A SYSTEM DYNAMICS ANALYSIS OF ENERGY DEPENDENCY AND CONSUMPTION IN TURKEY

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Abstract

This study includes a system dynamics model to analyze the energy demand, production and energy consumption in an integrated framework. The main focus of this study is on domestic and imported energy consumption in Turkey. We develop a system dynamics model to analyze energy market of Turkey. By investigating last ten years demand data showed that the energy consumption increases exponentially and Turkey has heavily dependent on import. In this study, energy consumption in the energy industry is estimated under various production and export scenarios while taking into account new energy prices to see the energy demand outlook over the next one or two decades. In this work scenarios are investigated to decrease the energy dependency in Turkey. It is shown that, potential reduction in energy consumption by using alternative energies can lead billions of dollars in savings for the twenty year period.

TÜRKİYE'NİN ENERJİ BAĞIMLILIĞI VE TÜKETİMİNİN SİSTEM DİNAMİĞİ İLE ANALİZİ

Özet

Bu çalışma enerji talep, üretim ve tüketimini birlikte analiz etmek amacıyla oluşturulan sistem dinamiği modelini içermektedir. Çalışmanın asıl yoğunlaştığı alan Türkiye'nin ithal ettiği enerji miktarı ve bunun ülkemize olan maliyetidir. Türk enerji piyasasının dinamiklerini analiz etmek amacıyla sistem dinamiği modeli oluşturuldu. Son on yıllık talep verileri incelendiğinde enerji tüketiminin önemli oranlarda arttığını ve bu yapının yüksek oranlarda ithalata bağlı olduğu göze çarpmaktadır. Yapılan çalışmayla ülkemizdeki enerji tüketiminin yapısı; kendi üretimimiz ve iç dinamiklerimizde ele alınarak farklı senaryolar eşliğinde önümüzdeki yirmi yıllık periyottaki enerji tüketimini tahminlemeyi ve bunun ülkemize olan faturasını gözönüne sermeyi amaçlamaktadır. Yaptığımız analiz ve çalışmalar alternatif enerjinin daha etkili bir biçimde kullanımıyla önümüzdeki on yıllık periyotta milyarlarca dolarlık tasarruf yapılabileceğini göstermiştir. Bu çalışmada Türkiye'nin enerji piyasası ve dışa bağımlı yapısı incelenmeye çalışılmıştır.

Acknowledgements

There are many people who helped to make my years at graduate school most valuable. First, I would like to thank to my supervisor, for his guidance.An honorable mention goes to my family and friends for their understandings and supports on us in completing this study.

To my family for their love, endless support and encouragement..

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List of Abbreviations

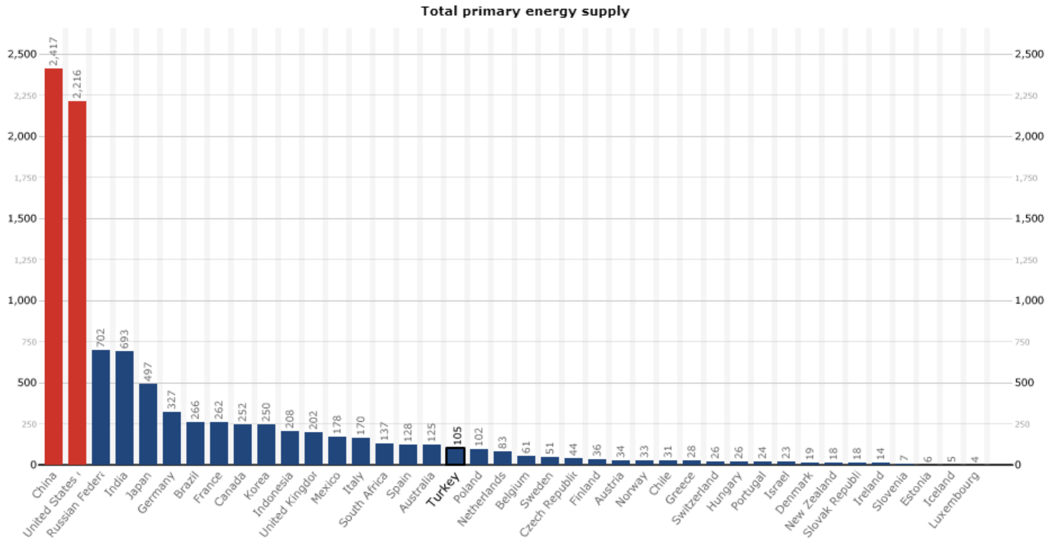
OECD	Organization for Economic Co-operation and Development
EU	European Union
GDP	Gross Domestic Product
SSA	Sub-Saharan Africa’s
US	United States
TPAO	Turkish Petroleum Corporation
BOTAS	Petroleum Pipeline Corporation
NPP	Nuclear Power Plant
EUAS	Turkish Electricity Production Company
lEA	International Energy Agency

1 Introduction

First of all, it would be reasonable to start with identifying the importance of the energy. Everything in the world runs on energy. The importance of it can be realized even in our bodies. They use energy by the burning of calories in order to function and produce the electricity our nerves use to control our movement. Examination of it shows that there are many different forms of it that we have been using to take advantage of them. When we come to the population of world it continues to grow past the 7 billion mark, the demand for energy is becoming an ever more critical challenge for the world's energy leaders. Governments are looking for sustainable solutions that provide the most competitive energy supplies from secure sources, whilst at the same time trying to balance the long-term, and in some cases, short-term needs of the environment[1]. Global energy demand expected to increase by over one-third for the next twenty year period. About half of the increase in global demand goes to power generation and one-fifth to meeting transport needs –mostly in the form of petroleum- based fuels.

Developing countries, whose economies and populations are growing fastest, contribute more than half of the increase in global primary energy use. The emerging countries China and India alone account for forty-five of the increase. In aggregate, developing countries make up more than half of the global energy market in twenty year period. This number is today is just forty percent.

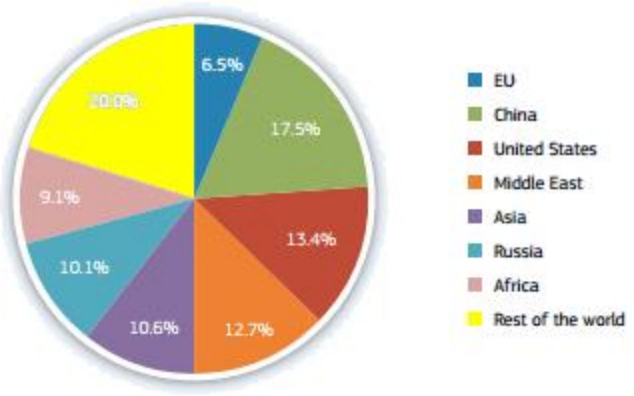
In order to analyze energy problems it is required that a comprehensive projection of the supply and demand data for all fuels. Energy supply growth was constant over the period thirty year period until 2008 economic crisis. In 2009 energy supply declined %1 but in 2010 it increased by %5. Strong economic development in Asia led to a large increase in the share of non-OECD Asia (including China) in world energy supply, from 13% to 31% over the same period[2]. Total primary energy supply by countries can be shown in Figure 1.1.



The unit of account adopted is the tonne of oil equivalent (toe).

Figure 1. 1 Total Primary Energy Supply

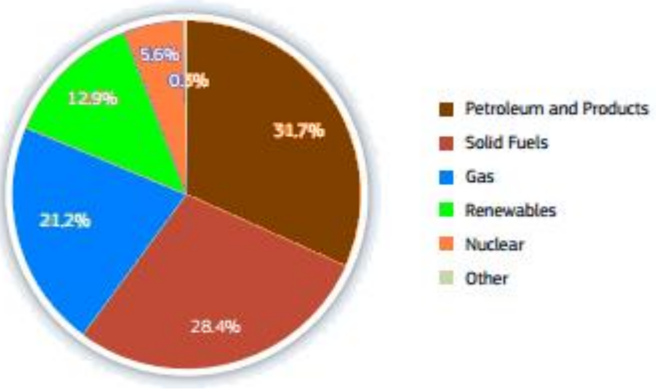
Analysis of the region which energy production occurs that can be seen the distribution in Figure 1.2



Total of 12840 Mtoe in year 2010.

Figure 1. 2 World Energy Production by Region

In the Figure 1.3 It can be seen that the amount of the production by the material type.



Total of 12840 Mtoe in year 2010.

Figure 1. 3 World Energy Production by Fuel (%)

It is projected that much of world energy consumption will grow more than half in the next twenty year period. It is analyzed that the growth in energy consumption occurs in countries outside the Organization for Economic Cooperation and Development (OECD), known as non-OECD, where demand is driven by strong, long-term economic growth. The World Energy Consumption can be shown in Figure 1.4 and Figure 1.5

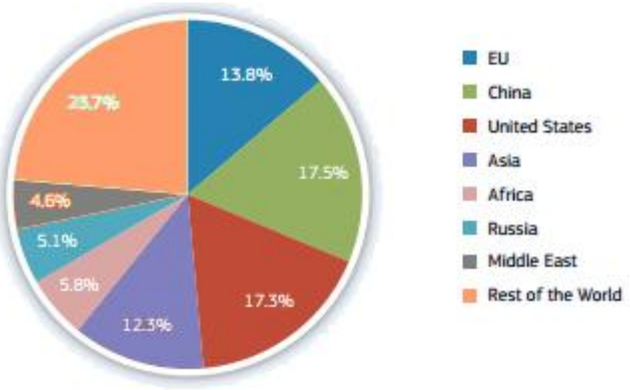


Figure 1. 4 World Energy Consumption by Region

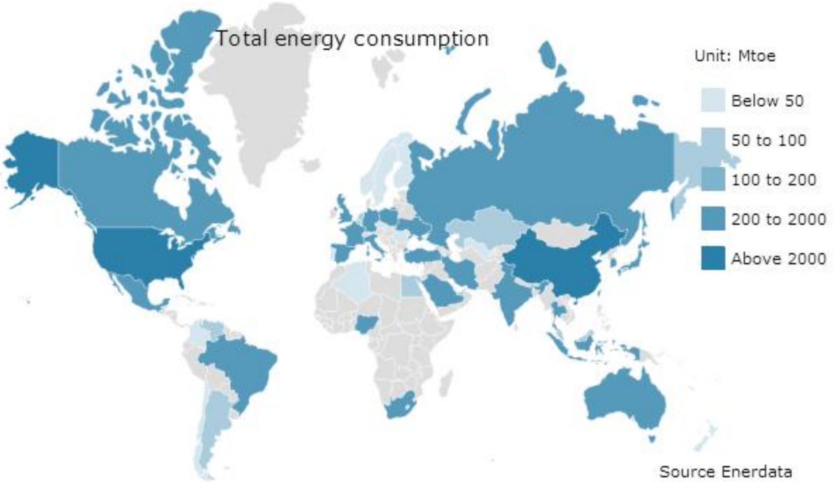


Figure 1. 5 Reflection of the Energy Consumption on the World

1.1 Asia

From the current estimations it can be seen that Asia is the world's largest and most populous continent. It covers 8.7% of the Earth's total surface area and comprises 30% of its land area. With approximately 4.3 billion people, it hosts 60% of the world's current human population. Asia has a high growth rate respectively.. It is bounded on the east by the Pacific Ocean, on the south by the Indian Ocean and on the north by the Arctic Ocean. China's population growth rate expected to decrease towards 2050, the average growth of India is assumed to continue at about 1.1%. As a result, the population of Asia will increase from 3.9 billion in 2005 to more than 4.5 billion in twenty year period. Because of the market-oriented economic progress and development in information technology, the world economy has become globalised at a rapid pace and has achieved an annual growth rate of 2.7% over the past 20 years[3]. In particular, Asian countries have attained high economic growth (4.0%), far exceeding that of the world economy thanks to the investment and export brought about by foreign direct investment, as well as active technology imports and a plentiful supply of a high quality workforce. These facts inditace that Asian countries have been the driving force for the world's economy, and Asia has a huge impact on the world's energy demand.

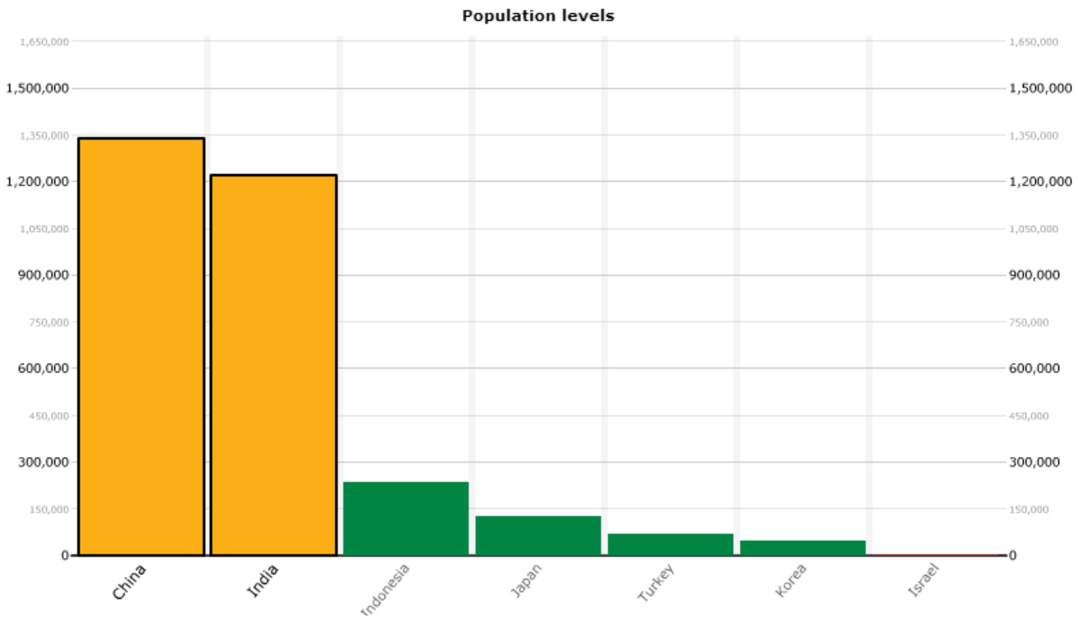


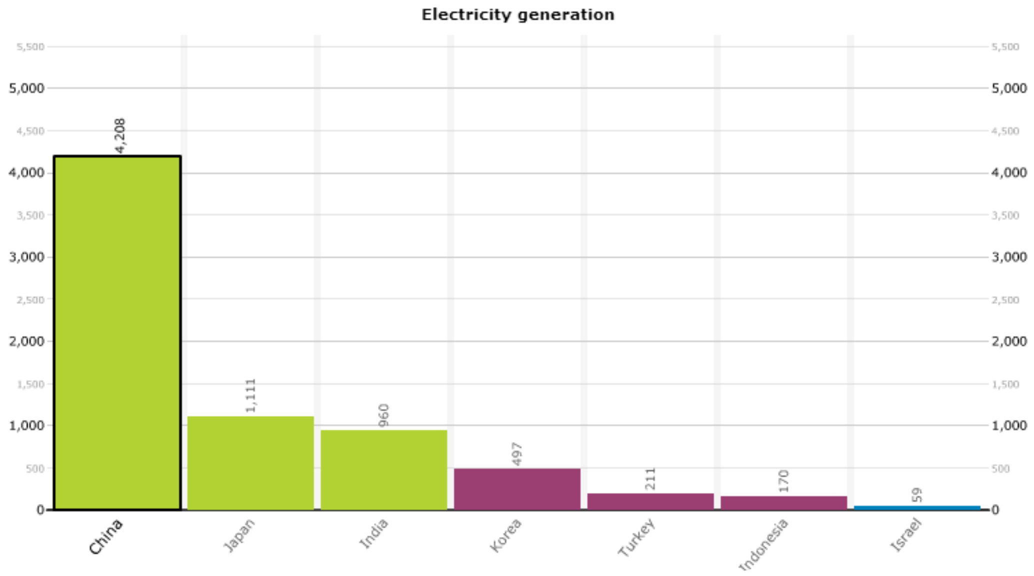
Figure 1. 6 Asian Countries Population in 2010.

The Asian share of the world's primary energy consumption is currently around 40% (it can be seen in Figure 1.4 and 1.5), while primary energy production is around 45%. With the support of its surging domestic demand, China's economy will sustain high rates of growth, and India has recently been rivaling China. Forecasts indicated that for the twenty year period,the economic growth rate of India might be higher than that of China and over the period to 2050 India may attain more stronger conditions than China. So, every aspect of this region like GDP and growth rate will for the most part depend on these two countries. Asian countries, especially emerging economies, have experienced increasing demand for electricity as a result of rapid economic growth. To meet the increasing demand, Asian economies are relying heavily upon coal and nuclear as their main energy sources.Asia's primary energy demand will grow at an average of 2% for the twenty year period. They require 15 billion tons of oil equivalent approximetaly. About 60% of the increase is for China and India. Fossil fuels account for almost 70% of the increase in consumption, therefore are expected to be an important energy resource for this period. As particular,coal is assumed to have the biggest pie of the increase, followed by oil and natural gas. Reasonably, the impact of the events in Japan following the accident at the Fukushima Daiichi nuclear power plant, while having affected the world, are probably more directly felt in Asia. The fact that Japan has seen the equivalent of a 72 per cent decrease in nuclear power generation, it has led them to thinking about other issues. To replace this supply, Japan has estimated six billion dollars on increased additional gas imports in 2011.

Developing Asian economies are becoming motorised societies as their standards of living improve and this trend will continue. With growing population and this in turn brings an increase in the demand for transportation fuel, oil, and to the extent that oil is scarce, coal conversion to liquid. As a results of at the Fukushima, Japan will also continue to export more LNG insted of nuclear energy.

Production of oil in Asia decelerates in the coming decades; however, total global production would meet increasing demands if combined with innovative, unconventional sources, thus avoiding an interruption of supplies. Neither China nor India produces enough oil or natural gas to meet its needs today and the shortfall is expected to grow. Natural gas is assumed to decline faster and shortages are made up to some extent with unconventional gas sources. Coal resources are much more abundant. As oil and gas supplies tighten, proven technologies for production of synthetic fuels through gasification/liquefaction of coal will be put into place as necessary.

Electricity supply expands along with the standard of living, boosted by its economic growth. For twenty year period, electricity consumption increases four-fold as a result of growing demand. In oil-equivalent terms, electricity generated by nuclear power is assumed to rise from 160 mtoe (million tons oil equivalent) in 2005 to the level of 1,000-1,500 mtoe in 2030, for an average annual growth rate of about 4.7%. Nuclear power plays a vital role in Asia, especially in China and India, which is predicted to account for about 70% of the nuclear power increase in Asia.



Electricity generation is measured in terawatt hours, which expresses the generation of 1 terawatt of electricity for one hour.

Figure 1. 7 Electricity Generation of Asian Countries

It has been expected for the future projections that there will be diffusion of renewable energy sources with little environmental burden, such as hydropower, geothermal energy, and new renewable energy (solar, wind, and biomass). Their share in primary energy production is anticipated to increase from 2% in 2005 to around 8% in 2030. However, collectively, they are not going to rank on a par with fossil resources as pillars of the base energy supply, due to their continuing high supply cost. New renewable sources of energy have to be encouraged, but developing countries cannot afford to be obsessed with it.

1.2 Africa

Africa is one of the most important continent as view of energy. It is the second largest continent of the world with an area of 30 million km2, representing 15% of the world's area and having a population of 865 million representing 13.5% of the world's population. Despite Africa being a rich continent in terms of abundant natural resources, diversified geographical regions, and different climate conditions, it is the least developed area in the world. About seventy per cent of Sub-Saharan Africa's (SSA) population (and 58 per cent of Africa's population) lack access to electricity, while some 80 per cent of SSA's population without access to electricity live in rural areas. The most important challenges are inadequate health care, education, a lack of clean water, energy poverty, very limited investments, weak infrastructure, lack of institutional capabilities and capacity-building, and inefficient utilities.

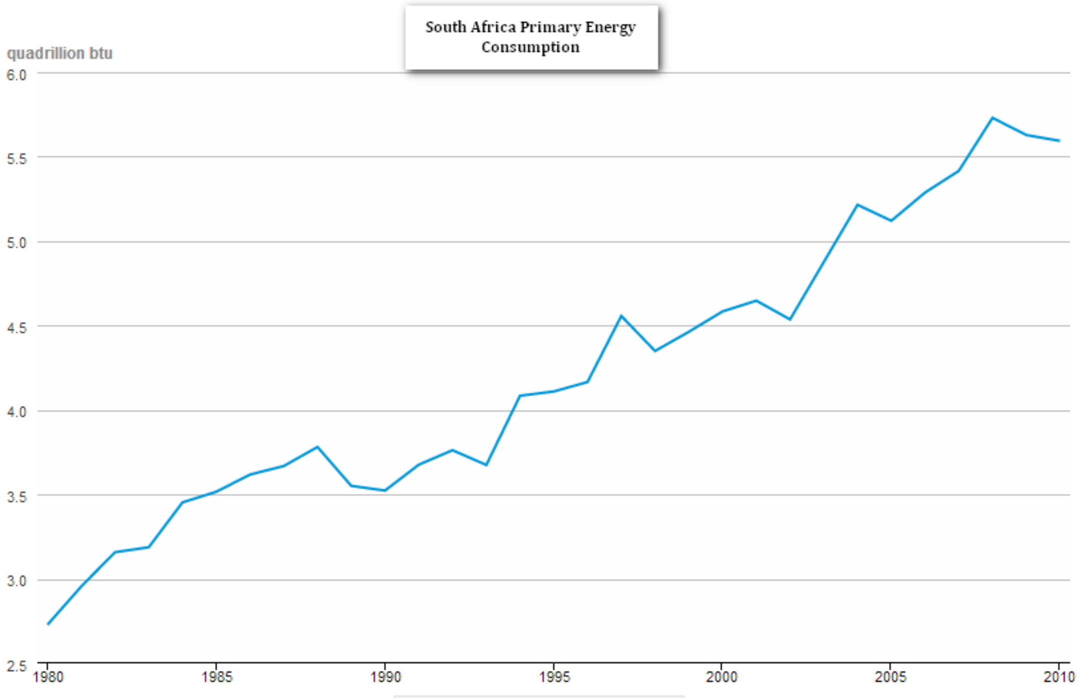


Figure 1. 8 South Africa Energy Consumption

As an effect on energy price change has indicated that increases in energy prices and rapid changes in energy markets represent a burden. It is not only on the economies of the most African countries on both macro and micro levels, but also on the daily life of the inhabitants, particularly those living in scattered remote areas. It has been crucial that there must be securing affordable modern energy supplies and services for sustainable development. Governments are required to strengthen cooperation and integration among its sub-regions as well as cooperation between the countries of the continent and the rest of the world. The role of private sector investment in accelerating development is vital, along with international cooperation. Overall, the African continent is a net energy exporter. In 2009 the net energy export was 40% of the energy production. Maximising the use of natural gas, associated gases, and promoting LPG, are essential for securing access to modern energy services, particularly in rural areas, as well as creating new job opportunities at local village levels. Promoting the use of nuclear power is considered one of the main solutions for the long-term energy sustainability of Africa.

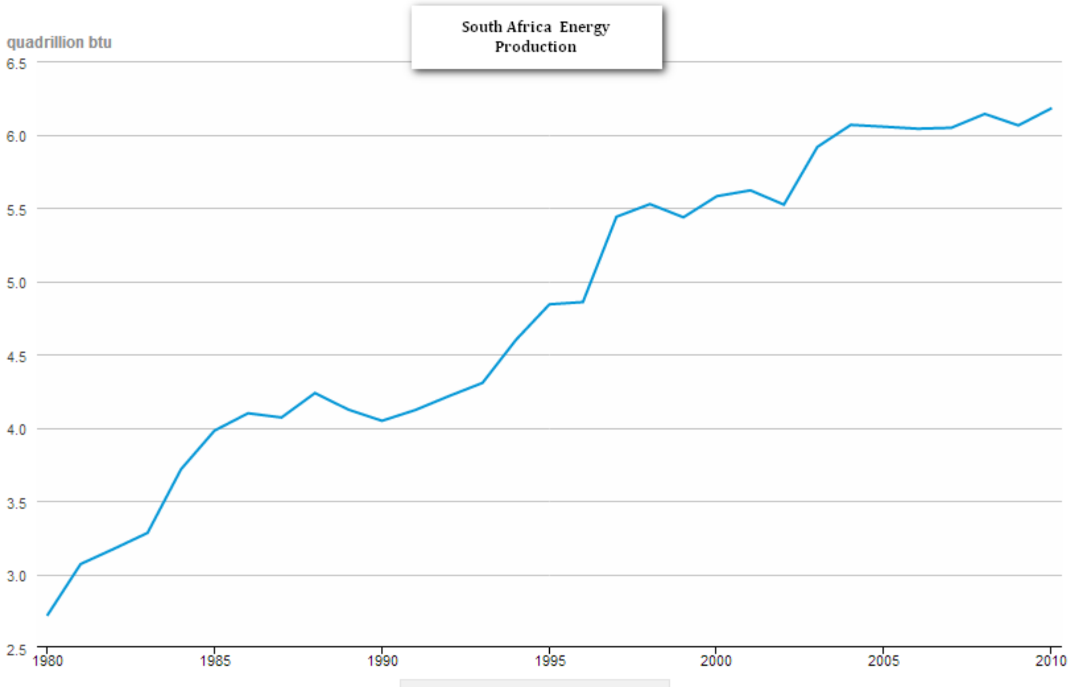


Figure 1. 9 South Africa Energy Production

1.3 Latin and North America

In the first part , the Latin America region and North America has analyzed. The Latin America region has a strong interest in the use of biofuels and hydroelectricity. One of the most important country of this region which Brazil is responsible for the most extensive global programme introducing biofuels into its energy matrix. Not only is the Brazilian programme responsible for the development of the domestic market and technologies, resulting in a high degree of efficiency along the entire ethanol production chain, but it also enabled the country to develop the sector that supplies foreign demand on a competitive basis. The region's dedication to bio-energy was recently underlined with the development of biodiesel as an alternative fuel, principally for transport. But, the Latin America region still demands large quantities of firewood for residential and industrial purposes. Besides being an inefficient and polluting energy source, the origin of this resource is mostly native forests, not always close to the point of consumption - implying high costs for the transportation of firewood. The most serious aspect related to the use of firewood, including charcoal, is the accelerated deforestation of certain regions with enormous damage to the environment. In terms of primary sources for electricity generation, the region is undergoing a process of diversification in its energy mix. Coal will likely become an alternative as technological advances mitigate the local air-pollution effects of generating electricity from coal.

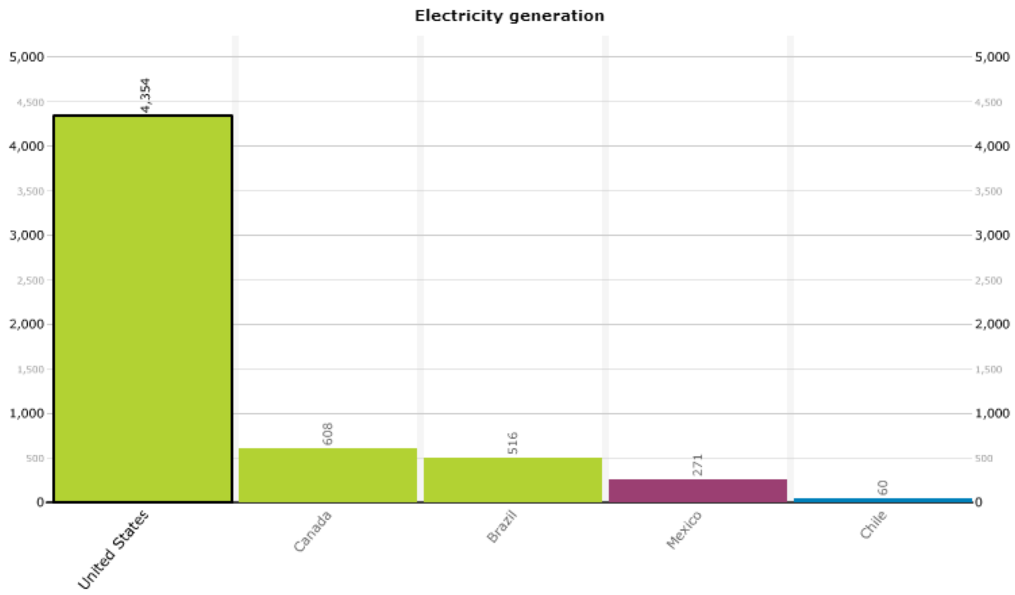
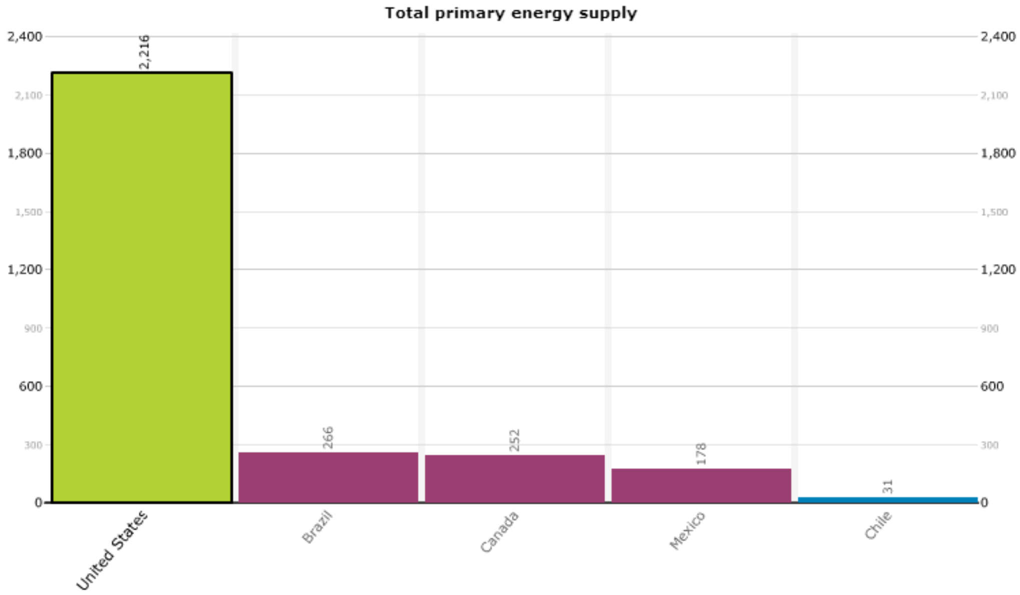


Figure 1. 10 Electricity Generation of Latin and North America

Other sources of energy could become more expensive with highly volatile international prices and heavy demand competition from developed countries. Furthermore, capital expenditures involved in harnessing some renewable energy sources and nuclear energy are still very high and their payback period very long. When it is analzed it can be realized that US has an huge impact on both supply and demand side not only in this continent but also in the world total energy sector.



The unit of account adopted is the tonne of oil equivalent (toe).

Figure 1. 11 Latin and North America Energy Supply

For the view of transportation, there is a need for more hybrid vehicles, as well as pure electrically driven cars and buses. This would decrease the region's dependence on oil products, and improve the environment from the reduction in greenhouse gas and other emissions. Moreover, the region faces enormous expansion and technological progress possibilities in terms of transport and related subjects. Its telecommunications sector offers an increasingly large range of products and services that reduce the need for moving people and printed information from one place to another, and consequently, should entail a significant reduction of energy consumption.

Investments in biofuels exports expand and as the interest in this product grows in other countries. A major effort on the part of the region is needed to leverage its competitive advantages, both existing and potential, in biofuel production. From the standpoint of imports, advances in technology for clean power generation from coal allow the region to import this product because a significant part of its own reserves are of comparatively low quality.

The region has to make substantial investments in order to successfully increase its energy independence and maximise local potential (natural gas in Bolivia and Trinidad and Tobago, oil and natural gas in Venezuela, hydroelectric power in Brazil and Colombia) to the benefit of the region as a whole. There is also economic parameters that affecting by energy sector , principally with respect to economic growth and income distribution because this provides the population with access to products of a higher quality and more advanced technology, thus making for the more efficient use of energy.Energy issues are becoming extremely challenged in the North American region. It is seen that nuclear is both a source of high uncertainty and high impact. With 104 reactors operating in. the United States, accounting for 20 per cent of America's electricity output, and two new reactors having been given Middle East dynamics are an important issue to the North American region as we now see coming to the fore with the impact of oil price on the United States' political landscape.

The need for energy supply continues to expand in North American region. Forecast studies have indicated that demand growth in North America will be more than 30% by twenty year period and could be as much as 50-70% for fifty year period. In order to overcome this challenges, North America will need to continue increasing its supply from all traditional sources, including oil, natural gas, coal, nuclear power, hydropower, and various renewable sources. Besides this, strong support is needed for new types of energy supply, including non-conventional sources, such as oil sands, oil shale, coal-bed methane, tight gas, and methane hydrates. There is also a need for additional supply from biofuels. Shale gas plays an important role in the global energy market as its global production will increase to 30%for twenty year period, and 70% of this will come from the US and Canada. As for oil sands, their environmental acceptability, including pipeline construction, will be the key element for their timely development and even the creation of a new market. Canadian government will look to new, emerging markets such as China. With the anticipated penetration of photovoltaic and wind energy into the grid and the much anticipated advent of the smart grid, the impact of electric storage may grow even bigger for the region. Free trade for North America is an important consideration for all three countries, especially energy. Canada and Mexico rank number 1 and 2, respectively, in exporting oil to the United States. There is also extensive trade in natural gas, uranium, coal, and electricity. Despite the abundance of indigenous energy resources in North America, there will be major energy trading outside North America. For example, the North America region will continue to be a major net importer of oil and natural gas and a significant net exporter of coal and uranium. In North

America, a variety of financing instruments is available for energy development and the risks are manageable, but some utility assets are discounted due to low returns.While the United States and Canada are generally considered attractive locations for such investment, Mexico is in a different situation which is related to the ownership and control of resources. Regional coordination is important for all three countries. The three countries entered into a North America Free Trade Agreement (NAFTA) in 1994 that provided opportunities for increased trade and the progressive removal of trade barriers.

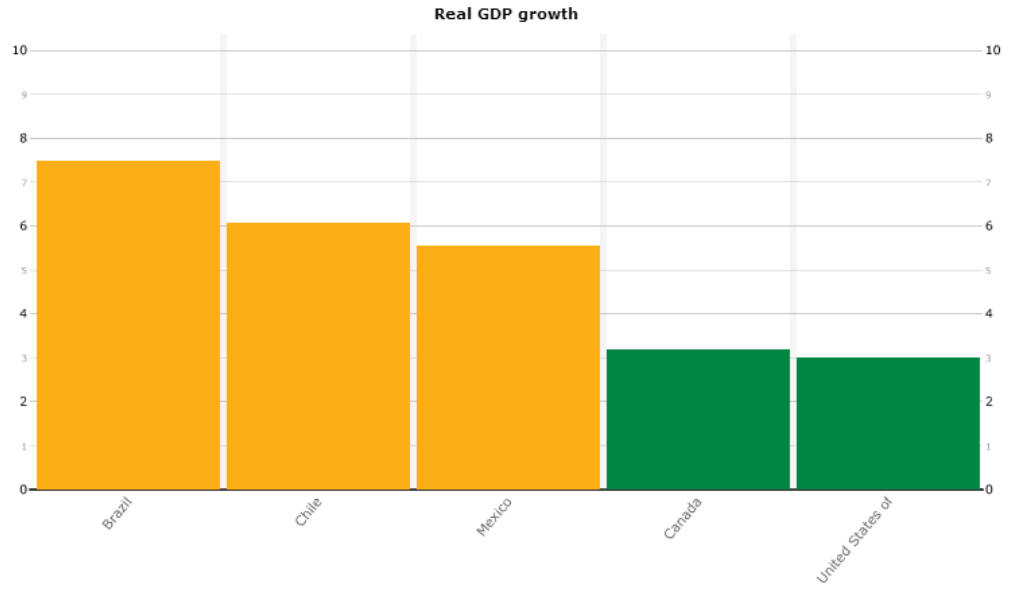


Figure 1. 12 GDP Growth of North and Latin American Countries

1.4 Europe

Energy infrastructure, including regional interconnection, is an important agenda for Europe. However, progress in areas such as large-scale, high-voltage transmission projects have been delayed by a lack of regulatory coherence. Transmission bottleneck issues could become more serious in future. The lack of an effective carbon market and a stagnating economy raise uncertainty regarding the future of technologies. In order to reach higher shares of green electricity there is a need for proper integration of renewables. So this strong need for new infrastructure is up against an economic situation that is currently a stress to investment. The region realizes that for a long time its culture and politics have inclined toward international orientation and cooperation. Looking from a world perspective, energy consumption per capita in the region is at a medium high level. An emission trading regime has come into force in the region, and finding the right balance between regulation and market now matters. Most important to Europe is accommodating the world at large, especially in China and India. This means that Europe believes it must significantly reduce carbon emissions.

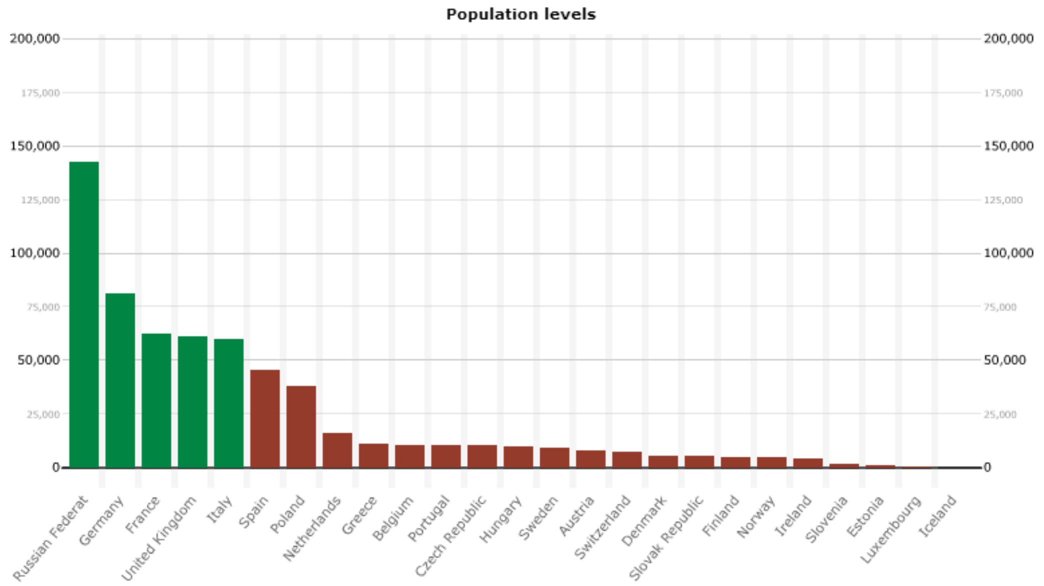


Figure 1. 13 Population of EU Countries

Coal in the European energy mix will be mostly for electricity generation. In that respect, it has to compete with other primary sources of electricity, mostly nuclear and renewables (including biomass). Unless supported by dedicated policies, coal use in electricity generation is determined by the costs of the various competing technologies, the prices of inputs, and the discount rate applied in the economic calculation. Socio-political constraints on nuclear power and renewable energy development might be larger than assumed. Nuclear power is invigorating in the EU in all scenarios, passing coal in almost all scenarios. This is not happening equally in Russia where the performance of coal is stronger. It could be worthwhile to explore further what this nuclear power revival in the EU would mean in terms of building programmes and fuel-cycle facilities.

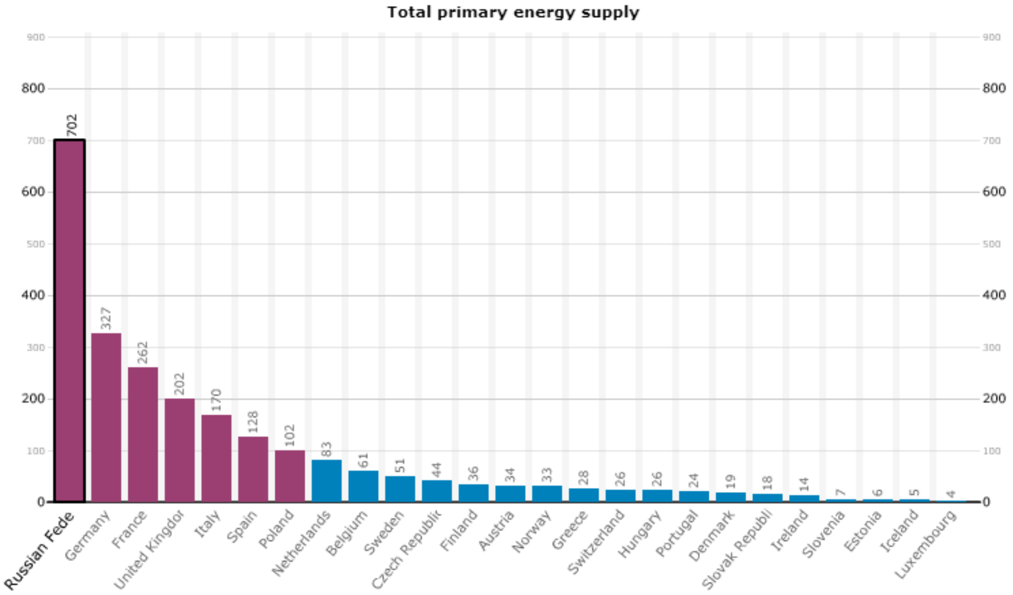
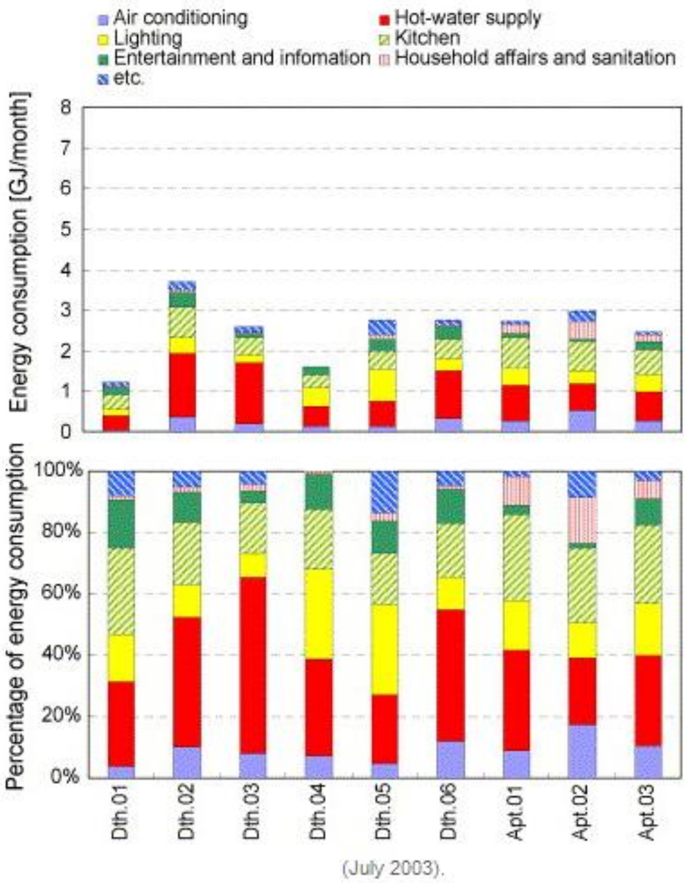


Figure 1. 14 European Countries Energy Production

2 Literature Review

2.1 Energy consumption behavior of residences in Japan

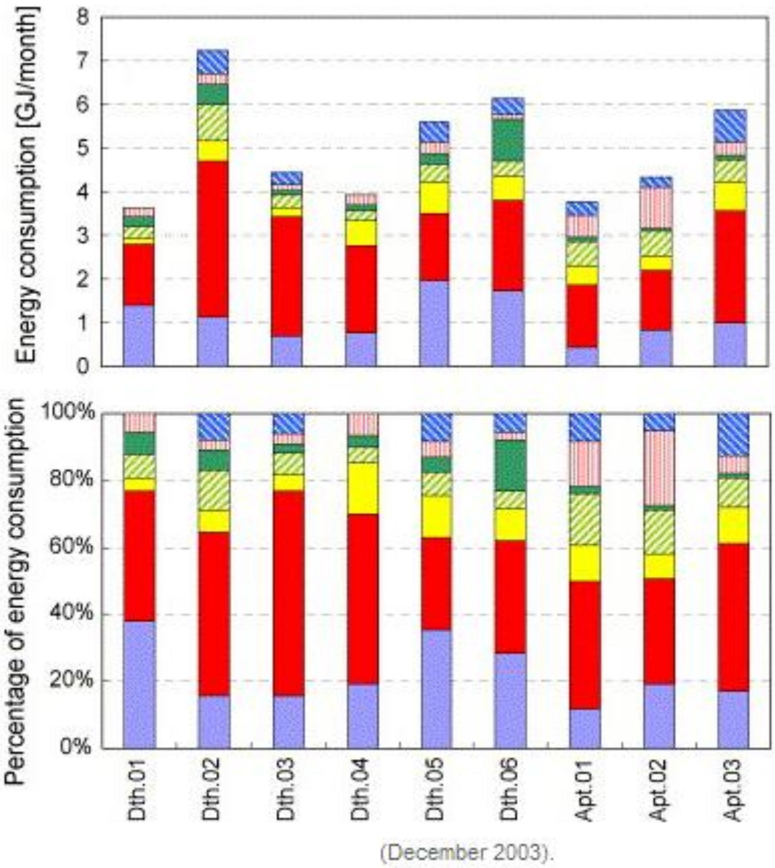
There are several studies in the literature have examined the energy consumption, production and its effects on economic growth. The results of these studies have no consensus because of using different data, period, and methodological approach. Therefore, some studies have found unidirectional causality running from energy consumption to economic growth, and running from economic growth to energy consumption. On the other hand, others have found some significant relation with some approaches between energy and economic growth. In this chapter it will be given some examples from the literature about importance of energy and affects on economic growth and sustainability. For example, household energy consumption at the national level is usually explained by macroeconomic indicators (e.g., GDP, employment rates, and price indices), climatic conditions, housing construction/demolition rates, and number of appliances in the residential sector. The advantage of this type of analysis is that it can be easily formulated to examine the effects of long-term changes or transitions of macroeconomic indicators on energy consumption and general trends, primarily for the purpose of determining supply requirements[4]. However, it is difficult to know whether and how households could respond to the policies derived from aggregate analysis. In the first study which is “Detailed research for energy consumption of residences in Northern Kyushu, Japan” energy consumption analyzed as seasonal. In this study every residence shows the largest percentage in energy for hot water supply that accounts for 14–58%. The energy for hot water supply, which is related to amount of hot water used and water supply temperature, tends to be consumed more as more family members live. But apartment Nos. 02 and 03, where residential bath with 24-h full automatic circulating system is used, consume less energy than other residences because the systems abate use of hot water. Energy consumption for hot water supply is 1.5 GJ/month at the most detached house No. 02, which decrease in use of hot water and increase in water supply temperature. The figure shows the summer energy consumption and winter energy consumption behaviours of Japan.[5]



Source :Energy and Buildings, Volume 38, Issue 11, November 2006, Pages 1349–1355

(Yasuto Takuma, Hiroyuki Inoue, Futoshi Nagano, Akihito Ozaki, Hiroto Takaguchi, Toshiyuki Watanabe)

Figure 2. 1 Energy Consumption of Japan in Summer 2003



Source :Energy and Buildings, Volume 38, Issue 11, November 2006, Pages 1349–1355

(Yasuto Takuma, Hiroyuki Inoue, Futoshi Nagano, Akihito Ozaki, Hiroto Takaguchi, Toshiyuki Watanabe)

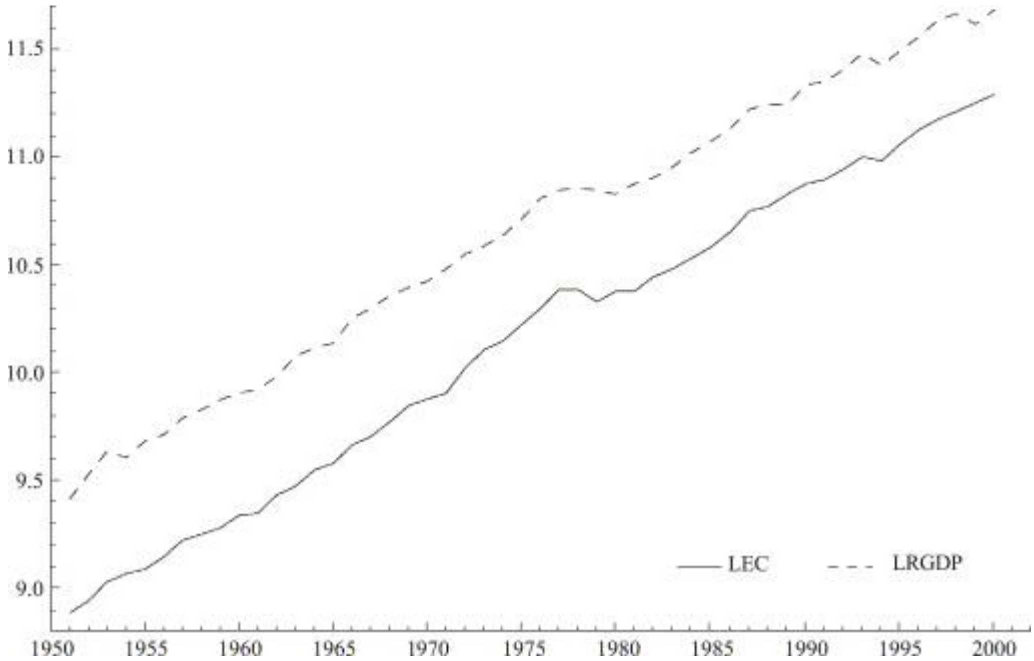
Figure 2. 2 Energy Consumption of Japan in Winter 2003

Study indicated that energy consumption for cooling is 8–34% of whole consumption. It varies according to residence because frequency of cooling and preset temperature affects the consumption. Energy consumption for lighting is 10–30% of all. Energy consumption for kitchen tends to increase in summer, which is because refrigerator requires more energy in summer. Energy consumption for entertainment and information, household affairs and sanitation is 6–18%. Detached house No. 02 consumes remarkably much energy, 4 GJ in July. Main reason is that energy for cooling, hot water supply and kitchen are used more. As energy reduction in cooling is thought possible with resident's consciousness, improving life-style is effective for energy saving.

As a result of this study they concluded that energy-saving apparatus will play an important role in saving residential energy consumption in the year to come. It is generated enough electric power to save 17.0% of all energy consumption through a year.

2.2 Energy Outlook of Turkey

In the other study it is investigated that a series of unit root and causality tests to detect causality between the GDP and energy consumption in Turkey. Studies show that the relationship between energy consumption and economic growth is still a controversial one.



Source: Energy Policy, Volume 37, Issue 3, March 2009, Pages 1156-1164

Ferda Halicioglu

Figure 2. 3 Plot of the log of real GDP and the log of energy consumption

Studies shows, coal and lignite make up almost half of the entire national production and, with added imports, nearly a third of national consumption. However, Turkish coal and lignite are largely inappropriate for the purposes of sustainable development as their usage is cost-ineffective and responsible for air pollution in urban centers. Even if both population and economic output were to grow more slowly than projected, it is almost certain that energy demand will increase[6]. Two factors critical to sustainable energy development in Turkey, however, are harder to predict. The first is the energy intensity of the economy. While the reported and predicted decreases seem impressive, it is by no means clear from this table whether this is the best that can be achieved in Turkey. In other words, the decision on the mix of energy production technologies and primary sources needs to be considered carefully, as certain combinations of technologies and primary sources are likely to result in more sustainable outcomes. It is important, therefore, to understand the determinants of energy intensity and energy supply. The nature of the energy supply is dependent on two main factors: resource availability and price. Resource availability refers to the geological, geographic and climatic conditions that shape available energy production. While certain policy tools can help discover energy sources or make their processing more efficient, resource availability is largely an exogenous variable that cannot be easily changed. Certain policy interventions, however, could have a dramatic impact on shaping the relationship between geological, geographic and climatic conditions and energy production. For example, in a country endowed with rich wind resources, policies supporting wind energy technologies can hold great potential. The price factor denotes both the relative and absolute cost of energy imports or production and is also largely independent of policy interventions. For example, international markets determine the price of oil and, with the possible exception of the US, countries cannot devise policies to influence it. The cost of converting primary sources to energy supply, however, could be influenced by technology policies that can either make energy production more effective or eliminate the need for importing advanced technologies, such as nuclear power reactors. Similarly, the state in Turkey is in a position to decide between competing technological solutions, such as hydro, wind, and nuclear energy[7].

Renewable energy sources	2000	2005	2010	2015	2020
Primary energy supply					
Hydropower (ktoe)	2656	4067	4903	7060	9419
Geothermal, solar and wind (ktoe)	978	1683	2896	4242	6397
Biomass and waste (ktoe)	6457	5325	4416	4001	3925
Renewable energy production (ktoe)	10,091	11,074	12,215	15,303	19,741
Share of total domestic production (%)	38	48	33	29	30
Share of TPES (%)	12	12	10	9	9
Generation					
Hydropower (GWh)	30,879	47,287	57,009	82,095	109,524
Geothermal, solar and wind (GWh)	109	490	5274	7020	8766
Renewable energy generation (GWh)	30,988	47,777	62,283	89,115	118,290
Share of total generation (%)	25	29	26	25	25
Total final consumption					
Geothermal, solar and wind (ktoe)	910	1385	2145	3341	5346
Biomass and waste (ktoe)	6457	5325	4416	4001	3925
Renewable total consumption (ktoe)	7367	6710	6561	7342	9271
Share of total final consumption (%)	12	10	7	6	6

Source: Renewable Energy, Volume 35, Issue 7, July 2010, Pages 1469-1476

Ibrahim Yüksel

Table 2.1 Renewable energy supply in Turkey

The study is concluded as renewable energy resources and their utilization in Turkey are intimately related to sustainable development. For the governments or societies to attain sustainable development, much effort should be devoted to utilizing sustainable energy resources in terms of renewables.Turkey's annual electric energy demand in 2010, 2015 and 2020 is predicted that it goes up to 270 TWh, 410 TWh and 571 TWh, respectively. Turkey's hydropower potential can meet 33–46% of its electric energy demand in 2020. By evaluating Hydropower (HP) plants, of which potential can be estimated to be in the order of some tens of TWh/yr, Turkey will provide important part of its electric energy demand from its own HP resources

3 Definition of Problem

3.1 Energy Sector in Turkey

Turkey's importance in the energy markets has been growing, both as a regional energy transit hub and as a growing consumer. Turkey, the sixth largest economy in Europe, is also a major consumer of energy. Economic growth in recent years has been outstanding, with GDP growing at approximately 9 per cent, strongly correlating with total primary energy consumption. Historic trends suggest that with sustained economic growth, energy consumption, and in particular electricity consumption, will increase at a similar pace to GDP. Turkey's energy demand has increased rapidly over the last few years and likely will continue to grow in the future. Concurrent with Turkey's economic expansion, its crude oil consumption has increased over the last decade. With very limited domestic reserves, Turkey imports nearly all of its oil supplies. Although there are a number of international firms operating in Turkey, TPAO has preferential rights in the upstream sector. Turkey plays an increasingly important role in the transit of oil. It is strategically located at the crossroads between oil-rich Former Soviet Union countries and the Middle East, and the European demand centers. In addition, it is home to one of the world's busiest chokepoints through which 2.9 million barrels per day flowed in 2010. Turkey holds a strategic role in natural gas between the world's second largest natural gas market, continental Europe, and the substantial gas reserves of the Caspian Basin and the Middle East. Turkey is increasingly dependent on natural gas imports as its domestic consumption rises each year. Natural gas is used domestically mainly in the electric power sector. Following the restructuring of the electricity sector, both consumption and generation of electricity have expanded. Most of the electricity is generated with conventional thermal sources, although the government plans to displace at least some of this generation with nuclear power. Total consumption per capita is low: 1.6 toe (and 2 680 kWh of electricity) compared to about 3.3 toe for the EU. Turkey imports about 90 percent of the hard coal it consumes. Volumes of imported coal may rise in the future as coal's importance for electricity generation increases. Turkey has limited oil and gas reserves (37 Mt and 6 bcm at the end of 2011). Its coal and lignite resources (1 Gt) are of poor quality and their extraction cost is high (for coal). The potential of renewables is high. The potential for hydroelectric power is estimated at 120 TWh/year. Total consumption increased at an average rate of 4.8%/year between 2001 (when an economic crisis occurred) and 2008. The next years will be dominated by two main issues: on the one hand, the need to deal with the rapidly growing energy consumption by increasing the production capacities and by restructuring the energy sector; and, on the other hand, the consolidation of Turkey's central role as a transit. This structure led Turkey to spend almost %40 of its total imports to the energy. The total bill of the energy imports approached sixty billion dollars in 2012 which was It is worth noting that Turkey's 2011 cost of imported energy was 54 billion dollars[8]. This perspective ,which has been noted by policy- and decision-makers, will mean that future policies will trend towards the development of generation technologies using indigenous energy resources, which can achieve supply security and sustainability. The high energy intensity of Turkey, which presents a further dilemma of energy utilisation, is expected to decrease considerably following new legislation and regulations which have been implemented in recent years. Considering that every ten years in Turkey, primary energy consumption increases by 50 per cent and electricity usage by approximately 100 per cent, the vast investment required to meet demand is a major concern.

From the explanations and data from the above indicated that energy is everything. It powers human progress. From job generation to economic competitiveness, from strengthening security to empowering women, energy is the great integrator: it cuts across all sectors and lies at the heart of all countries' core interests. Now more than ever , the world needs to ensure that benefits of modern energy are available to all and that is provided me to study on the energy dependent structure of the Turkey. In the following major resource types of energy.

3.2 Oil

Oil is one of the major component of energy sector for most countries. When Turkey's structure has examined, it has seen that Turkey's energy resources are quite diversified and include hard coal, lignite, asphaltite, oil, natural gas, hydro and geothermal. Oil and natural gas reserves are limited and almost all of Turkey's proven oil reserves lie beneath southeast Anatolia. The major part of Turkey's proven natural gas reserves are in Thrace. According to Oil and Gas Journal (OGJ), Turkey had 300 million barrels of proven oil reserves as of January 2006. Oil consumption has increased in recent years, and this trend is expected to continue. The state-owned Turkish Petroleum Corporation (TPAO) dominates oil exploration and production activities and currently accounts for roughly 70 percent of Turkey's domestic oil output. Although Turkey is not a major oil producer, it is, due to its strategic location, an important oil transit country. The Baku-Tbilisi-Ceyhan (BTC) Pipeline, which is the first direct pipeline to deliver crude oil from the Caspian Sea to the Mediterranean without crossing Russian soil or passing through the Bosporus or Turkish Straits, is 1,100-mile long and cost in the region of $4 billion to build. The pipeline is operated by a BP-led consortium of 11 national and international oil companies[9].

The domestic crude oil produced by TPAO. Selling points of crude oil are Batman, Dörtyol and Marmara Ereğlisi Terminals. Crude oil produced by TPAO is still purchased by TUPRAS, Turkish Petroleum Refineries Co., the leading refinery in the country. In 2011, TPAO produced 12.1 million barrels of crude oil from its fields, which constituted 74% of the total crude oil production of Turkey. 71% of our total oil production is from Batman Region, 28% is from Adıyaman Region and 1% is from Thrace Region. Turkey's proved oil reserves at 270 million barrels, located mostly in the southeast region. Turkey's oil production peaked in 1991 at 85 thousand barrels per day (bbl/d), but then declined each year and bottomed out in 2004 at 43 thousand barrels per day. Although Turkey's production of liquid fuels has increased slightly since 2004, it is far short of what the country consumes each year. It is described that why Turkey spend billions of dollars to have crude oil. Turkey's economy was one of the fastest growing economies in the world, at over 8 percent annual growth rates, and with this economic expansion, Turkey's oil consumption grew. In 2011, Turkey's consumption averaged 706 thousand bbl/d in 2011. While the economic expansion appeared to be slowing in 2012, preliminary data for 2012 show that total consumption of liquid fuels in Turkey increased during the year. Its domestic production, however, shows no signs of any meaningful increase in the short-term. In 2011, Turkey imported more than 90 percent of its total liquid fuels consumption. The majority of Turkey's oil imports originated in Iran, which supplied about 51 percent of Turkey's crude oil imports in 2011. However, given the imposition of sanctions on Iranian crude oil exports, it is likely that imports from Iran will fall for the remainder of 2012. Russia, once the largest source country of Turkey's crude oil has fallen behind Iraq in terms of volumes and is now the third-largest supplier of crude oil to Turkey.

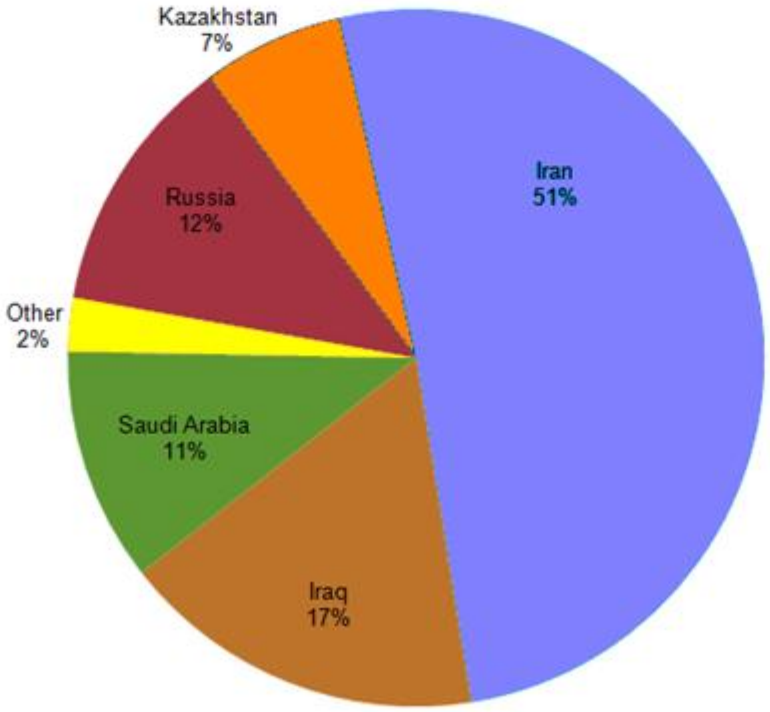


Figure 3. 1 Share of Turkey’s Oil Imports, 2011

The government offers several types of tax breaks to encourage exploration and production, including lower corporate tax rates, exemptions from import duties for material and equipment, and exemptions from value-added tax for exploration activities. Turkey is not rich country as an oi perspective. Most of Turkey's 270 million barrels of proven oil reserves are located in the Hakkari Basin with additional deposits found in Thrace in the northwest. There also may be significant reserves under the Aegean Sea. However, this has not been confirmed as a result of the ongoing territorial dispute with Greece. The Black Sea may hold significant oil production potential for Turkey. The Turkish national oil company, TPAO, has increased its exploration activities in the Black Sea, which could hold between 7 and 10 billion barrels of oil.

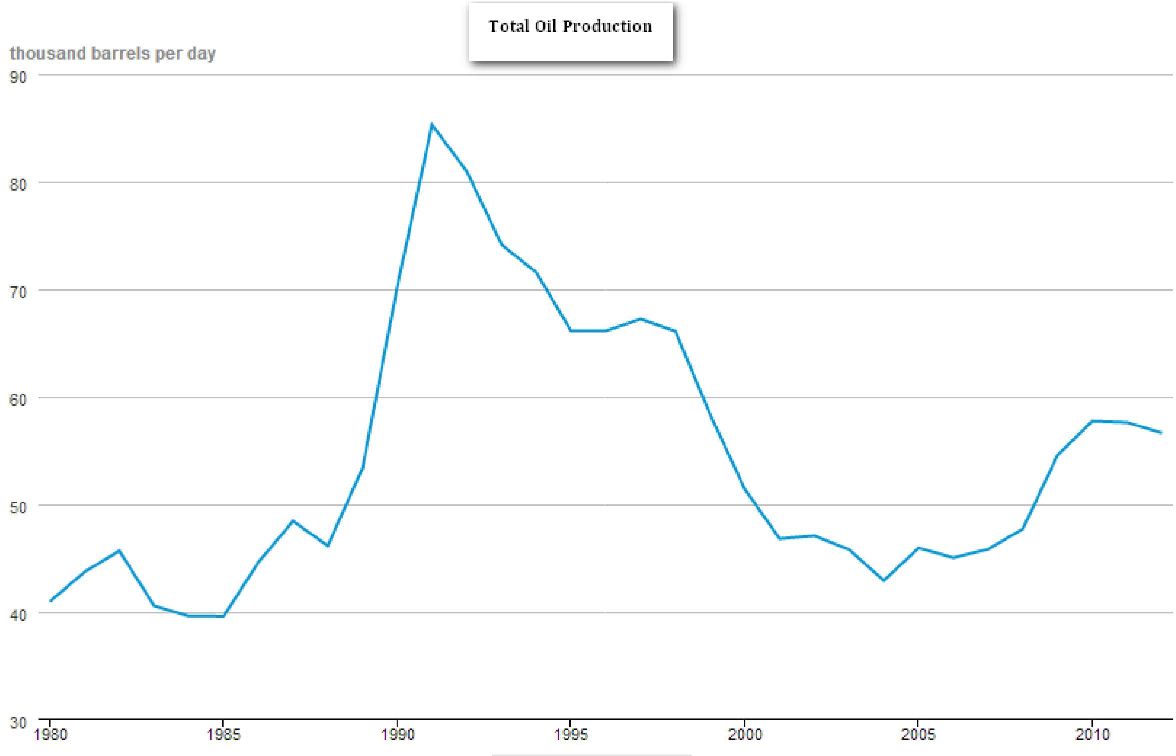


Figure 3. 2 Turkey Total Oil Production

When it is compared consumption of oil is almost 10 times more than daily production of Turkey.

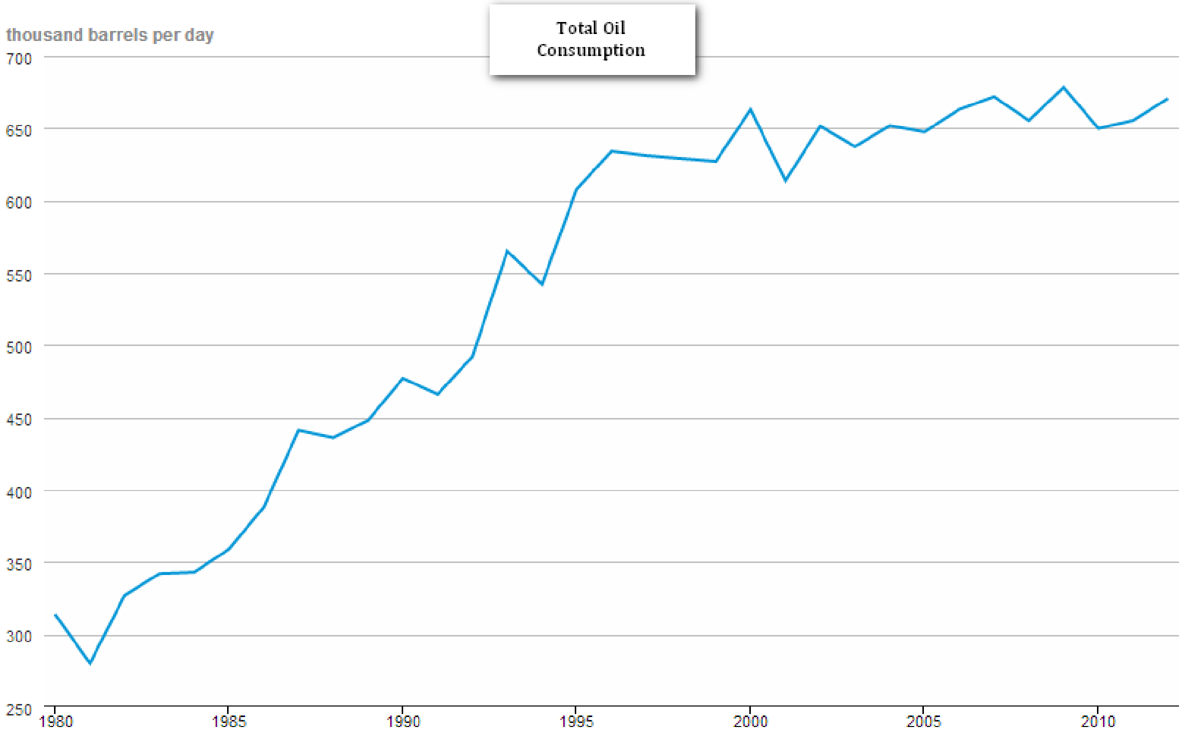


Figure 3. 3 Turkey Oil Consumption

There were a number of bypass options proposed in Turkey over the last decade, including: The First one is Samsun-Ceyhan Pipeline which would transport oil from Turkey's Black Sea port of Samsun to Ceyhan on the Mediterranean coast. The project includes the construction of a 350-mile oil pipeline, a new terminal for receiving oil at Samsun,a terminal for exporting the oil, and a storage plant at Ceyhan. The oil pipeline will have a maximum initial transportation capacity of 1 million bbl/d, which can eventually be increased to 1.5 million bbl/d.Second one is Kiyikoy-Ibrikbaba Pipeline which is a 1.2 million bbl/d pipeline that would run between Kiyikoy on the Black Sea and Ibrikbaba on the Aegean Sea near Greece. This pipeline was proposed more than six years ago, but very little progress has occurred.Agva-Izmit Pipeline is the another one that would connect the Black Sea to the Tupras' (Turkish Petroleum Refineries Company) Izmit refinery. Last of all Canal Istanbul which is a proposed 30-mile link between the Black Sea and the Sea of Marmara. The waterway would be located on the European side of the Bosporus and is planned to be completed by 2023[10]. However, given the size of the undertaking and cost associated, this project is the least desirable and feasible option and thus it likely will not be completed.

From the projections and analysis showing that Turkey has crucial role as transit but it has almost 90% import dependent structure in oil requirement and its consumption has an increasing trend as well. According to the experts an extra $10 a barrel on the oil price "adds about $4bn a year to Turkey’s import bill.

The transport sector makes up the single largest share of oil consumption in Turkey. Following the transport sector, the industry sector represented 24% of total oil demand.The remaining part consumed by residentals and other sectors.

3.3 Coal

Turkey imports about 90 percent of the hard coal it consumes. Volumes of imported coal may rise in the future as coal's importance for electricity generation increases. Coal is also a large energy source in Turkey, whose share in the country’s TPES increased to 30% in the same year. It imports coal mainly from Russia, Australia, and the United States. Around 40 percent of Turkey's lignite is located in the Afsin-Elbistan basin of southeastern Anatolia, while hard coal is mined only in one location, the Zonguldak basin of northwestern Turkey. In 2008, Turkey had total recoverable coal reserves of 2.6 billion short tons, of which only 583 million short tons (MMst), or about 23 percent, was "hard coal" (anthracite and bituminous). The remainder, around 2,000 MMst, consists of lignite coal reserves. In 2010, Turkey produced 79 MMst of total coal and consumed about 109 MMst of total primary coal in 2010[11].

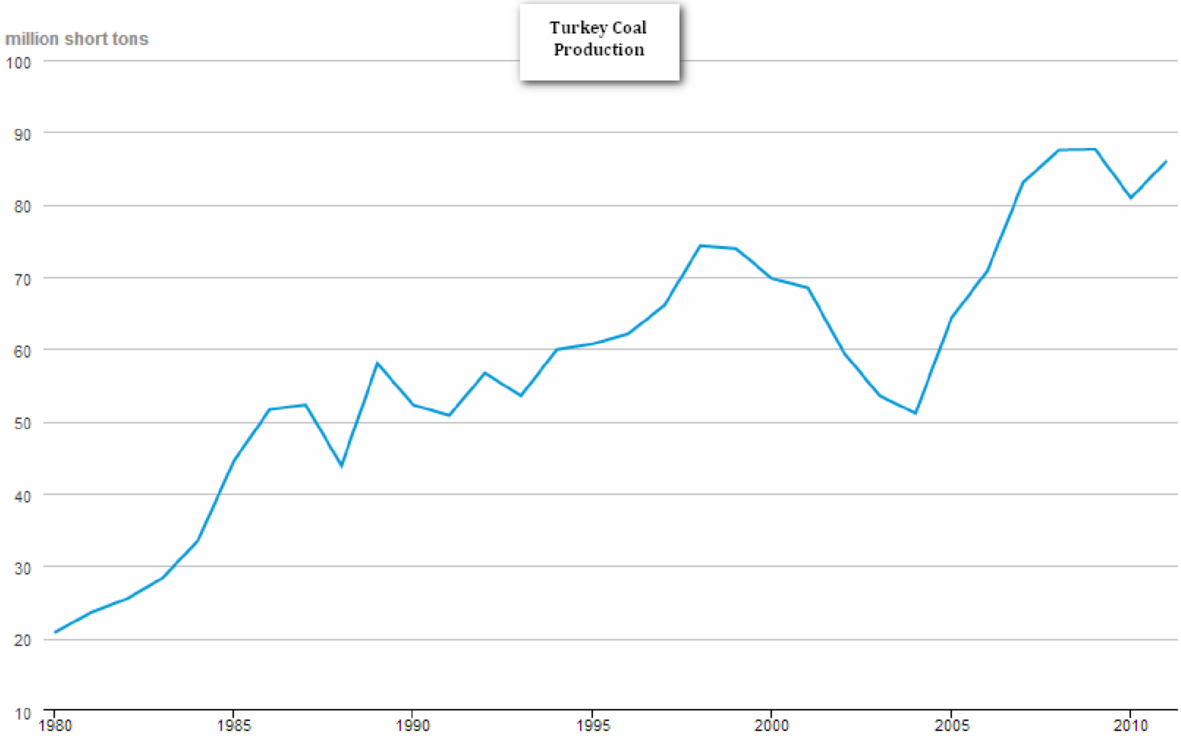


Figure 3. 4 Turkey Coal Production

With comparing two graphs it can be realized that each year consumption almost %20 higher than the production of coal in Turkey. Furthermore, Figure 3.6 indicated significantly that imports of oil much more higher than our exports.

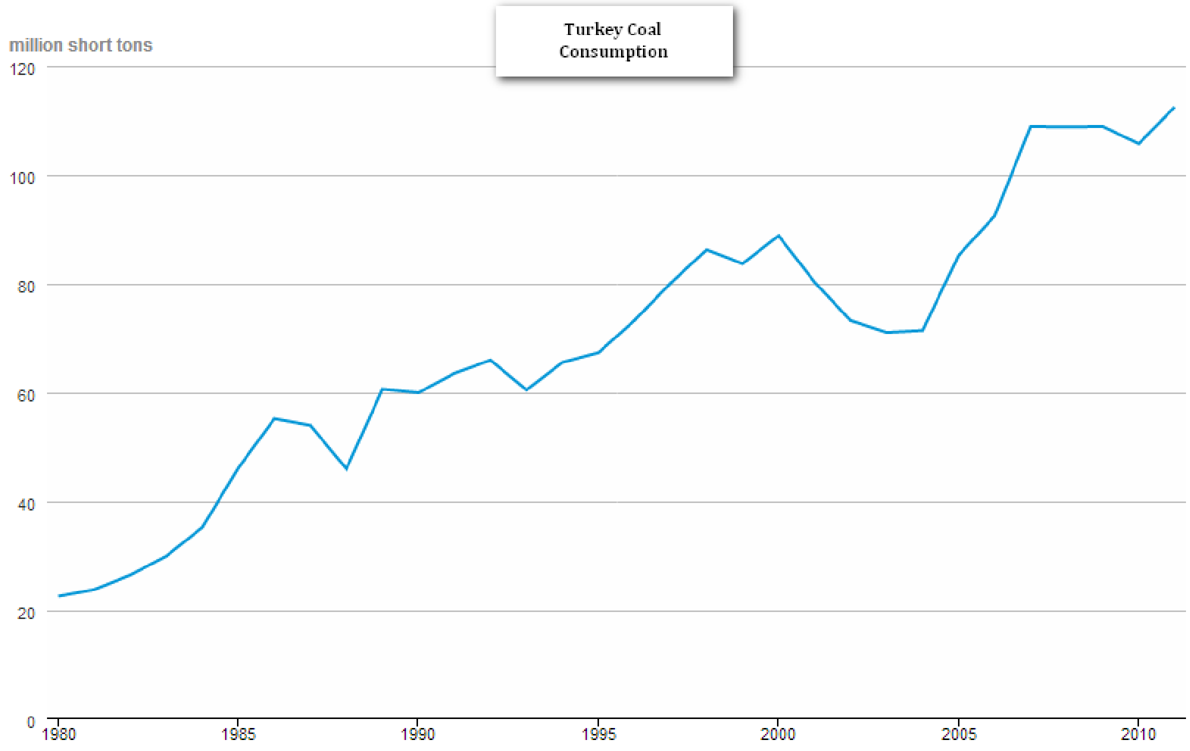


Figure 3. 5 Turkey Coal Consumption

Turkey's coal imports of 106 percent over the last decade, has increased 540 percent in the last two decades. Coal imports in 2012, an increase of 24 per cent compared with the previous year rose to the level of 30 million tons. Coal import bill was $ 4.6 billion.

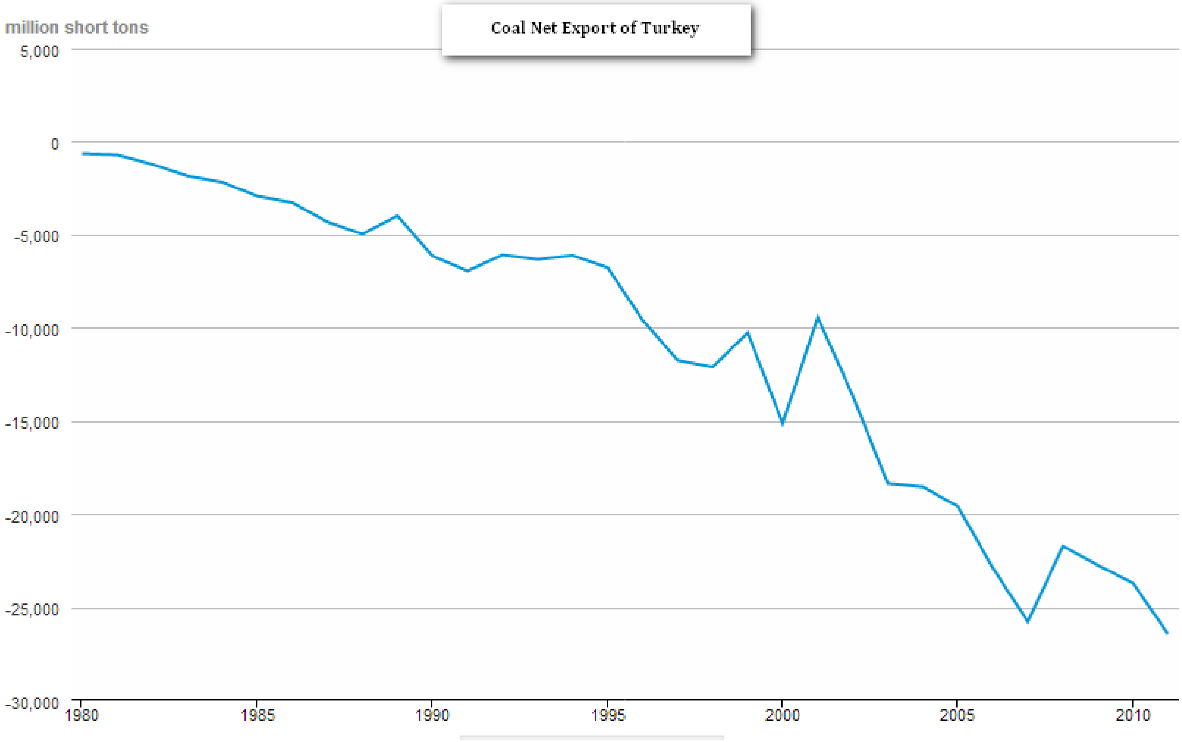


Figure 3. 6 Turkey Net Export of Coal

3.4 Natural Gas

The importance of Natural Gas has been increasing for Turkey. Turkey holds a strategic role in natural gas between the world's second largest natural gas market, continental Europe, and the substantial gas reserves of the Caspian Basin and the Middle East. Turkish natural gas reserves at 218 billion cubic feet (Bcf). Turkey produced 27 Bcf of natural gas in 2011, relying almost exclusively on imports to meet domestic demand. Turkey's energy demand growth has been among the fastest in the world in 2010 and 2011, although slower economic growth in 2012 has occured the natural gas consumption increase to some extent.Natural gas is accounting for an increasing share of the energy mix in Turkey and it has overtaken oil and become the most important fuel in terms of volume consumed.Current estimations indicate that natural gas consumption in Turkey exceeded oil and coal consumption by about 0.3 quadrillion British thermal units in 2011. The state-owned Petroleum Pipeline Corporation (BOTAS) dominates the natural gas sector, although the majority of the market is open to competition. BOTAS also builds and operates gas pipelines in Turkey and dominates in the wholesale market and in exports of natural gas. Turkey's midstream natural gas market has been led by BOTAS for decades, and the company continues to exercise the Turkish state's mandate for developing the country's pipeline networks and procuring sufficient natural gas supplies. In addition to ensuring adequate supply for the domestic market, a key part of this mandate has been participation in international pipeline projects that can take advantage of Turkey's location as a key corridor between Europe and the Middle East and Central Asia to play an active role in trans-regional energy supply.

Unfortunately,with proven reserves, Turkey produces a very small amount of natural gas, with the total production amounting to 27 billion cubic feet (Bcf) in 2011. There are 14 gas fields in Turkey, the largest being Marmara Kuzey, an offshore field in the Sea of Marmara in the Thrace-Gallipoli Basin. Gas production is mainly carried out by three companies: Turkiye Petrolery A.O. (TPAO), BP, and Shell. A number of natural gas fields have been brought onstream in the Black Sea, including the Akcakoca, East Ayazli, Akkaya, and Ayazli fields. Turkey is increasingly dependent on natural gas imports as its domestic consumption rises each year. Natural gas is used domestically mainly in the electric power sector. For Turkey to function as a gas transit state, it must be able to import enough gas to satisfy both domestic demand and any re-export commitments as well as provide enough pipeline capacity to transport Caspian natural gas across Turkey to Europe. While Turkey enjoyed considerable excess import capacity a few years ago, this excess pipeline capacity has eroded as Turkey now uses most of its pipeline capacity to meet its domestic demand. Furthermore, possible restrictions on imports of Iranian natural gas because of sanctions would remove Turkey's excess capacity during peak demand months. But, excess capacity on these pipelines is much lower during peak demand months. Turkey's natural gas demand is highly seasonal, with heating season months (November through February just like literature review' example) exhibiting natural gas demand that is significantly higher than in other months. Additionally, natural gas import infrastructure in Turkey has been a frequent target of terrorists, and Turkey is extremely vulnerable to supply disruptions. The Tabriz-Dogubayazit pipeline has been increasingly targeted by the Kurdish rebel militants. These attacks have increased in frequency and damage in recent months. Flows on the Tabriz-Dogubayazit pipeline were disrupted a number of times in last year, with two such disruptions occurring during October alone. The Baku-Tbilisi-Erzurum pipeline has also been a terrorist target, and flows on this pipeline were halted two times in 2012.

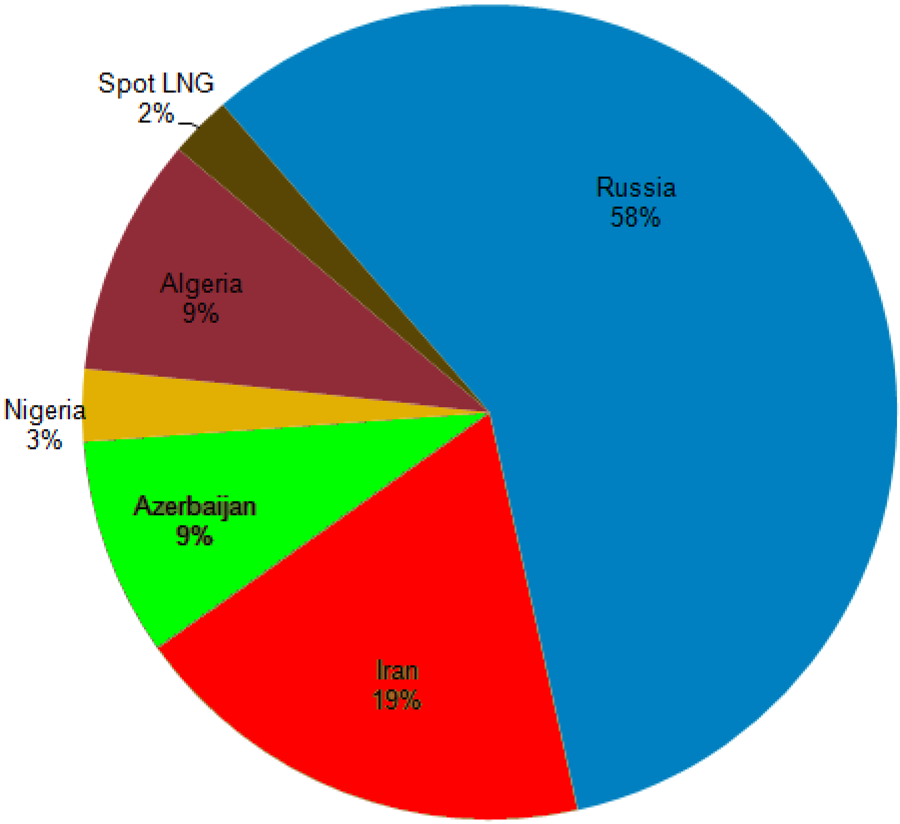


Figure 3. 7 Natural Gas Importers of Turkey

A number of pipeline projects have been proposed, most of which envision that Turkey would play a vital role. Although none of these projects have commenced, consuming nations in Europe are particularly interested in realizing at least some of these projects[12]. First of it is Nabucco Pipeline,which is the longest-running and much-delayed proposal. If built, it would carry 1.1 Tcf of gas per day through Turkey, Bulgaria, Romania, Hungary to Austria. Second one is South East European Pipeline which (SEEP) was proposed by BP, although details on the proposal are scarce. SEEP would require the construction of only 800 miles of pipeline as it would rely on existing infrastructure and may exceed Nabucco's planned capacity.Another one is Trans Anatolian Pipeline (TANAP) which project was proposed as an alternative to the much-delayed Nabucco. This project is considering two alternatives, which include the possibility of upgrading the current BOTAS pipeline network and/or construction of a new standalone pipeline across Turkey in order to facilitate shipping of Azerbaijan's natural gas from the Shah Deniz II field. The pipeline's capacity would be 30 billion cubic meters per year. Expansion of the Interconnector The other one is Turkey-

Greece-Italy Pipeline (ITGI). The Turkey-Greece section has been operational since 2007. The remaining Greece-Italy section would transport about 350 Bcf per day of natural gas. Last of them is Turkey-Iraq Pipeline which would give Turkey access to Iraq's natural gas resources. Although a memorandum of understanding was signed a number of years ago, planning for construction has yet to take place

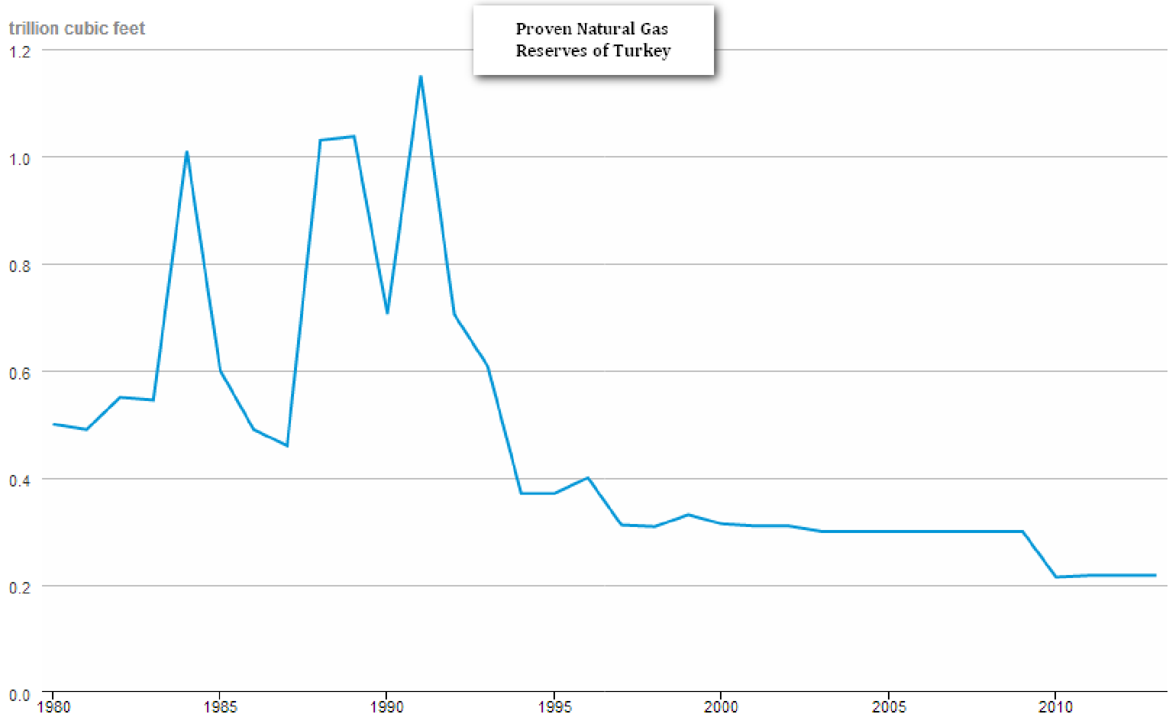


Figure 3. 8 Natural Gas Reserves of Turkey

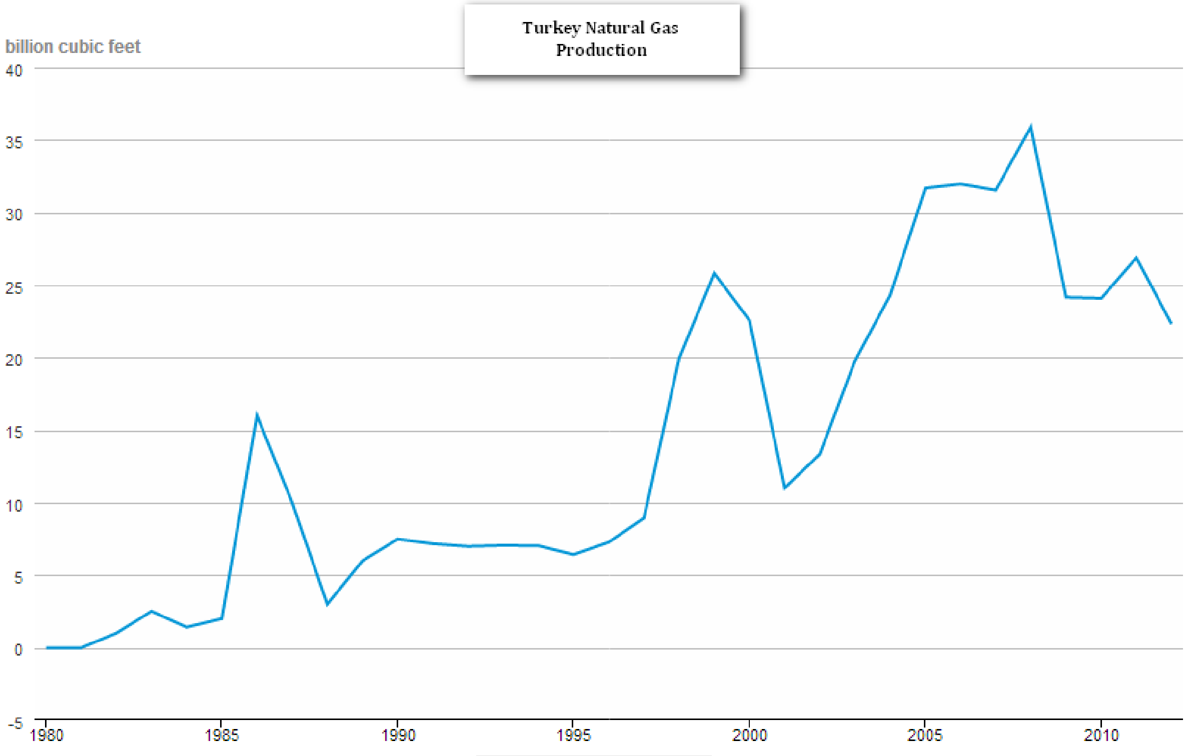


Figure 3. 9 Natural Gas Production of Turkey

98-fold increase in imports of natural gas since 1987 when BOTAS started its operations. Turkey paid $ 60 billion natural gas and oil bill last year (2012). Comparing of two graphs indicated significantly that consumption is far more than production of natural gas in Turkey.

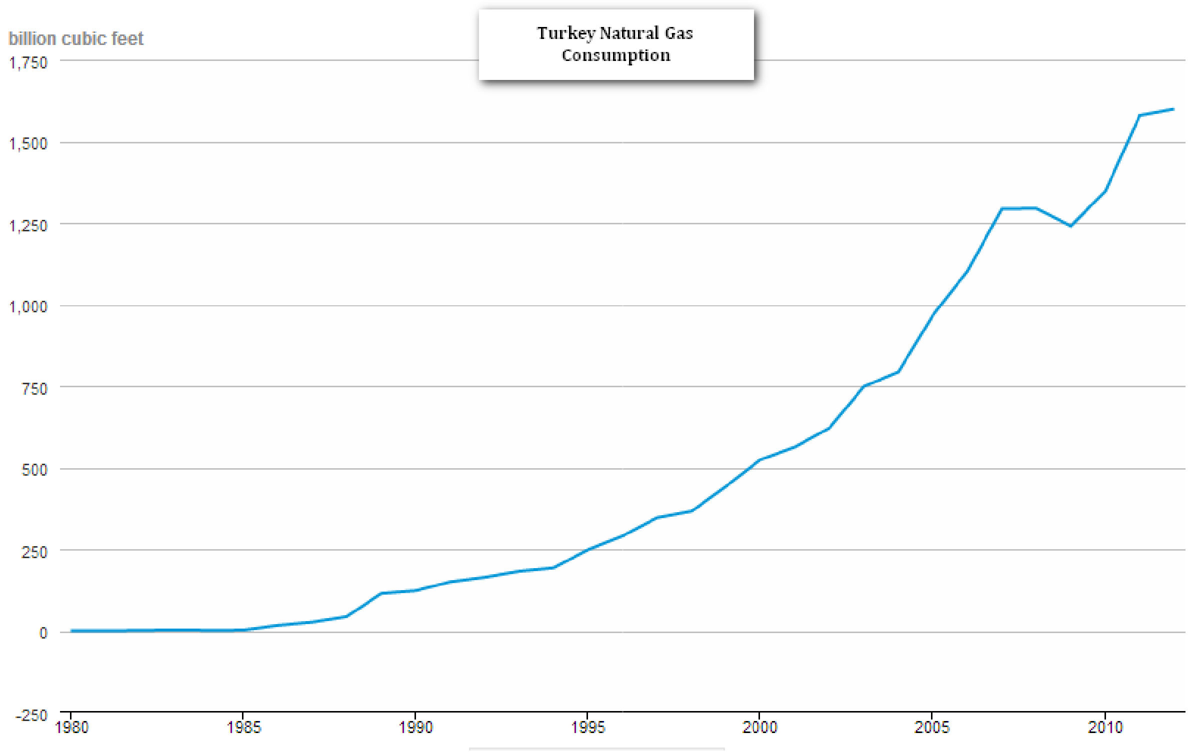


Figure 3. 10 Natural Gas Consumption of Turkey

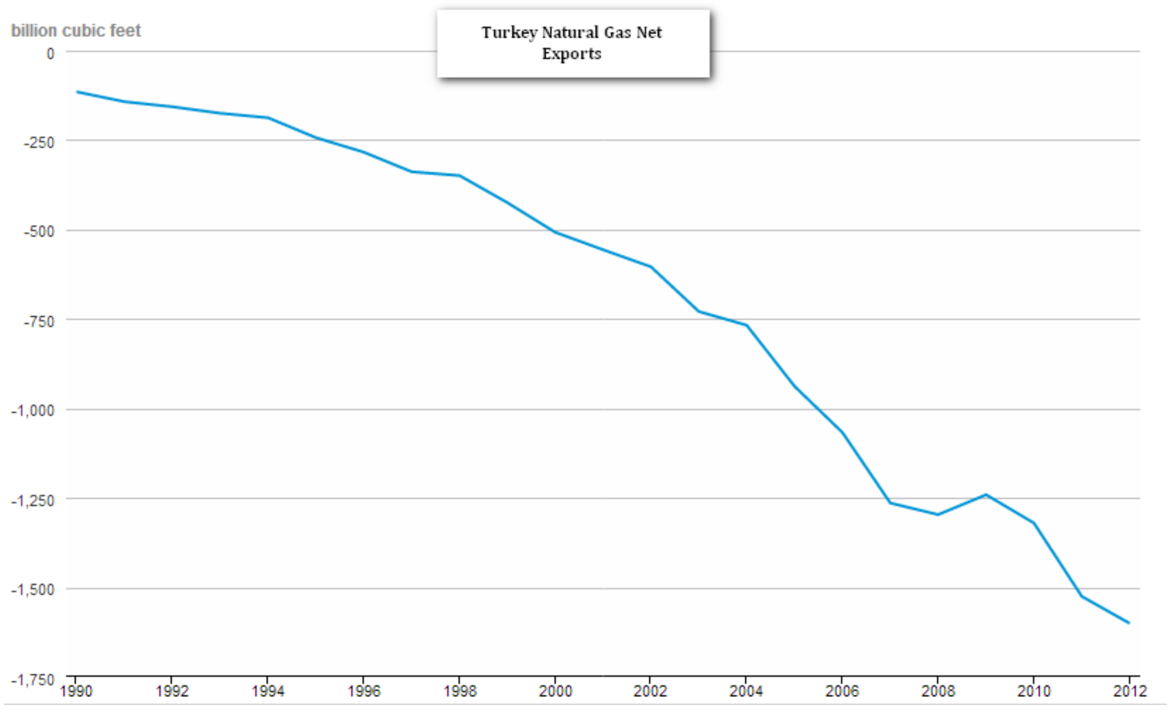


Figure 3. 11 Natural Gas Net Export of Turkey

3.5 Nuclear Energy

Throughout the world Nuclear energy is one of the most important part of sector with high potential of energy supply. Currently, 73 reactors are under construction in 15 countries. Some new countries will be starting their first nuclear power plants including Turkey and Belarus, Vietnam, United Arab Emirates, Jordan, Ghana, Morocco and Saudi Arabia.

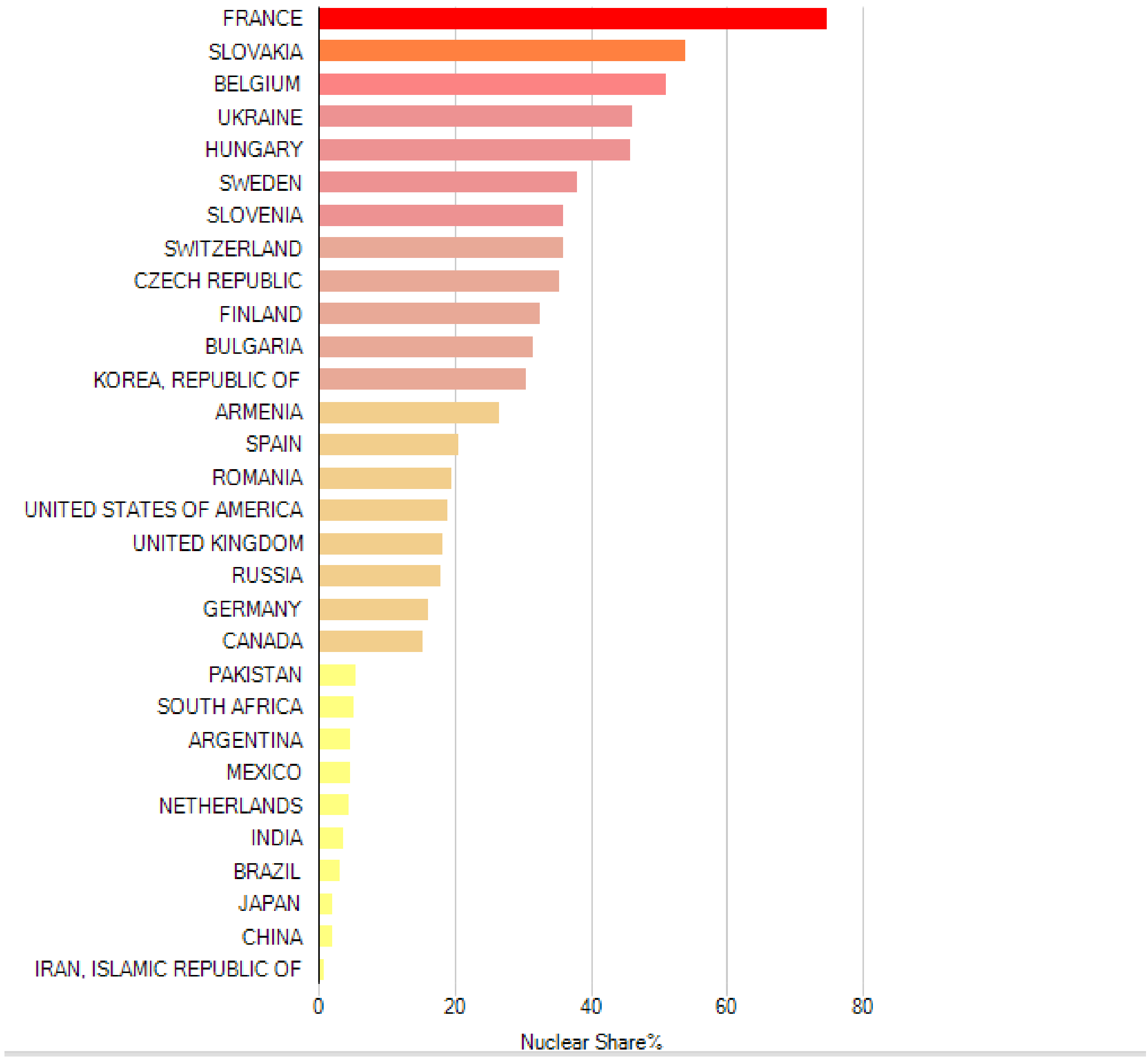


Figure 3. 12 Nuclear Share of Electricity Generation in 2012

It is known that %19 of US ,%78 of France %18 of Germany's electricity produced by Nuclear Energy. Many existing nuclear power plants have already been paid for. Their operating costs are therefore low, and the electricity produced is among the cheapest in comparison with other sources. Cost projections show that new power reactors will also be competitive, even assuming low gas prices and heavy subsidies for wind power[13].

Technology	Operating hours	€ per MWh
Nuclear	8000 hours/year	35,0
Peat		43,6
Coal		45,7
Gas		51,2
Wood		73,6
Wind	2200 hours/year	52,9

Source: Lappeenranta University of Technology, Finland, January 2008;

Table 3.1 Cost comparison: nuclear, gas and wind power in the EU

Turkey has had plans for establishing nuclear power generation since 1970. Today, plans for nuclear power are a key aspect of the country's aim for economic growth.From the structure that have been explained above indicated that import dependency of Turkey. Recent developments have seen Russia take a leading role in offering to finance and build 4800 MWe of nuclear capacity. Application has been made for construction and operating licences for the first plant, at Akkuyu, and these are expected in mid 2014. A Franco-Japanese consortium is to build the second nuclear plant, at Sinop. Today Turkey imports much of its energy, including nearly all of its oil and gas, and in 2012 this amounted to more than $60 billion. Improving energy efficiency and energy security are high priorities. In 2011 Turkey's electricity production was 228 billion kWh gross from almost 50 GWe of plant. Of this, 102 TWh (45%) came from gas (two thirds of this from Russia, most of the rest from Iran), 65 TWh (28.5%) from coal, and 52 TWh (23%) from hydro. Per capita consumption has risen from 800 kWh/yr in 1990 to about 2300 kWh/yr. Demand in 2023 is expected to be 450 billion kWh, implying new investment by then of $100 billion. Peak demand was 40 GWe in first half of 2013. Plans for nuclear power are a key aspect of the country's aim for economic growth, and it aims to cut back its vulnerable reliance on Russian and Iranian gas for electricity. Plans are to have 30 GWe of coal-fired capacity by 2023. However, much of the country's coal resources are lignite with low calorific value – less than 12.5 MJ/kg, and a substantial amount (Afsin Elbistan) at less than 5 MJ/kg. Early in 2006 the province of the port city of Sinop on the Black Sea was chosen to host a commercial nuclear power plant. This has the advantage of cooling water temperatures about 5 degrees C below those at Akkuyu, allowing about 1% greater power output from any thermal unit. The project company was to apply for all licences within twelve months, and the first reactor is to be on line within seven years of receiving these, with the others to follow at one-year intervals in Akkuyu. The Akkuyu NPP project will have 4 power units with capacity of 1200 MW each. The service life of Akkuyu NPP is 60 years. The company expected to commission the first unit in 2021. Some $1.3 billion expenditure on the project was budgeted for Akkuyu[14].

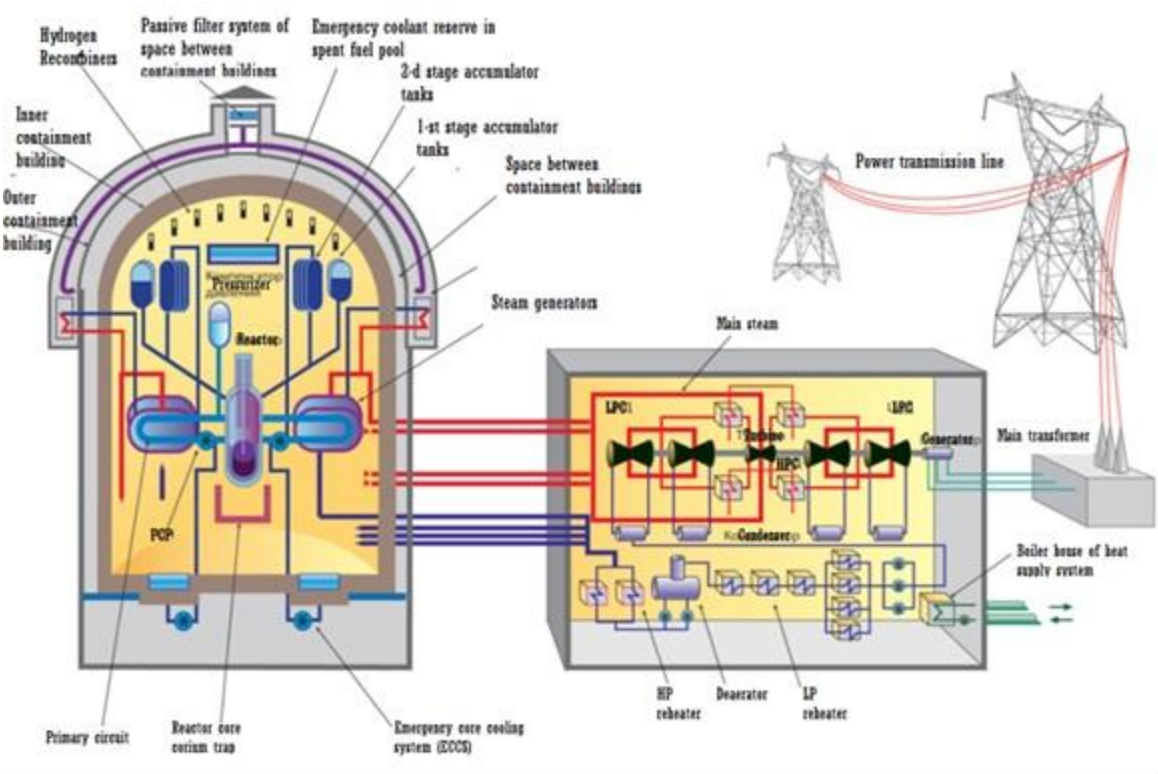
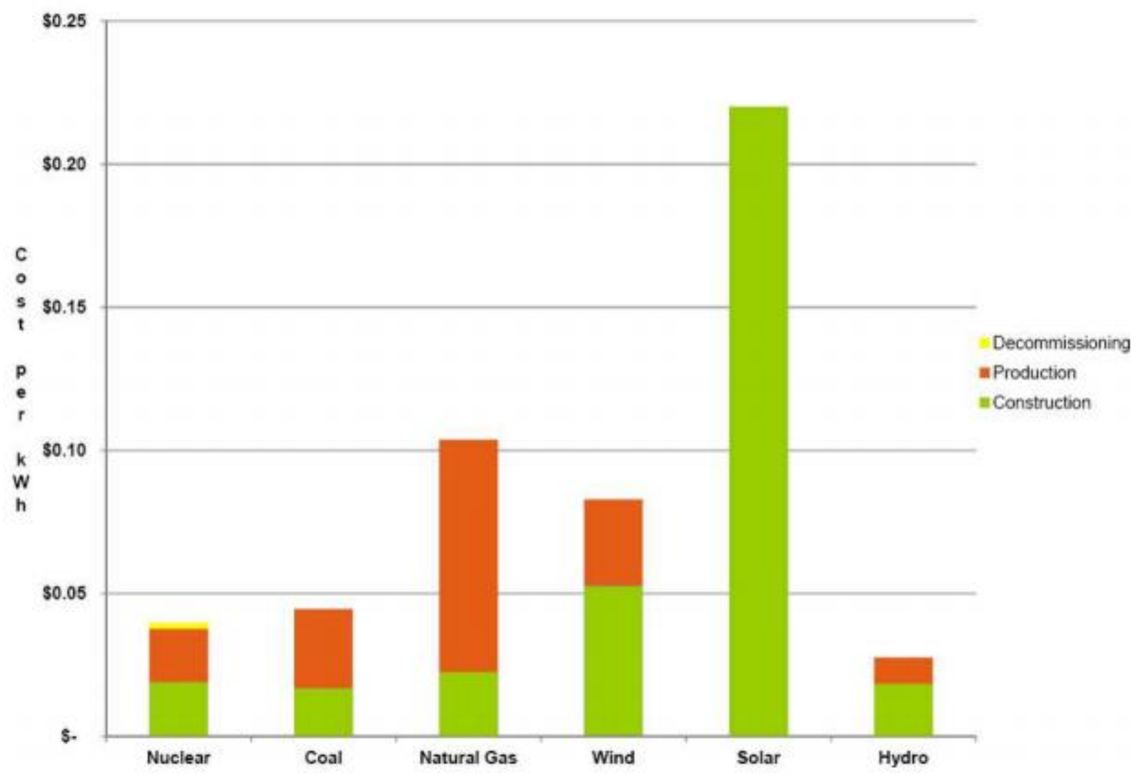


Figure 3. 13 Diagram of the power circuit and safety systems of Akkuyu NPP

Turkey total primary energy supply (TPES) was 106 million tons of oil equivalents (Mtoe) in 2009. Fossil fuels (oil, natural gas and coal) accounted for 90% of TPES in Turkey while renewable energy provided the rest. The construction of a nuclear power plant is seen as a long-term strategy to decrease its energy dependence. Experts in Turkey have systematically warned that under this economic growth and increasing fossil fuel prices Turkey will face serious difficulties to satisfy its needs. The Turkish Government expects that within 10-15 years electricity demand will double and it estimates that 5% of its total energy production will come from nuclear energy. The Sinop Nuclear Power Plant is a planned nuclear plant located at Sinop in northern Turkey. It will be the country's second nuclear power plant after the projected Akkuyu Nuclear Power Plant. It is projected that the first unit of Sinop plant will be active by 2023, and the fourth unit enter service by 2028. French and Japanese companies placed their bid for the project, which is estimated to cost up to USD 25 billion.

3.6 Renewables Energy

Unlike fossil fuels, which are exhaustible, renewable energy sources regenerate and can be sustained indefinitely. The five renewable sources used most often are biomass, water (hydropower), geothermal, wind, and solar. Over the past few years, policymakers in Turkey have realised the role that renewable energy can play in expanding power generation and diversifying the energy supply mix in an environmentally sustainable way. As Turkey's reliance on imported natural gas for power generation has given rise to concerns over supply security and the country's bulging current account deficit, support of domestic energy sources such as coal and renewables has gained a new urgency. In this regard, Turkey's new Renewable Energy Support Mechanism is an important step forward. Turkey has committed to a target that 30% of its total energy come from renewable sources by 2023.Despite the global financial crisis, the renewable energy sector has achieved important advances in technology and power generation project development over the past few years. Strong government support played a big role in shielding the sector from the crisis and propelling its growth. In 2010, 195 GW of new power generation capacity was established globally and approximately half of this capacity is based on renewables. Renewables constitute nearly 25% of the global installed capacity, whereas in power generation the share of renewables is around 20%.Turkey has abundant solar energy resources, as it is located in a sunny belt. The natural energy potential of the country is estimated to be 1.3 billion tons of oil equivalents (15,120 TWh) and is scattered to different regions. Wind power met 2-2.5% of the global power demand by the end of 2010, and this ratio was much higher in some states such as Spain (15.4%) and Germany (6%). Due to its geographic location, Turkey is under the influence of different pressure systems. In winter, the Island High Pressure system expands its impact area to southern latitudes of Turkey, causing strong, gusting winds from the north and especially north eastern directions. Anatolia, especially the western side, is under the influence of western and north western winds[15]. In summer, Turkey is influenced by the Azores High Pressure center, causing constant winds from the north, especially in the western regions of Turkey. The strong gradient of the Azores High Pressure center and the Basra Low Pressure center in the east creates gusting north eastern winds in the eastern region. Southern, as well as eastern regions are generally under the impact of winds from the south and south-eastern direction. Approximately 20GW of this potential is estimated to be economically feasible in Turkey. Turkey's technically feasible electricity potential from wind power plants ranges between 200 and 400 TWh. However, the economically feasible potential lies between 35 and 70 TWh. the installed capacity rose from 20.1 MW in 2005 to 1,799 MW in 2011, an increase of about 8,950%. Despite this tremendous increase, the desired level of installed capacity is still not reached and a big share of the economic potential has still not been used. Only %15 of total potential of wind power being utilized by Turkey today. Turkey attributes significant importance to; encouraging the energy production from renewables in a secure, economic and cost effective manner, expanding the utilization of our renewable resources for generating electrical energy, increasing the diversification of energy resources, reducing greenhouse gas emissions, making use of waste products and protecting the environment, developing the related mechanical and/or electro-mechanical manufacturing sector. Government plan is that at least %30 of total electricity production supplied from renewables. There are 278 electricity market production licence in the field of Wind energy in Turkey while 34 Biodiesel facilities received Processing License for biodiesel production. Moreover, totally 25 projects of 634.67 MWe capacity are licensed in geothermal energy[16].



Source: Jason Morgan, "Comparing Energy Costs of Nuclear, Coal, Gas, Wind and Solar," Nuclear Fissionary, 2010

Figure 3. 14 Total Electricity Cost Comparison of Energy Types

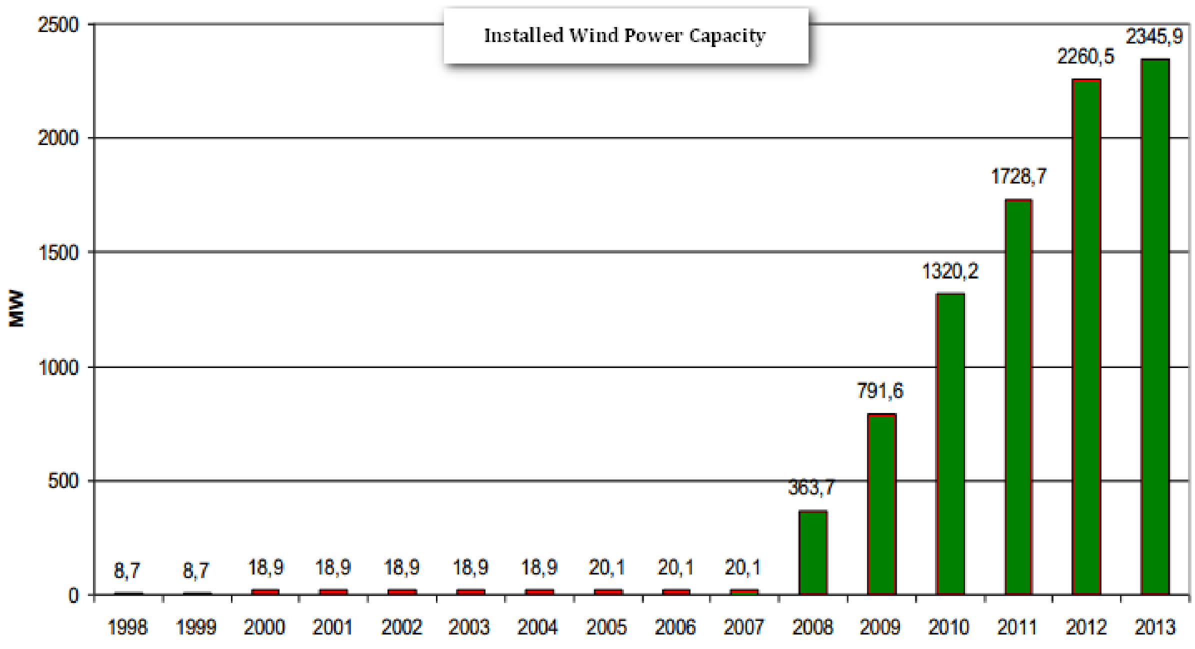


Figure 3. 15 Installed Wind Power Capacity of Turkey

In brief, renewable energy consumption in Turkey should definitely increase both in terms of environmental effects and the abundance of its sources. However, because it is an expensive energy source, it might affect economic growth negatively until the initial investments are made. Indeed, studies reveal that the relationship between energy consumption and economic growth is generally based on conservation hypothesis in poorer countries

3.7 Hyroelectricity

Hydroelectric power plants are the leading recipient of renewable energy investments in Turkey. While renewable energy sources require no fuel and their operation and maintenance costs (O&M) are generally low, the initial capital costs of renewables are relatively high for per unit of capacity installed. High capital cost is considered to be one of the major barriers to greater use of renewable technologies. Higher generation costs of renewable energy might be attributed to two main aspects. First, renewable energy has higher capital costs than fossilfuelled systems. Second, external environmental and social costs of fossil fuels have been ignored by markets. These costs include pollution, greenhouse gas emissions, and even military expenditures to defend overseas oil supplies. Another vital factor in the development and use of hydropower is financing. Much of the cost of generating electricity with oil, coal and gas is the cost of fuel and therefore a thermal investment is made and recouped in relatively short period of time. With renewable technologies, however, the initial capital outlay is large and must be recovered slowly over a period of many years, making it difficult to attract capital. Thus, investment in hydropower is discouraged at the outset. Like other renewable energy sources, hydropower. January 2012, there are 832 licenses entitled by the EPDK, with a total capacity of 29,570 MW. While approximately 15,275 MW of this capacity is in operation, 14,295 MW is under construction. 11,629 MW of the installed hydropower belongs to the Turkish Electricity Production Company (EUAS). Some of these power plants, including Karakaya (1,800 MW), Ataturk (2,405 MW) and Keban (1,330 MW), will remain outside the government's privatisation portfolio. Big private holding companies are also active in this sector. Dogus Holding, Akenerji and Aksa all have hydroelectricity investments. The biggest hydropower project under construction now is the Boyabat Hydro Electricity Plant. The project is owned by a consortium of big investors in Turkey: Dogus and Dogan holdings as well as Unit Investment. The 528 MW capacity project is financed with a project finance loan amounting to $750 million. Another large project is the Cetin Project to be constructed on the Dicle River. The project is the third investment by Norwegian Energy firm Statkraft in Turkey. The Cetin project, which will have a capacity of 517 MW, is expected to start operation in 2015. This project will bring Statkraft's total installed capacity to 639 MW. There are currently 444 hydropower projects with a capacity over 3MW under development[17].

	Company	Project	Location	Capacity (MWm)	Expected Generation (kWh/y)
1	Boyabat Elektrik Üretim ve Tic. Ltd. Şti.	Boyabat HES	Çorum	528,0	1 468 000 000
2	Çetin Enerji A.Ş.	Çetin Barajı ve HES	Siirt	386,0	1 208 814 000
3	Doğuş Enerji Üretim ve Ticaret A.Ş.	Artvin Barajı ve Hes	Artvin	340,0	1 026 000 000
4	Yedigöze Elektrik Üretim ve Tic.Ltd.Şti.	Yedigöze HES	Adana	317,0	966 530 000
5	Kalehan Enerji Üretim ve Ticaret A.Ş.	Beyhanı Barajı ve HES ile Palu Reg. Ve HES	Elazığ	310,0	1 434 740 000
6	Kalehan Enerji Üretim ve Ticaret A.Ş.	Kaleköy Barajı ve HES	Bingöl	300,0	1 292 630 000
7	Bereket Enerji Üretim A.Ş.	Göktaş HES	Adana	292,5	1 117 660 000
8	Pervari Elektrik Üretim San. Ve Tic. A.Ş.	Pervari Baraj ve HES	Siirt	249,8	842 310 000
9	Limak Hidroelektrik Santral Yatırımları A.Ş.	Alkumru Barajı ve HES	Siirt	247,4	828 070 000
10	Akköy Enerji A.Ş.	Akköy 2 HES	Gümüşhane	233,6	898 667 000
11	Doka Enerji Sanayi İnşaat Ticaret A.Ş.	Arkun Barajı ve HES	Artvin	231,3	818 040 000
12	Onk Elektrik Üretim San. Ve Tic. A.Ş.	Pervari Reg. ve HES	Van	223,2	721 940 000
13	Enerjisa Enerji Üretim A.Ş.	Kandil Enerji Projesi HES	Kahramanmaraş	217,6	531 689 000
14	Konaktepe Elektrik Üretim A.Ş.	Konaktepe I-II Barajı ve HES	Tunceli	207,0	582 981 000
15	Enerjisa Enerji Üretim A.Ş.	Kavşak Bendi ve HES	Adana	185,5	741 030 000
16	İçkale Enerji Elektrik Üretim ve Tic. A.Ş.	Kemah Barajı ve HES	Erzincan	163,3	527 020 000
17	Enerjisa Enerji Üretim A.Ş.	Hacınınoğlu HES	Kahramanmaraş	144,4	359 794 000
18	Oren Enerji Elektrik Üretim A.Ş.	Bağıştaş I HES	Erzincan	138,0	422 430 000
19	Çalık Enerji Elektrik Üretim ve Madencilik A.Ş.	Aksu (Çoruh-Anakol) Barajı ve HES	Bursa	134,0	363 278 000
20	Özdoğan Enerji A.Ş.	Ayvalı (Çoruh) HES	Erzurum	130,3	318 160 000

Table 3.2 The largest hydropower projects under construction of Turkey

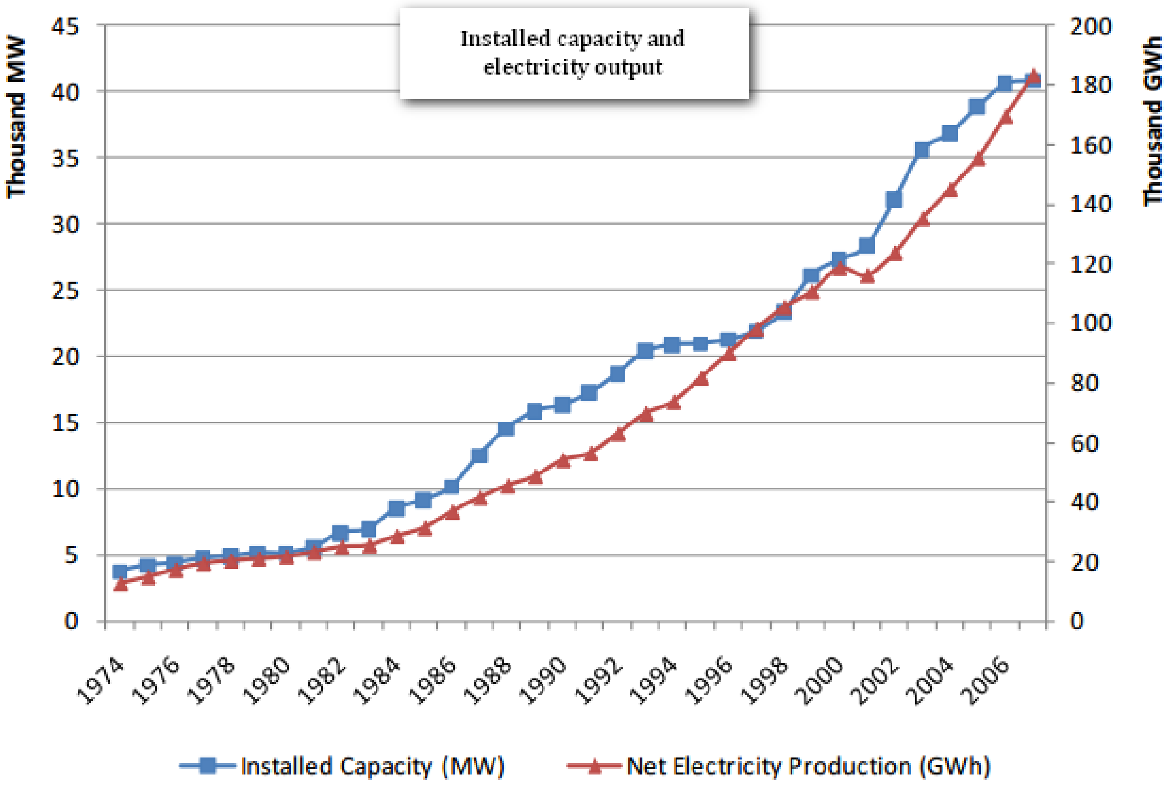


Figure 3. 16 Installed capacity and electricity output from 1974.

The most widely used turbine type in Turkey is Francis turbines followed by Kaplan and Pelton turbines. More than 80% of the hydropower projects use Francis turbines as the projects developers refer them as multi-purpose and more flexible. Apart from the new projects, there is scope for renovation of older hydro projects. The currently privatized Run-of-River hydro projects and EUASs further six portfolios contain numerous old hydro plants and the winning bidders would be expected to renovate those prior to commercial operations. Particularly EUAS six portfolio contains 27 hydro plants 10 of which were commissioned before 1980. In the privately owned hydro projects, there will not be a need for renovation as those are newer projects and will continue to operate at least another 10-15 years to the future.

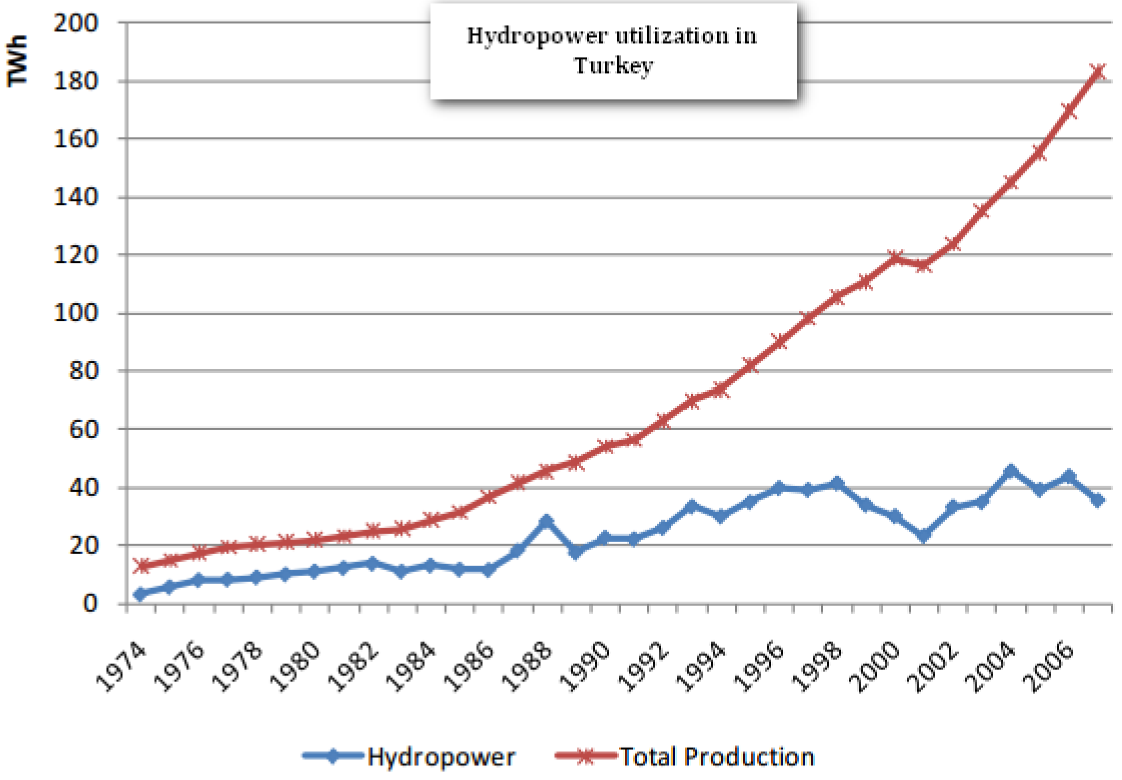


Figure 3. 17 Hydropower utilization in Turkey since 1974

4 Modeling the System

4.1 System Dynamics

System dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality. The field developed initially from the work of Jay W. Forrester. His seminal book Industrial Dynamics (Forrester 1961) is still a significant statement of philosophy and methodology in the field. Within ten years of its publication, the span of applications grew from corporate and industrial problems to include the management of research and development, urban stagnation and decay, commodity cycles, and the dynamics of growth in a finite world. It is now applied in economics, public policy, environmental studies, defense, theory-building in social science, and other areas, as well as its home field, management. The name industrial dynamics no longer does justice to the breadth of the field, so it has become generalized to system dynamics. The modern name suggests links to other systems methodologies, but the links are weak and misleading. System dynamics emerges out of servomechanisms engineering, not general systems theory or cybernetics (Richardson 1991). The approach begins with defining problems dynamically, proceeds through mapping and modeling stages, to steps for building confidence in the model and its policy implications. Mathematically, the basic structure of a formal system dynamics computer simulation model is a system of coupled, nonlinear, first-order differential (or integral) equations. Simulation of such systems is easily accomplished by partitioning simulated time into discrete intervals of length dt and stepping the system through time one dt at a time. In the system dynamic model, stocks (levels) and the flows (rates) that affect them are essential components of system structure. Stocks (accumulations, state variables) are the memory of a dynamic system and are the sources of its disequilibrium and dynamic behavior.

Most of our posts include causal loop diagrams because some things are better expressed with a visual model than in words alone. Systems thinking takes on complex, dynamic systems and how they behave over time, which calls for a different sort of language. In the example below, causal loop diagrams through a population model can be shown. Causal loop diagrams consist of variables (things, actions or feelings) connected by causal links (arrows) with polarities (+ and –); + polarities indicates direct correlation while – polarities indicates inverse correlation.. The two things that cause the population to change are births and deaths, so we use arrows to represent these causal links. We know that more births lead to a greater Population, and fewer births will lead to a lower population, all else equal. We would say this relationship has a positive polarity, meaning that the two variables move in the same direction: more leads to more, or less leads to less. We indicate that a causal relationship has a positive polarity by placing a + sign next to the arrow head. We also know that more deaths lead to a lower population, and fewer deaths lead to a greater population. The variables move in the opposite direction, more leads to less, or less leads to more, so we would say that this relationship has a negative polarity. We represent this by labeling the arrow head with a sign.

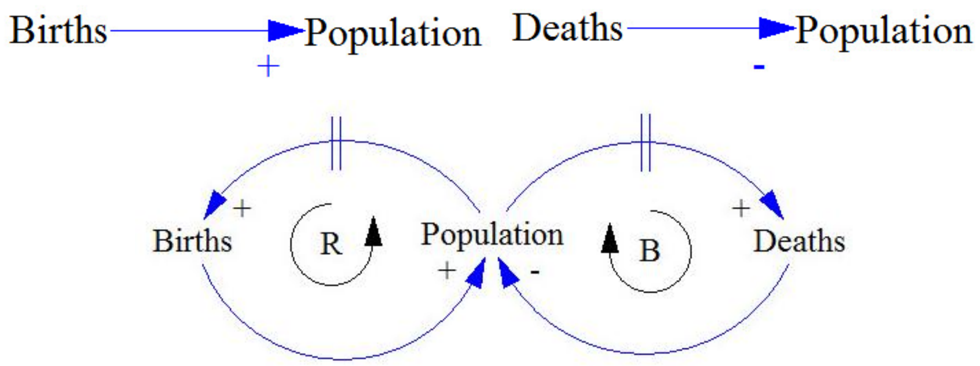


Figure 4. 1 Population Model

In system dynamics modeling, dynamic behavior is thought to arise due to the principle of accumulation. More precisely, this principle states that all dynamic behavior in the world occurs when flows accumulate instocks. The rate has a single arrowhead, indicating the direction that material can flow (the rate can only increase the level). This is only a diagram, in a simulation model the equation governs the direction that material can flow. However, we can use the diagram to indicate whether the flow is intended to be one way or two way. Stock is an accumulation of “stuff,” either concrete (e.g., dollars) or abstract (e.g., anger), that can increase or decreaseover time. Stocks are the “nouns” in the system and should be named (and labeled) as such. Stocks can only be modified through flows.

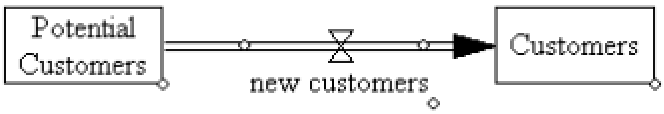


Figure 4. 2 Stock-Flow Model

4.2 Vensim

Vensim is a visual modeling tool that allows you to conceptualize, document, simulate, analyze, and optimize models of dynamic systems. Vensim provides a simple and flexible way of building simulation models from causal loop or stock and flow diagrams.

By connecting words with arrows, relationships among system variables are entered and recorded as causal connections. This information is used by the equation editor to help you form a complete simulation model. You can analyze your model throughout the building process, looking at the causes and uses of a variable, and also at the loops involving the variable. When you have built a model that can be simulated, vensim lets you thoroughly explore the behavior of the model.

Vensim uses an interface that can be thought of as a workbench and a set of tools. The main vensim window is the workbench, which always includes the title bar, the nenu, the toolbar, and the analysis tools. When vensim has a model open (as shown below), the sketch tools and the status bar also appear[18].

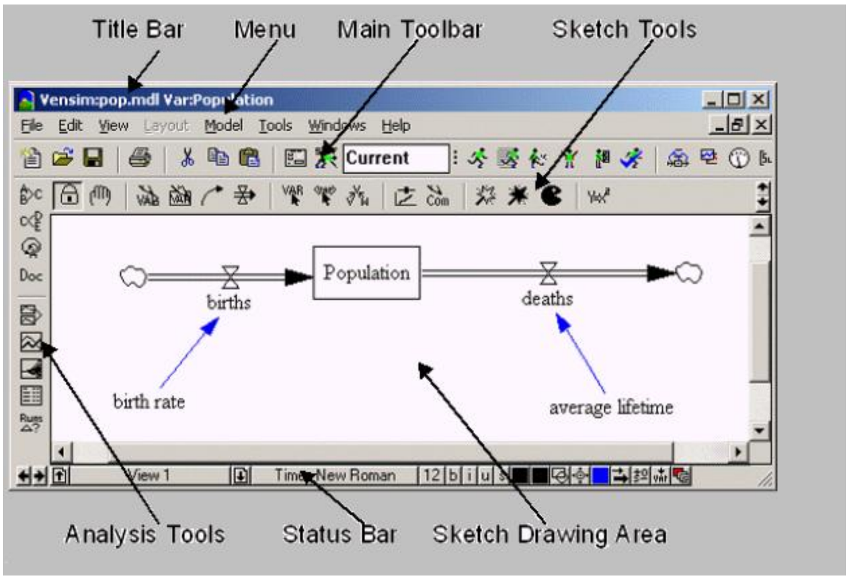


Figure 4. 3 Vensim Interface

4.3 Model

In the field of energy system analysis, different models can be used to analyze complex systems and provide appropriate and transparent decision support. Examples of such complex issues are the relations between climate change, market liberalization, globalization or energy and environmental policies and the energy system. The aim of this paper is to present a study of the analization of energy dependency. The analysis is carried out using a simulation model, which is based on the system dynamics methodology. The simulation model presented in this paper, is used to simulate the effects of the energy imports on the economic structure and system behaviour in Turkey. The objective of the simulation model is in particular the analysis of short and long-term reactions to the energy dependency, as a consequence of different energy policies. In an initial step,it is developed the simulation model, based on the system dynamics theory, for the analysis of the energy dependency in Turkey. It covers a period extending from 1997 until 2030.

Model properties can be seen.

MODEL PROPERTIES	
Model Type	System Dynamic Model
Sector	Energy Sector
Time Horizon	In yearly period ,1997-2030
Analysis of principal energy types	Coal,Natural Gas,Oil,Renewables

Table 4.1 Model Specifications

In this model, the Turkish energy sector is modelled with different feedback loops. This model type allows visualizing causal relations among interrelated variables and shows how one variable affects another. In this figure population is increasing with population growth (or births) while decreasing with deaths.

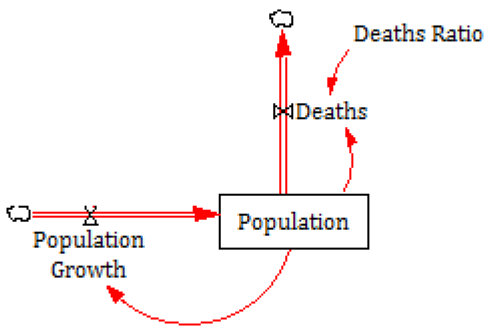


Figure 4. 4 Example of Stock-Flow of Population in the model.

Four interconnected components constitute of the model of the energy sector: demand, production, resources, economics. In this study, including the model have three components: energy supply and production, energy demand, and the consumption of energy. The energy demand component of the model calculates the net energy demand, which changes over time as a result of economic activities and technological change. Energy Resources contains the non-renewable energy reserves used as primary energy sources(coal,naturas gas,crude oil) and renewable energy reserves just like wind energy, solar energy, hydroelectricty. The amounts of energy resources with current situations is represented in this study. The Energy Economics component of the model includes determination of the total investment in the with production capacities, which is based both on historical trends as well as the division of that total among competing production technologies, which can be based on market forces, in the case of coal-, oil-, and natural gas-fired plants and alternative energy sources, or on the prescriptions of decisions makers, in the case of nuclear and hydroelectric power. The economics component also includes capital costs and their change over time, production costs and market prices, average energy prices, and technology market shares.

In the studied model,consumptions of primary energy resources divided two major category which are: household consumptions, industry consumptions. Because of the huge structure of the model it is added to the appendix a while the explanations will be given in this chapter .

Firstly total crude oil consumption has been analyzed. Dependence on imported on oil, has become one of the most important issue in world energy supply security beginning with the oil crises period of 1970s. The issue of oil import dependency has regained importance, especially in developing countries, due to abrupt increases in oil prices during last decade which is reminiscent of the 1970s crises. Depleting crude oil reserves in such countries, which may have limited energy resources compared to demand, highlighted the issue with a marked increase in the total amount of imported oil all over the world. One of the main factors affecting the international oil trade was the price because of that the model is integrated with economic tools. Turkey's primary energy consumption increased from 6.92 to 106.34 mtoe between 1950 and 2008 with an average rate of increase of 4.9%. On the other hand, its domestic production rose from 6.43 mtoe in 1950 to its peak level of 29.32 mtoe in 1998, before decreasing to 23.78 mtoe in 2003. Even though production has gradually increased since 2003, reaching a level of 29.26 mtoe in 2008, this level has not yet proven to be sustainable. Since most of the primary energy imports were crude oil, a good correlation exists between the primary energy and crude oil imports in total consumption with high correlation coefficient. On the economic side; the crude oil import bill has always been an important factor in Turkish macro economy. In 2007, shares of value of oil import in total import bill and GDP of Turkey were 6.9% and 1.8%, respectively.

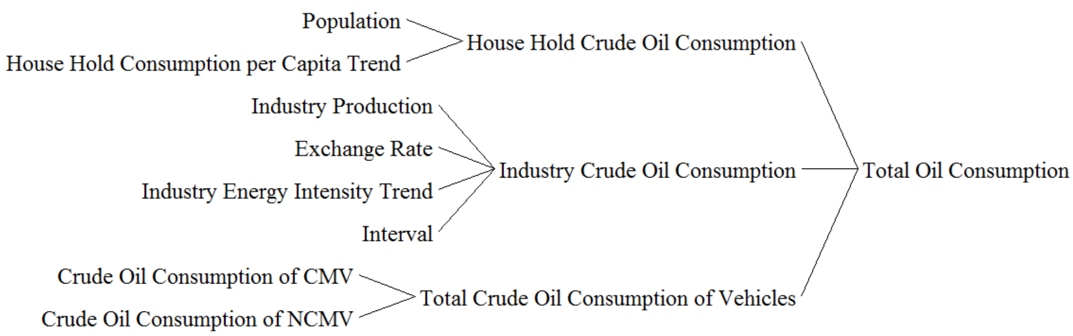


Figure 4. 5 Analysis of "Total Oil Consumption" in the model

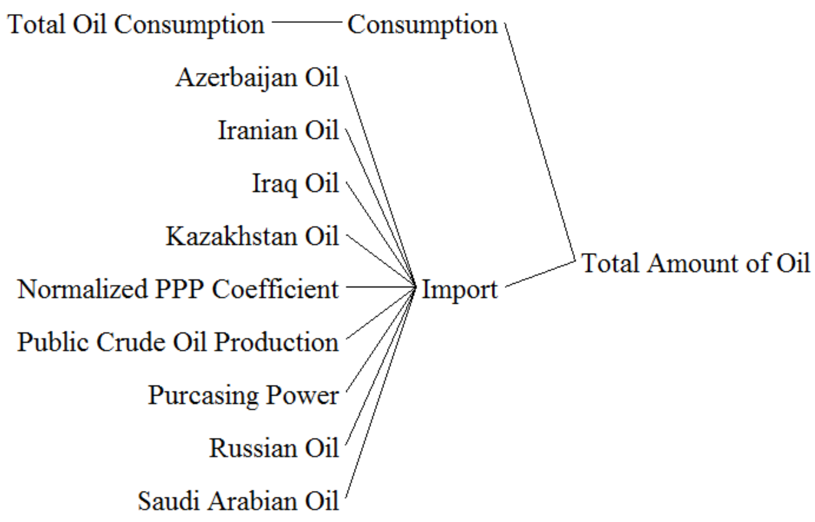


Figure 4. 6 Analysis of "Total Amount of Oil" in the model

Secondly total natural gas consumption has been analyzed. As it can be observed from the system dynamic model natural gas is used mainly in the electric power sector. In the next years, both in Turkey and worldwide natural gas consumption and consequently the importance of the natural gas are expected to increase rapidly.In order to diversify energy supply sources. Turkey's annual natural gas consumption levels have got closer to 40 billion cubic meters. Natural gas has become the most important primary energy source of the Turkey's energy market. Today, the cost of natural gas imports to Turkey's economy is at high levels.It is estimated that total natural gas bill for the past years was approximetaly 100 billion dollars. Even this information is enough to demonstrate the importance of natural gas for Turkey. Unfortunately Turkey's 98% dependence on natural gas imports continues. There are some efforts to reduce the import dependency of Turkey, natural gas exploration and extraction investments continue. Turkey has natural gas purchase contracts with countries that showing below.

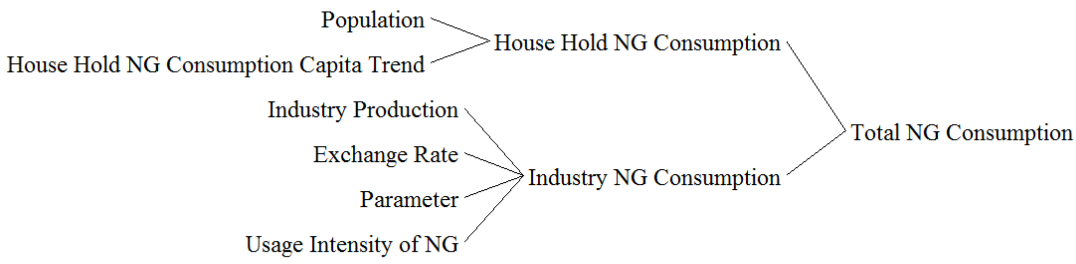


Figure 4. 7 Analysis of "Total Natural Gas Consumption" in the model

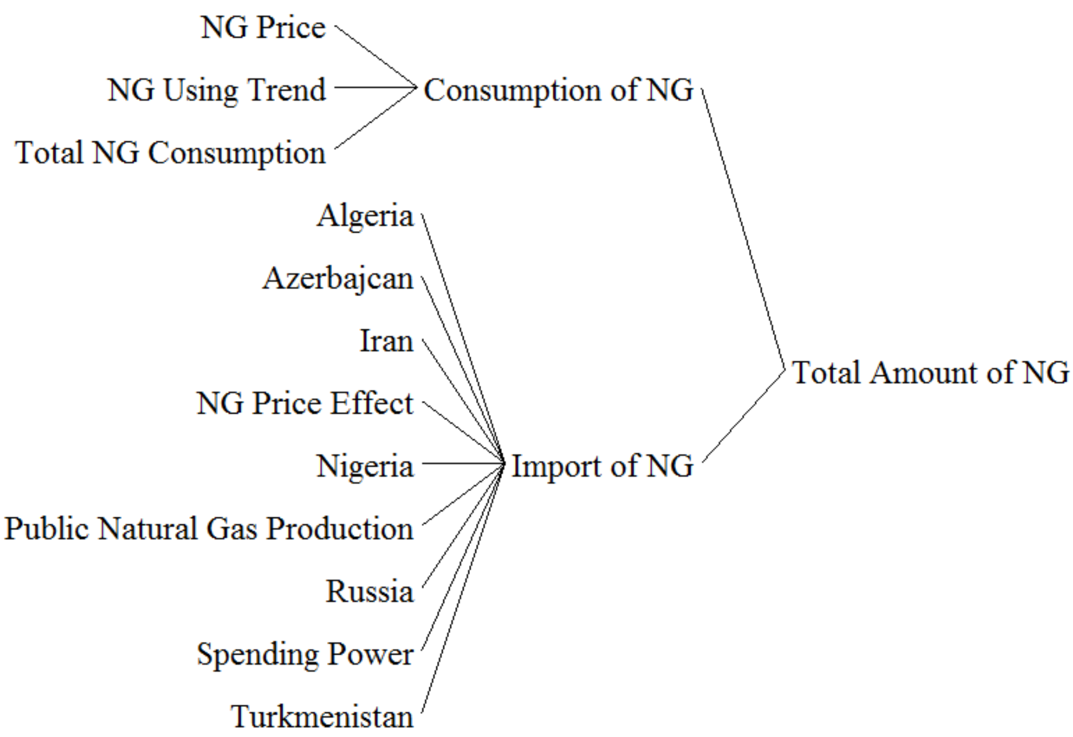


Figure 4. 8 Analysis of “Total Amount of Natural Gas” in the model

When coal consumption of Turkey has been analyzed it is observed that; although domestic coal supply has been increasing, imports of coal has been increased significantly currently. Coal is a reliable energy source and the most economical of fossil fuels; therefore, it keeps its favorable position. There are mainly two sectors on coal consumption;heating pn household and in the industry to produce electricity. Currently %29 of total electric power has been generated by source of coal. Volumes of imported coal might increase in the future as coal's importance for electricity generation increases. Turkey’s primary energy consumption is higher than energy production. In other words, the increase rate of primary energy consumption is about 6 times of that of the production. If this rate increased in the following years, Turkey would become more import dependent country in terms of energy in the following years. On the other hand production depth reached 1000 meters in some regions. Such difficult working conditions caused that the unit costs increased and this affected the competitive power of the country in world's markets.

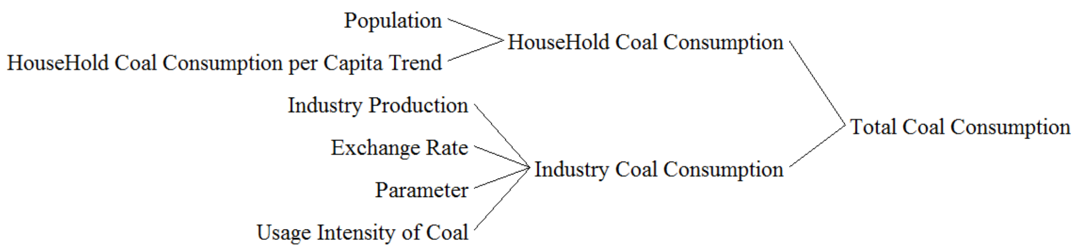


Figure 4. 9 Analysis of "Total Coal Consumption" in the model

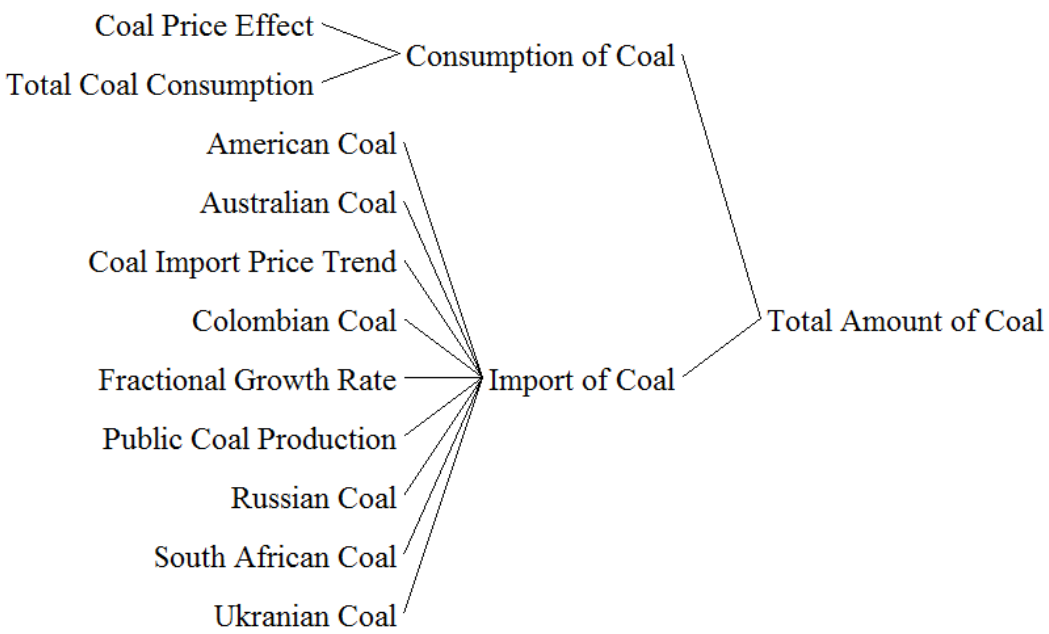


Figure 4. 10 Analysis of "Total Amount of Coal" in the model

In the model from the all three primary resource electricity generation has been also integrated with renewable energy resources. It is obvious that Turkey must have immediate and substantial investment in its electricity generating infrastructure. While electricity demand has been rising significantly currently the importance of renewable energy resource has been also increased. For the last ten year period, Turkey power demand growth is %55. Almost half of the electricity generation has supplied by natural gas; coal has followed it and the remaining part has supplied by hydroelectric power plants and renewable energies. In the system dynamic model; electricity generation also analyzed with economic perspective. Turkey has realized the role that renewable energy can play in expanding power generation and diversifying the energy supply mix in an environmentally sustainable way. Renewable energy became an essential part of energy sector because of the highly dependent structure.

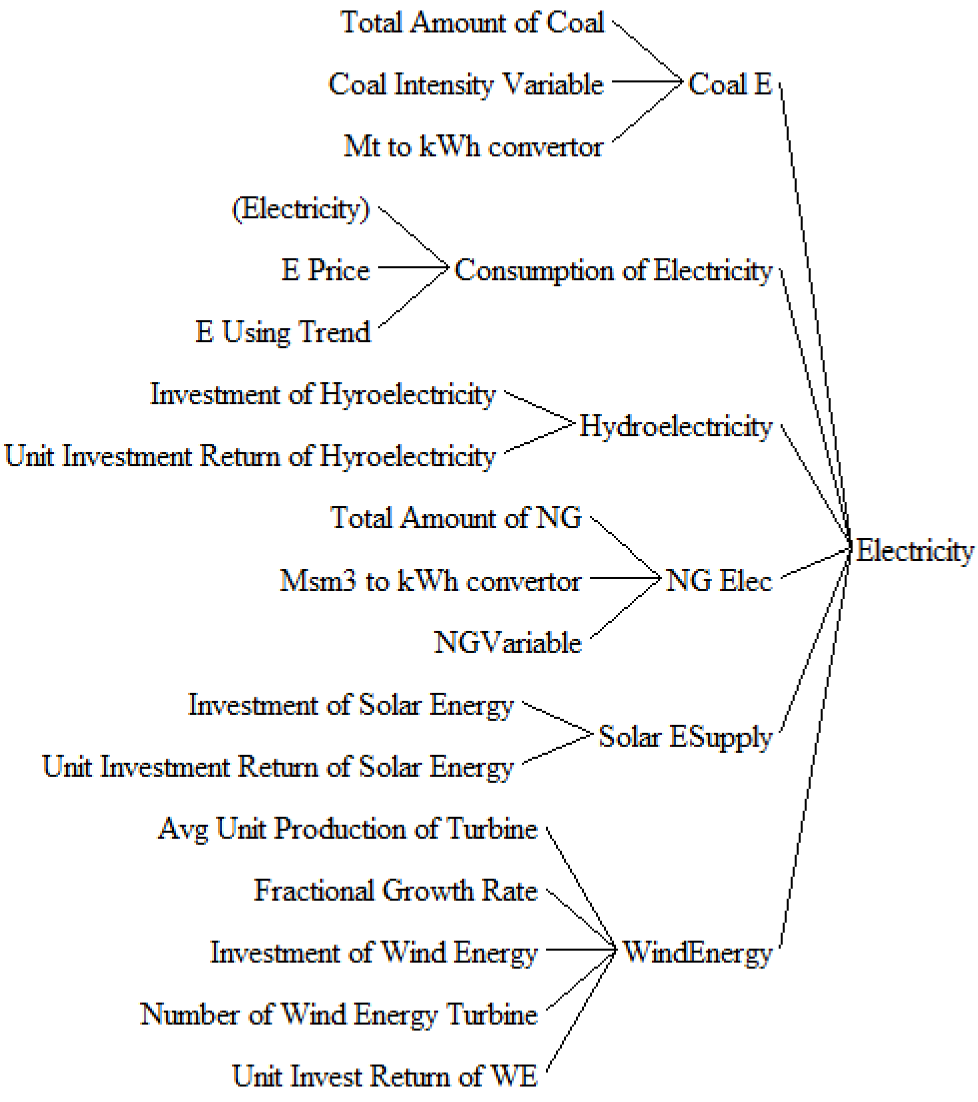


Figure 4. 11 Electricity production view in the system dynamic model.

With this system dynamic model we have got some forecast about energy production and consumptions.

It is expected that electricity demand will be 550 TWh in 2030. To meet the predicted demand, the current installed energy capacity of about 50 GW has to be extended to over 100 GW.

Total primary energy demand is expected double by 2030, reaching 300.4 Mtoe

Currently Turkey has an overall natural hydropower potential of 430 terawatt hours (TWh), which is about 1.1% of the worldwide and 13.75% of the European potential. However, only about 30% (130 TWh) of the potential is deemed to be economically feasible.

Since 2009, 172 hydroelectric power plants, with a total installed capacity of 13.7 GW and an annual energy production of 47.8 TWh, are in operation. Another 94 HEPPs, with a total capacity of 5, 2 GW and an annual energy potential of around 17,560 GWh, are under construction. An additional 542 hydroelectric plants will be constructed in the future, reaching a total installed capacity of 63.24 GW and an annual production of about 190 TWh in 2030 according to the model forecast.

The technical wind energy potential is estimated to be about 114 GW of capacity in regions where the wind speed is higher than 7.0 meters above the ground at 50 meters height. Assuming a capacity factor, which represents the share of actual produced power by a wind power plant compared to the theoretical maximal energy production over the year of the same wind power plant, between 20 and 40% the annual energy production is estimated. Turkey’s technically feasible electricity potential from wind power plants ranges between 200 and 400 TWh. However, the economically feasible potential lies between 35 and 70 TWh.

According to the model Turkey’s energy bill will exceed 100 billion dollars in 2030. In order to minimize import bill renewable energy resources has crucial role.

In terms of the electricity, Turkey intends to meet 30% of predicted demand with renewable energies by 2023 and according to the model if enough investment has been made on 10 year period there will be significant decrease on dependency on energy. With model expectations by the year 2030, domestic energy consumption will reach 300.4 Mtoe, while domestic production will be at 101.2 Mtoe, or 33% of national demand. Model indicated that for the twenty year period ,domestic coal production, renewable energy resources will be very efficient factor on import dependency of Turkey’s energy demand. According to the model it is predicted in year 2020 and 2030 that it goes up to 570 TWh and 700 TWh, respectively. Turkey's hydropower potential can meet one-third of its electric energy demand in 2030.

In the following the results of model can be seen ;

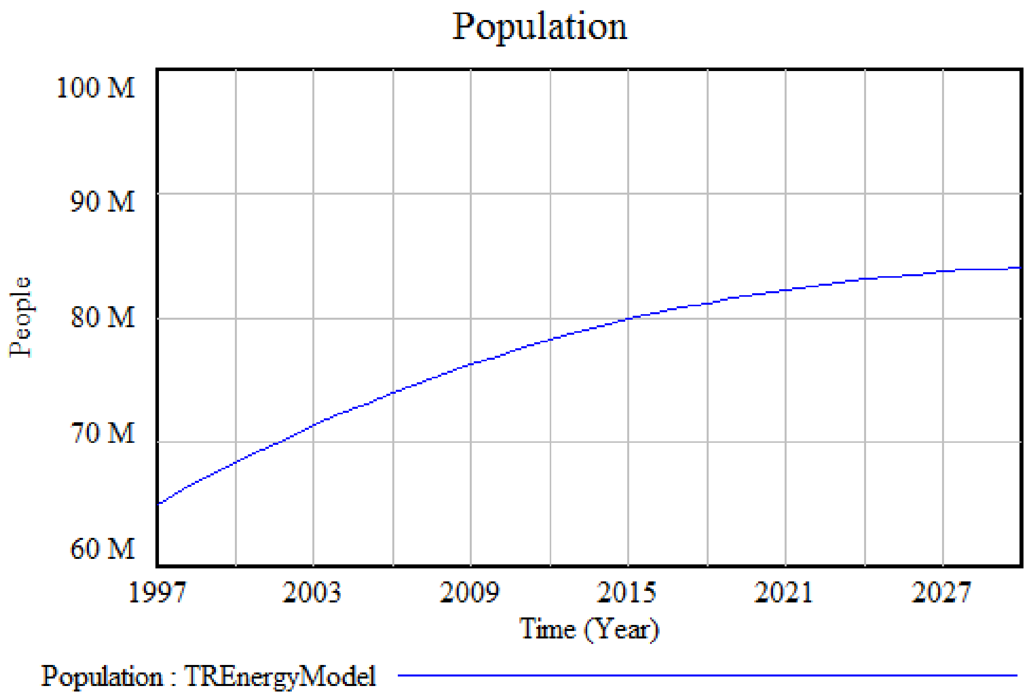


Figure 4. 12 Population growth in the system dynamic model.

According to the system dynamic model Turkey' Population will grow but the growth rate will decrease. Population projection of Turkey in 2023 is 83 million people.

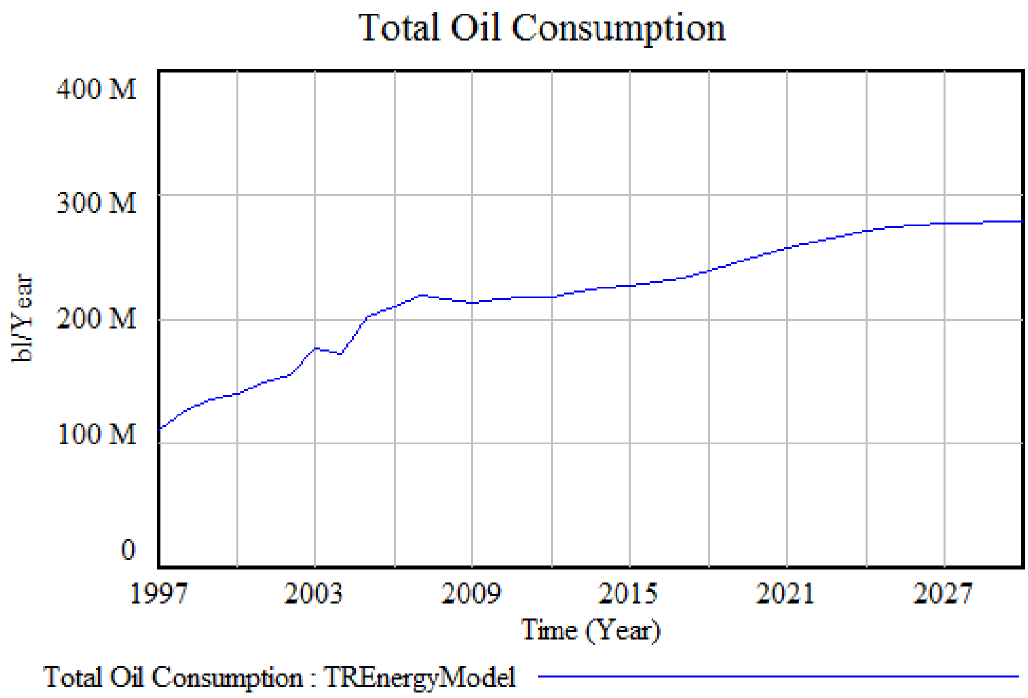


Figure 4. 13 Total Crude Oil Consumption in the system dynamic model.

The crude oil consumption has some flactutations with respect to economical crisis but with increasing total consumption of energy it has increased and it will approach 280M Barrels/Year in 2030. It indicates that expectations on consumption will increase more than %20. Current consumption of crude oil is exceeds 220M barrels.

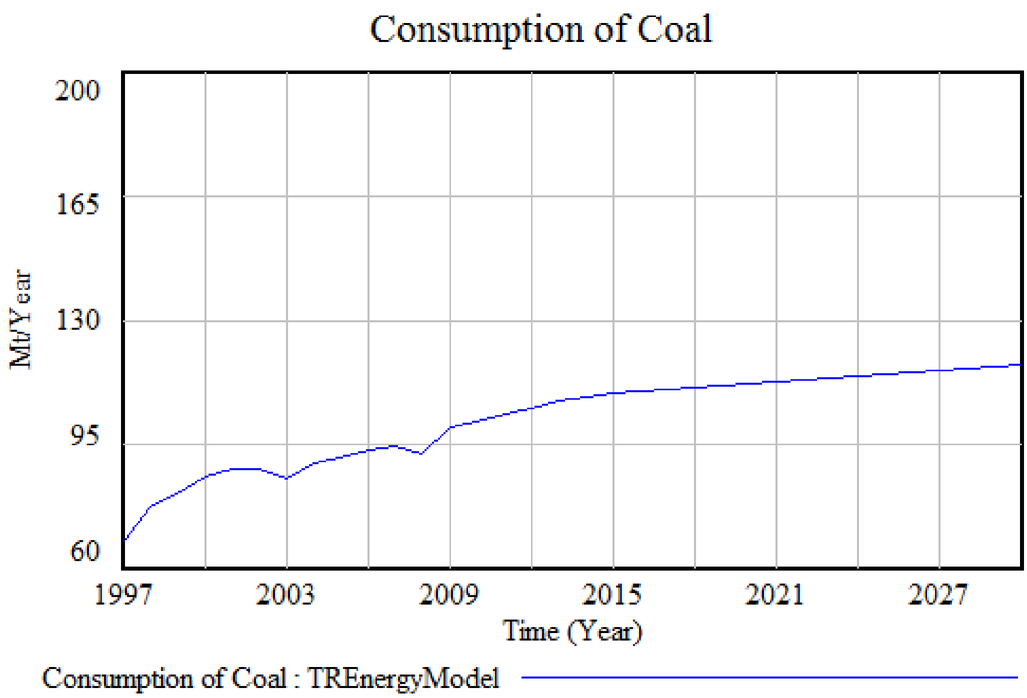


Figure 4. 14 Total amount of Coal Consumption in the system dynamic model.

In the model coal consumption has been also had an increasing trend. Currently 106 M Tonnes coal consumption exists and it is expected to increase to 120M Tonnes. It shows that while hard coal production has a decreasing trend, lignite production has been increasing currently. %25-30 of the hard coal has been imported while most of the lignite produced domestically.

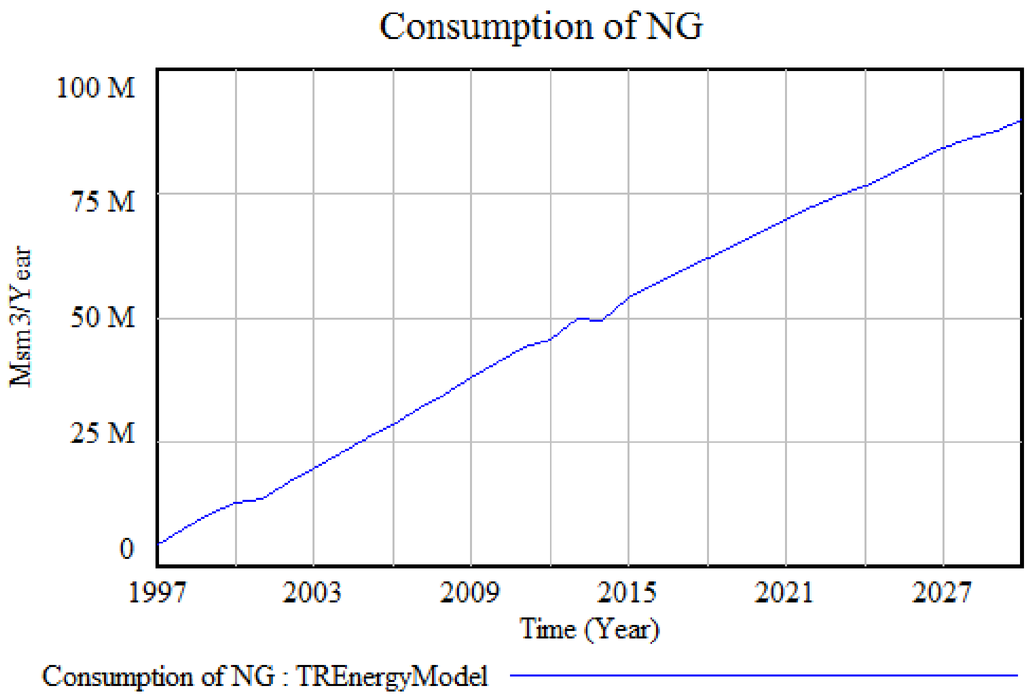


Figure 4. 15 Total Natural Gas Consumption in the system dynamic model.

Turkey has spent more than $50 billion for natural gas and oil import. Although the other energy resources production and proved reserves has been increased it is not enough for energy consumption of Turkey domestically. In the above the natural gas consumption trend can be easily seen. At the end of 2011, the natural gas consumption attained 44,145 billion Sm^3. It will increase 88,000 billion Sm^3 in 2030 according to the projections of system dynamic model. Most of the imports used for electricity generation. Although it will increase as an amount, it is expected to decrease in growth because of the nuclear power plants and raising importance of renewable energies.

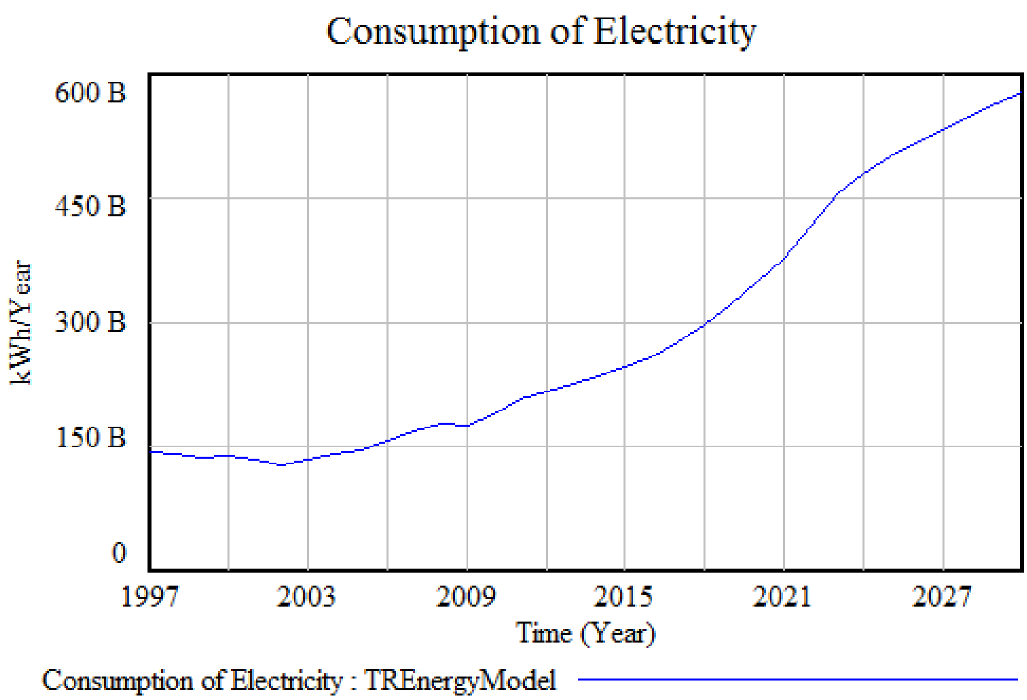


Figure 4. 16 Consumption of Electricity in the system dynamic model.

The figure above indicate the consumption of electricity. With growing population it will approach 600 Billion kwh/year in 2030. In the model it is seen that the distribution of electricity generation according to the energy types as follows.

%20 from coal, %23 from hydroelectric power plants, %30 from natural gas, %15 from natural gas and %10 from wind energy. In the model there is an opportunity to change the production rate with respect to investment and current situation, thus, the percentages can be change. But in the model's current structure the distribution is just explained above.

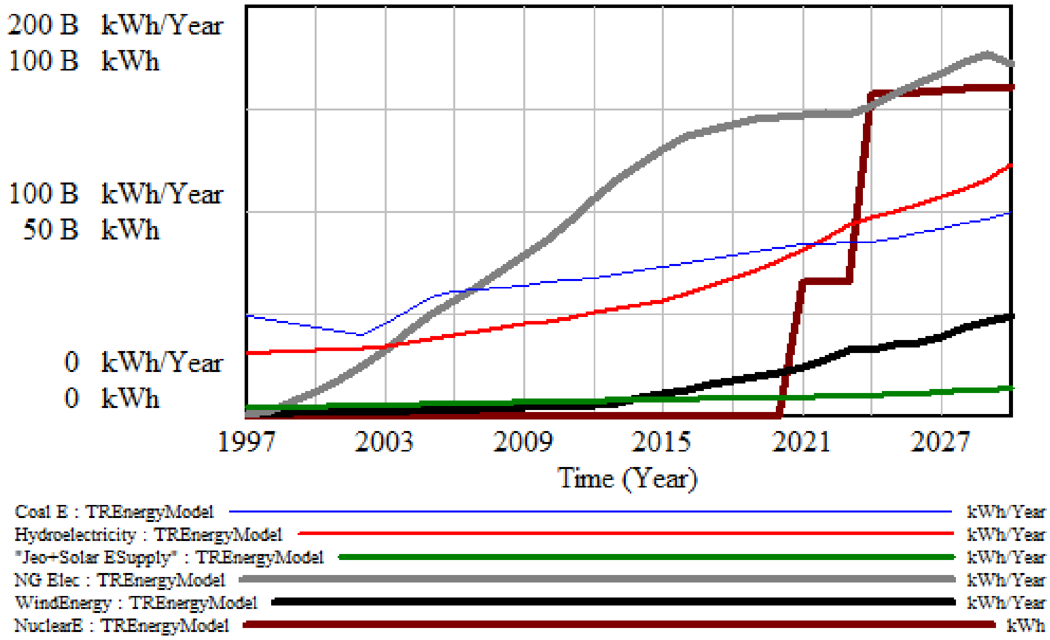


Figure 4. 17 Electricity Production of Turkey in the system dynamic model.

In the figure 4.18 it can be seen that the energy resources and its electricity production trends as billion kwh/year in 30-year period.

Conclusion

In this project it is investigated that the relationship among energy production, consumption, capital, and economic growth for Turkey for the period of 1997-2030 using system dynamic approach. As mentioned above, it extends the current literature exactly on the causal relationship between energy consumption and economic growth. The study indicated that Turkey’s objective must be diversify its energy supply routes and source countries, increase the share of renewables and include the nuclear in its energy mix, take significant steps to increase energy efficiency. It is estimated by the International Energy Agency (lEA) that Turkey will likely see the fastest medium to long-term growth in energy demand among the IEA member countries. On the other hand, it is estimated that total final energy demand and the total primary energy demand will more than double . In order to meet such an immense growth in energy demand, huge levels of investment is required as well in all three sectors alike. While it is known that Turkey is not an rich country as natural gas and crude oil it would be logical to invest more on renewable energies. It is shown that renewable energy consumption has a negative impact on economic growth, and ones from causality tests show that there is a unidirectional causality running from economic growth to renewable energy consumption. In the literature, most of the empirical results suggest feedback or growth hypothesis for developed countries, but this study suggests conservation hypothesis for the relationship between renewable energy consumption and economic growth in Turkey. Renewable energy is an expensive energy source for developing countries, as abundant research studies have revealed that increase in income is a vital supporter behind increased renewable energy consumption. Although this does not mean that energy consumption is not vital for Turkish economy, it could be stated that the role of renewable energy consumption is relatively smaller than the other sources. Also, this result has vital consequences regarding policy, as it suggests that renewable energy limitations do not seem to damage economic growth in Turkey. Renewable energy resources and their utilization in Turkey are intimately related to sustainable development. Turkey has some targets defined related with renewables until 2023 are as follows, at least 30% of total electricity production from renewables,600 MWe geothermal and 3000 MW of solar energy will be implemented,20,000 MW capacity of wind power plant will be in operation. (It is known that wind energy potential of Turkey is 48000MW). It is expected that the annual electricity consumption will be approach 600 billion kWh in 2030 while it is expected 100 million less production if we go with same policy. But if we invest more on renewable and with 2 nuclear plants this gap would be compensated.

In short, the study indicate that Turkey's energy strategy must be multi-dimensional. It strives at diversifying its energy supply sources and routes, as well as its energy basket by increasing the share of the renewables and adding the nuclear energy. Moreover; it is known that uninsulated buildings leads to the loss of energy equivalent to 10 billion dollars for Turkish economy.

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Curriculum Vitae

Muhammet Fatih AK was born on 2 January 1989, in Sivas. He received his BS degree in Industrial Engineering in 2012 from Işık University. He worked as a research assistant at the department of industrial engineering of Işık University from 2012 to 2013. His research interests include operations research, system dynamics, forecasting and supply chain.

Appendices

Appendix A.1 Model