency and reduce the emissions have been justified and classified with respect to their types together with the conventional technologies. Moreover, necessity of Carbon Capture & Storage (CCS) systems to achieve to retain the temperature rise at most 2°C has been briefly stated. Cost evaluation between different generation technologies also considering CCS has been made. The recent developments and power plants in terms of CCT implementation in Turkey have been mentioned. Finally, alternative solutions have been addressed to prevent environmental damages such as coal dust, water pollution and wastes. On the other hand, the bigger problem which triggers the environmental impacts has been emphasized: aggressive investment plans with minimum environmental concerns. As a last statement, it has been underlined that the government should take action to prevent these plans in order to keep proposed coal-fired power plants away from the ecological areas.

Certain outcomes are determined regarding the return of coal case depending on efforts to draw a conclusion in this research. An inclination to coal in Turkish electricity market will significantly alleviate negative impacts of issues depending on external dependency in energy supply considering economic concerns. Apart from the fact that coal has much lower fuel cost, flexibility of coal mainly stems from having sufficient lignite reserves as a domestic resource in the Turkish case. Apart from the lignite, however, hard coal might be still a feasible option comparing to gas import with heavy liability. Thus, risks depending on the gas import, which would end up as price fluctuation in the market, might be diminished. In terms of environmental concerns, the most serious issue is an ability of private investors to bypass monitoring processes of government regarding the environmental availability. All environmental challenges that Turkey has been facing due to coal-fired power generation has technical solutions. On the other hand, certain incidents occurred recently indicate that main problem is poor efforts of government to prevent power plant projects to be constructed nearby terrestrial habitats. Therefore, government policies, which are effective enough to keep detrimental projects away from environmentally vulnerable areas will certainly decrease level of the environmental damages to a large extent.

The thesis has three major limitations. The first one is the difficulty to reach a well-structured cost comparison for Turkish electricity market. Albeit the market is said to be transparent, it is almost impossible to find out capital cost or operation cost for a specific power plant regardless of fuel used to generate. The second challenge is to find any instructive study about the costs of Clean Coal Technologies along with Carbon Capture & Storage systems, especially for the Turkish market. Even though there are few coal-fired power plants which have CCTs, a type of study could not be found. Besides, it is surprisingly difficult to find a certain study about clean coal systems, except “The Future of Coal” of MIT Press published in 2007. There could not be seen a work that slightly mentions the costs without referring to “The Future of Coal”. As a third limitation, issues such as work safety in mining facilities were not completely compatible with the scope of the research question. Therefore, Soma mining disaster, the most catastrophic mining accident for the last several decades happened recently, could not be comprehensively evaluated in the context of return of coal case.

Considering the general flow of thesis with the limitations mentioned, two further questions might be derived in order to be asked. The first one is about matching the right technology with the right coal type: What will be the most feasible combination of a certain Clean Coal Technology and coal type in Turkish electricity market economically and environmentally? Which set of options will provide an optimum level of GHG emissions along with an optimal cost structure? The second further question is about the behavior of power market: Considering the return of coal case, what will be the behavior of the private power plant investments if the government carries more strict environmental regulations? Will be any shift to any other resources for power generation? If so, which resource will be shifted? What is the status of market in terms of prices and stability?

The thesis clearly indicates that the return of coal, which means an inclination to coal, is an economically viable however environmentally infeasible case for Turkish electricity market. It is economically viable, because it is more cost effective than gas import, which dominates the power market, considering high import prices, heavy contract obligations and high level of external dependency of the gas. Moreover, natural gas also caused crises for several times due to capacity constraint of gas pipeline, exacerbation of locational asymmetry of installed capacity and external factors. The return of coal case are quite able to mitigate the risks depending on the gas import, thus more predictable power market in terms of prices might be established. This would be possible with utilization of coal as a domestic fuel and increasing coal-fired power plant projects in regions dominated by natural gas power plants. Apart from the economic aspect, on the other hand, the return of coal will be harmful for the environment because of negative impacts, such as greenhouse gas emissions, water pollution, air pollution, and spread of coal dust. There are two actions for mitigating the environmental risks: the most feasible CCT technology should be implemented and coal-fired power plants should be established at places by far distant from ecological regions. In order to make the second action happen, the government should strictly prevent the private companies with minimum environmental concerns. Therefore, coal will be environmentally reasonable option more than before and a point close to optimality between economic and environmental aspects will be found.

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