Nuclear Power in Open Energy Markets: A case study of Turkey

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Abstract

For many decades, like many developed countries, Turkey has controlled her electricity sector as a state-owned monopoly. However, faced with rapid electricity demand growth, Turkey started to consider nuclear option. The present paper aims at evaluating both the present status of nuclear power in general and its implications for Turkish energy market in particular. After examining existing nuclear power technology and providing a brief overview of nuclear power economics; it focuses on the repercussions of nuclear power for Turkish energy market. The paper concludes that, in the short run, it may be considered to keep nuclear power within Turkish energy mix because it is an important carbon-free source of power that can potentially make a significant contribution to both Turkey's future electricity supply and efforts to strengthen Turkey's security of supply. However, in the long term, nuclear power should be retained in Turkey only if it has a lower cost than competing technologies.

Keywords: *Turkish energy market, nuclear power, electricity*

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1. Introduction

The Republic of Turkey (thereafter Turkey) is located between Europe[1] and Asia, bordering the Mediterranean, Aegean and Black Seas. Turkish economy, the world's 16th largest economy, is a dynamic and emerging one (Ozturk et al., 2005). In 2004, Gross National Product (GNP) was realized as 269 billion USD, which corresponds to 3,750 USD per capita. In 2004, annual GDP growth rate was 8.9%. Population of Turkey is about 71.7 million and the population growth rate is 1.4% (World Bank, 2006). The economy has undergone a significant shift away from agriculture towards the industrial and especially the services sector in the last three decades, although 29% of the active population is still employed in agriculture (Turkstat, 2006). The net effect of all these factors is that Turkey's energy demand has grown rapidly almost every year and is expected to continue growing.

With an average final electricity consumption growth rate of 8.3% per annum over the 1973-2002 period, Turkey is among the fastest growing energy markets in the world[2] (IEA, 2004, p. II.624). The government expects demand growth to accelerate in the coming decades with an average annual growth rate between 6.3% - 8.4% (see Table 1)[3].

[*Table 1 goes here*]

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[1] In October 2005, accession negotiations are opened with Turkey, who has been an associate member of the EU since 1963 and an official candidate since 1999. For a more detailed discussion of EU-Turkey relations, see Erdogdu (2002).

[2] During the same period, on average, final electricity consumption increased by only 2.9% annually in OECD countries, which corresponds to about 1/3 of the figure for Turkey (IEA, 2004, p. I.46).

[3] However, official projections highly overestimate the electricity demand in Turkey. For more information on Turkish electricity demand, see Erdogdu (2006b).

In short, it is obvious that electricity consumption in Turkey is growing very rapidly. To cope with the expected increase in electricity consumption, there exist some options, among which one of the most controversial is nuclear.

Stimulated by the urgency of the Second World War, nuclear science progressed rapidly from the discovery of the neutron by Sir James Chadwick in 1932. The first controlled chain reaction took place in 1943, the first atomic weapon was developed in 1945, and in 1951 electricity is produced using nuclear energy for the first time. Following its first application for generating electricity in the United States, nuclear energy began to be applied to the production of electricity in the United Kingdom (1953), Russia (1954), France (1956), and Germany (1961); that is, five countries within the first decade. Ten more countries began nuclear-based generation in the 1960s followed by another ten in the 1970s. The oil crisis of the early 1970s provoked a surge in nuclear power plant orders and construction. Later that decade, the world economic slowdown combined with the declining price of fossil fuels curtailed the growth of nuclear energy demand. As this took effect, two accidents, at Three Mile Island in the United States (1979) and at Chernobyl in the former Soviet Union (1986), raised serious questions in the public mind about nuclear safety. The overall effect was a significant slowing of nuclear energy's growth in the 1990s. Nevertheless, some countries continued to push ahead strongly with reactor construction, thus contributing to small increases in nuclear electricity production (OECD, 2003). Today, there are 441 nuclear reactors in operation worldwide, with an additional 35 under construction. Nuclear power provides about 17% of the world's electricity (Duffy, 2004). To put it shortly, the 50-year history of commercial nuclear power has been punctuated by dramatic policy changes. The first 20 years, marked by limited public participation, tight government control, and promises of clean, abundant energy, were followed by a period of intense social and political conflict over the technology's environmental and safety implications. Nuclear policy in the United States and most European nations shifted from all-out support to a more ambivalent posture, which led to a dramatic slowdown in the construction of new plants.

For many decades, like many developed countries, Turkey has controlled her electricity sector as a state-owned monopoly. However, faced with rapid electricity demand growth, Turkey started to consider nuclear option[4]. The present paper aims at evaluating both the present status of nuclear power in general (including existing nuclear technology, nuclear power economics and current status of nuclear power in the world) and its implications for Turkish energy market in particular. Following part of the article provides a brief overview of nuclear power economics. Next part not only sets out the development and current context of nuclear power in the world but also focuses on its repercussions for the open energy markets. Fourth part considers both the historical background and current status of nuclear power in Turkey. Energy policymakers and others whose main interest is in nuclear-related policy matters may wish to concentrate on the final part.

[4] Actually, in the first place, Turkey has initiated a comprehensive energy market liberalization process to cope with rapid energy demand growth. For more information on Turkish energy market reform process, see Erdogdu (2006a).

2.1. Costs of Nuclear Power

Figure 1 shows the life cycle revenues and costs for a typical nuclear power plant. It demonstrates the factors that characterize the economics of nuclear energy, that is;

- high capital investment costs;
- long planning horizons[5] and operational life;
- low fuel, operating and maintenance (O&M) costs;
- significant costs incurred after cessation of power generation (notably management and disposal of radioactive waste and decommissioning).

[*Figure 1 goes here*]

Nuclear power's cost structure makes it well-suited for baseload power generation[6], since it has a high fraction of fixed capital costs and a low fraction of variable operating costs[7].

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[5] Although the construction times of nuclear power plants have been sometimes rather long in the past, many recent nuclear power plants were constructed and put into service within no more than four years.

[6] That is, nuclear power plants should be operated at almost full capacity whenever they operate.

[7] A baseload power plant is one that is operated continuously. The fixed costs per kWh energy produced declines rapidly as time passes in such a plant. Even, in the long run, they disappear as the plant pays itself back. Also, in this kind of plants, operating costs needs to be low; otherwise, the total cost of production increases enormously as it operates constantly. So, from the perspective of commercial economics, a power plant is well suited for baseload power generation if it has a high fraction of fixed construction costs and a low fraction of variable operating costs.

2.1.1 Operating Costs of Nuclear Power

Operating costs of nuclear power has two main components: operation and maintenance (O&M) costs and fuel costs.

O&M costs include all costs that are not considered capital or fuel costs, the main elements being the costs of operating and support staff, training, security, health and safety, and management and disposal of operational waste.

Fuel costs include costs related to the fuel cycle, including the costs of purchasing, converting and enriching uranium, fuel fabrication, spent fuel conditioning, reprocessing, disposal of the spent fuel or the high-level waste resulting from reprocessing and transport. Fuel costs make up only about 20% of the costs of nuclear-generated electricity, which is therefore relatively insensitive to fuel price fluctuations - in contrast to the position of fossil fuels (OECD, 2003).

2.1.2. Capital Costs of Nuclear Power

The capital costs include those of design and construction, major refurbishing, decommissioning and high-level waste disposal. The last two comprises all the costs incurred from the shutdown of the plant until the site is released.

Not including interest paid during construction, current designs of nuclear plants have capital costs of roughly $2000/kW (compared to $1200/kW for coal-fired plants and $500/kW for combined-cycle gas turbines). Capital costs typically account for 60% to 75% of nuclear power's total generation cost, while in coal plants they are only about 50% and in gas-fired plants they can be 25% or less (OECD, 2001).

Investment costs must be financed, and they thus incur interest charges. These are amortized over some set period, perhaps on the order of 20-25 years, and the debt service[8] becomes part of the costs of electricity generation. Due to interest charges, delays in construction and commissioning can increase the capital cost significantly. If plant construction is financed with foreign loans, currency devaluation would also increase costs in the country where the plant is installed.

Provisions are also required to be set aside or paid by plant operators for decommissioning and high-level waste disposal, a process that can take many decades. Decommissioning and waste management liabilities may be the most important of the various economic risks of nuclear power in competitive electricity markets.

Although decommissioning costs are not spent until after the nuclear power plant has been retired, once nuclear fuel has been loaded into the reactor and the reactor experiences a self-sustaining nuclear reaction,

[8] Debt service refers to the cash required over a given period for the repayment of interest and principal on a debt.

regulatory authorities in general require that the owner-operator set aside funds to pay for the decommissioning[9].

Funding for spent fuel and high-level waste disposal is somewhat similar to that for decommissioning. In many cases, a levy for the cost of nuclear spent fuel and/or high-level waste disposal is taken into account in nuclear fuel costs. However, most countries have not yet fully implemented spent fuel and high-level waste disposal policies. Some countries require nuclear generators to contribute to a fund for implementing the waste disposal policy that will ultimately be adopted. A critical consequence of not having a policy is that a range of uncertainties remain on the cost for waste disposal. This large potential liability stands as a strong deterrent to future private capital investment in nuclear power as financial institutions will not invest in operations that have undefined and unsecured liabilities of such potential magnitude.

2.2. Financial Risks of Nuclear Power

A decision to build or to continue to operate a nuclear power plant represents greater commercial risk than is normally associated with alternative energy sources, for such reasons as (OECD, 2003):

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[9] Because of the wide variety of cost estimates, the cost of decommissioning is assumed to be one-third of the direct construction cost, discounted 40 years to the start of operations (Rothwell, 2004). To cover this cost, some countries require an initial endowment and annual contributions from nuclear generators, usually assessed as a fixed amount per kWh of generation, while others require nuclear generators to include funding for decommissioning costs in their financial plans. In many countries a separate fund, managed by the government or by power generators, has been established to cover decommissioning costs.

- The long planning timescale and operational life provides greater potential for long-term changes in the market to impact revenues negatively or positively.
- The high fixed-cost element, due largely to the high investment costs, produces greater vulnerability to short-term fluctuations in market conditions.
- The strong regulatory framework reduces operational flexibility and introduces the possibility of changes in regulatory requirements that could impact adversely on costs (and historically have done so).
- Uncertainties exist associated with the costs of decommissioning and long-lived waste disposal, including the time periods involved.
- Whereas non-nuclear plants can trade or sell much of their cost base under negative economic conditions, this is in practice largely ruled out for nuclear power plants (e.g. a gas-fired power plant can sell its gas supply on the open market).

2.3 Externalities

Commercial economic evaluations do not include externalities. By definition, externalities are costs and benefits that are not incorporated in market decisions unless governments take specific policy actions. In the context of nuclear power, externalities mainly refer to the cost of nuclear power's contribution to sustainable development and the security of energy supply.

The question of the sustainability of different energy sources is likely to assume greater significance; and in this context, nuclear energy has certain advantages in its carbon-free generation of electricity and heat, as well as in security of supply.

In the long term, the competitive margin of nuclear power significantly increases if the external costs, which presently are not included in market electricity prices, are taken into account.

2.3.1. Sustainable Development

Today the concept of sustainable development[10] is widely accepted and the need to integrate economic, environmental and social aspects within development policies is progressively recognized in many developed countries.

Nuclear energy already contributes to reducing greenhouse gas emissions. At present, if nuclear power plants were replaced by modern fossil-fuelled power plants, carbon dioxide emissions from the electricity sector would increase by more than 15% (OECD, 2000).

Nuclear power is one of the few energy sources that emit virtually no air-polluting or greenhouse gases. The entire nuclear fuel cycle including mining of ore and the construction of power plants has been estimated to emit between 2.5 and 6 grams of carbon equivalent per kWh of energy

[10] The concept of sustainable development was elaborated in the late 1980s and defined by the Bruntland Report as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

produced. This is roughly equal to the estimated releases from the use of renewable sources (wind, hydro and solar power) and about 20-75 times less than the emissions from natural gas power sources, the cleanest fossil fuel available (OECD, 2003). Nuclear power is thus one of the prime means available for limiting the emission of carbon into the environment. Figure 2 presents the greenhouse gas emissions from electricity generation by different sources.

[*Figure 2 goes here*]

2.3.2. Security of Supply

As a nation's dependency on foreign sources for its energy increases, so do the costs and economic consequences of any disruption. Any energy source that reduces dependence on external fuel sources can be said to enhance the security of energy supplies and ultimately the security of the nation. Security has always been one of the main aims of energy policy in almost all countries.

In this framework, nuclear energy can be seen to have two potential positive influences. First, importing relatively small amounts of uranium would be more attractive than importing relatively large amounts of coal, oil or gas. Fuel costs are a major component in the price of fossil fuel electricity. Hence the tendency towards fluctuations in fossil fuel prices translates itself into variations in the price of electricity, especially in a competitive market. The low share of fuel costs and high share of fixed costs in the case of nuclear electricity generation have, by contrast, a potentially stabilizing effect on electricity costs and prices. Second, Uranium resources are abundant and spread in several world regions[11]. Unlike fossil fuels, nuclear fuel and fuel feedstock are compact and easy to stockpile; large inventories can be kept at comparatively low cost. About 25 tonnes of fuel assemblies will provide a year's fuel for a 1 GW current generation pressurized water reactor. A coal-fired plant of similar output would require 3 million tonnes of fuel, i.e. more than 100,000 times as much (OECD, 2003).

3. Overview of Nuclear Power in the World

3.1. Present Status of Nuclear Power in the World

As presented by Figure 3, nuclear energy increased its share of world electricity generation from 3.3% in 1973 to 17.1% in 2001. So far, 32 countries have produced electricity from nuclear reactors. As of 1 January 2003, there were 441 commercially operating nuclear reactors (see Table 2) representing an installed generating capacity of about 356 Gigawatts (GW) net supplying about 7% of the world's total energy and about 17% of the world's electricity (OECD, 2003).

[*Figure 3 goes here*]

[*Table 2 goes here*]

[11] On the other hand, oil and gas have a fairly limited geographical availability, with Middle Eastern countries and the Russian Federation controlling over 70% of world crude oil reserves and about two-thirds of natural gas reserves. Quite aside from the political instability that has sometimes characterized the oil and gas supplier regions, the long supply routes to major markets are also vulnerable to disruption by political action (OECD, 2003).

A number of countries have chosen to forego the nuclear option, especially in the post-Chernobyl era: Australia, Austria, Denmark, Italy, Ireland, and Norway. Sweden continues to operate its 11 nuclear reactors (1 was closed in 1999) and has extended the 2010 date calling for the shutdown of all plants due to a 1980 national referendum, but it continues its policy of phasing out nuclear power. Germany, an early enthusiast for nuclear energy, passed legislation in 1998 for the eventual phase out of nuclear power but subsequently modified the policy in 2001 to limit the operational lives of existing plants to 32 years, thereby deferring any immediate closures. On the other hand; some countries such as France, Japan, South Korea China, Taiwan, India and Pakistan have ordered new nuclear capacity in the last two decades (Rosa and Rice, 2004).

3.2. Nuclear Power in Open Energy Markets

There has been a growing recent trend towards opening electricity markets to competitive supply and pricing. While there are few doubts that economic deregulation will improve the overall economic effectiveness of electricity production, its impact on nuclear power is a matter for discussion. One consequence of market liberalization is that generating companies no longer have a guaranteed market and must examine more carefully the costs and anticipated revenues from the sale of electricity.

In general, it is argued that competitive markets favor short-term investments with high returns and low risks. Two observations are often made to support these views: the first is that introducing competition creates a state of investment uncertainty; and the second observation is that investors in electricity generating plants have shown a strong preference for gas-fired combined cycle power plants as these plants have short development times and low capital costs. However, there exists a decisive difference between transitional uncertainties as competition is introduced and market behavior when market conditions have stabilized. It is true that, during a transition to competition, investors tend to focus on short-term investments with low risks because long-term market conditions may not be clear; but this trend may be reversed when transition is completed. Also, at present, it is true that decreasing real price of natural gas, combined with steadily improving combined-cycle generation (CCGT) technology, has made natural gas the cheapest option for baseload power generation in regions with pipelines to access natural gas; however, the trend towards the construction of CCGTs may also be reversed if the price of gas increases.

Under competition, investment decisions for new nuclear power plants will depend ultimately upon their profitability. The prospects for building new nuclear power plants in competitive markets are not clear. Although some arguments can be made for and against building new nuclear power plants in these markets, decisions in many countries are likely to be influenced by public opinion, political will, and the pace of implementation of spent fuel and other high-level waste disposal facilities.

An OECD/NEA study on Nuclear Power in Competitive Electricity Markets, published in 2000, found that nuclear power plants in Finland, Germany, the Netherlands, Spain, Sweden, the United States and the United Kingdom had been competitive in their respective deregulated markets (OECD, 2003). Based on current production costs and the trend of performance improvement in many countries, a large number of existing nuclear power plants are expected to be able to compete well with other power technologies in competitive electricity markets (OECD, 2000). Also, Nuclear power plants in Finland[12] and Sweden have been operating successfully within the Nordic electricity market, and Spanish, German and Dutch nuclear power plants have successfully competed in the competitive markets that were introduced at the beginning of 1998 (OECD, 2003). During the past year, there has been increasing publicity about an apparent international revival in nuclear ordering. In July 2005, there were 24 plants under construction worldwide, with a capacity of 19GW (Herring, 2004).

3.3. Nuclear Fuel Supply

Unlike fossil fuels, nuclear fuel must be specially processed and placed into engineered fuel assemblies before it can be used in power plants. The raw energy commodity for nuclear power production is natural uranium. In its commercial form it is called uranium oxide, or yellowcake. There is no other major civilian use for uranium apart from electricity production. Therefore, uranium mining activity and uranium prices depend substantially on nuclear power generation.

[12] The decision of Finland's TVO (Teollisuuden Voima Oy) company, a large electricity co-operative, to proceed with the investment in a nuclear plant is the first by a company in a competitive electricity market (Andersson and Haden, 1997).

Uranium is widely dispersed in the earth's crust and in the oceans. At the beginning of 2001, estimated conventional uranium resources (known and undiscovered) totaled above 16 million tonnes or nearly 250 years of supply at the prevailing rate of usage (OECD, 2003). Uranium was mined in 23 countries in 2001. Canada and Australia provided more than half of the world's supply in the same year (see Table 3). In terms of uranium conversion and enrichment, US, Russia and France controls about 90% of the world capacity (see Table 4).

[*Table 3 goes here*]

[*Table 4 goes here*]

Other advanced techniques currently envisaged (but not developed so far) could employ thorium as a fuel feedstock rather than uranium, thereby further expanding nuclear fuel resources. India, in particular, with large thorium reserves, is working to implement a thorium fuel cycle. In essence, nuclear energy cannot be considered to be resource-limited.

3.4. Non-proliferation

Perhaps the most sensitive issue in the early years of the 21st century is nuclear proliferation and the related concern of nuclear terrorism. The terrorist attacks of September 11, 2001 have pushed nuclear power into the spotlight and revealed loopholes in the current international agreements and their enforcement mechanisms. It also made it obvious that the major challenge nuclear energy is facing today is to provide an impermeable solution for managing the nuclear fuel cycle in order to prevent proliferation and to eliminate the risk of misusing nuclear material. The risk of weapons proliferation will remain an issue for nuclear energy and an important concern for the public as long as the link between civilian and military use of nuclear energy cannot be effectively and permanently cut.

Today, International Atomic Energy Agency (IAEA)[13] - an independent intergovernmental science- and technology-based organization within the United Nations family - serves as the global focal point for nuclear cooperation. IAEA has played a vital role in international nuclear security and a minor role, if any, in the development and application of nuclear power. As a universal organization, it is used by Western countries for purposes of controlling “nuclear risk” in the developing countries. It has to coexist with other specialized nuclear agencies such as Nuclear Energy Agency (NEA) of OECD, and the EU's special nuclear agency. The IAEA has no direct regulatory powers but has a major, if not the most dominant, influence on regulation by national agencies with direct regulatory powers. Therefore, in practice, it acts as a global nuclear regulatory agency. Today, its main task is to safeguard the use of nuclear materials and facilities not only in member countries under the Non-Proliferation Treaty[14] (NPT) but also in non-NPT countries.

[13] The IAEA was established by treaty, effective in 1957.

[14] The Nuclear Non-proliferation Treaty of 1968 is the fundamental legal basis for the international nuclear non-proliferation regime. The NPT divides the world into two groups - States that had nuclear weapons when the Treaty came into place (that is, 1970), or the "nuclear weapon States" which included China, France, Russia, the United Kingdom and the United States; and the remainder of the signatories called the "non-nuclear weapon States". As of 2006, there are 188 signatories of the treaty. Each nuclear weapon State pledged not to transfer nuclear weapons, not to assist any non-nuclear weapon State to develop nuclear

3.5. Future of Nuclear Power

Nuclear power is important, but its future is uncertain. The outlook for nuclear power is affected by many factors. Commercial economics is a key factor. Governments are liberalizing their energy markets, increasing the importance of cost-effectiveness for all electricity generation sources. The long-term future for nuclear power, like that for other energy sources, will increasingly be based upon its cost-effectiveness. However, commercial economics is far from being the only key factor. The wider energy policy framework remains a vital consideration for future decisions on nuclear power.

The list of worries related to nuclear energy comprises economic performance, proliferation of dangerous material, the threat of terrorism, operation safety, radioactive waste disposal, and, as a result of all these, public acceptance. The resolution of these concerns will be a complex social process involving relatively clear-cut technical, technological, and economic factors as well as particularly contentious social and political choices. The outcome of this process will determine the role nuclear might play in the world energy balance in the long-term future.

The future of nuclear energy depends on the interplay between five factors:

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weapons and to work to achieve nuclear disarmament. India, Israel and Pakistan have so far refused to sign the NPT.

1. Growth in energy demand,
2. Cost-competitiveness with other fuel sources,
3. Environmental[15] and security of supply considerations,
4. Concerns about the proliferation of nuclear weapons, and
5. Questions of public attitude and perception.

Depending on the satisfactory resolution of these factors, many new and enlarged applications of nuclear energy can be envisaged.

4. Nuclear Power in Turkish Energy Market

4.1. History of Turkish Electricity Market

Hepbasli (2005) reports that in Turkey "the first electric generator was a 2 kW dynamo connected to the water mill installed in Tarsus" in 1902; and, he continues, "[t]he first bigger power plant was installed in Silahtaraga, Istanbul, in 1913". The following evolution of Turkish energy market may be summarized as follows.

The Republic of Turkey was founded in 1923, and until the 1930s the electricity industry was heavily dependent on foreign investment as the country was trying a liberal economy. In the 1930s, there was a widespread belief all over the world in the benefits of public ownership of the electricity industry. Following this trend, nationalization of Turkish electricity industry

[15] Nuclear power does not emit greenhouse gases, therefore, the competitiveness of nuclear power will significantly improve if the external environmental costs are reasonably reflected in market prices, e.g. through a carbon dioxide tax.

started in 1938 and, by 1944, almost all electricity industry had been placed within the public domain.

In the 1960s, the government started the "development plans era". The Ministry of Energy and Natural Resources (MENR) was established in 1963, and was responsible for Turkey's energy policy. This was followed in 1970 by the creation of Turkish Electricity Administration (TEK), which would have a monopoly in the Turkish electricity sector at almost all stages apart from distribution, which were left to the local administrations[16].

In the early 1980s, as was the case in many European countries, the Turkish electricity industry was dominated by a state-owned vertically integrated company, TEK. Starting from the 1980s, the government sought to attract private participation into the industry in order to ease the investment burden on the general budget. In 1982, the monopoly of public sector on generation was abolished and the private sector was allowed to build power plants and sell their electricity to TEK. In 1984, TEK was restructured and gained the status of state-owned enterprise.

Various private sector participation models short of privatization were put into practice. The first law setting up a framework for private participation in electricity industry was enacted in 1984 (Law No. 3096). This Law forms the legal basis for private participation through Build Operate and Transfer (BOT) contracts for new generation facilities, Transfer of Operating Rights (TOOR) contracts for existing generation and distribution assets, and the

[16] In 1982, however, distribution was also transferred to TEK, thus making TEK a national vertically integrated monopoly fully owned by the state.

autoproducer system for companies to produce their own electricity. Under a BOT concession, a private company would build and operate a plant for up to 99 years (subsequently reduced to 49 years) and then transfer it to the state at no cost. Under a TOOR, the private enterprise would operate (and rehabilitate where necessary) an existing government-owned facility through a lease-type arrangement (Atiyas and Dutz, 2003).

In 1993, TEK was incorporated into privatization plan and split into two separate state-owned enterprises, namely Turkish Electricity Generation Transmission Co. (TEAS) and Turkish Electricity Distribution Co. (TEDAS). However, the constitutional court of Turkey issued a series of rulings in 1994 and 1995 making the privatization almost impossible to implement in electricity industry. To overcome the deadlock; in August 1999, the parliament passed a constitutional amendment permitting the privatization of public utility services and allowing international arbitration for resolving disputes. However, during this interval, Turkey not only lost five invaluable years in terms of reform process that could never get back but also, and more importantly, tried to enhance the attractiveness of BOT projects by providing “take or pay” guarantees by the Undersecretariat of Treasury for adding new generation capacity to meet anticipated demand. An additional law, namely the Build Operate and Own[17] (BOO) Law (No. 4283), for private sector participation in the construction and operation of new power plants was also enacted in 1997 again with guarantees provided by the Treasury[18].

[17] Under the BOO model, investors retain ownership of the facility at the end of the contract period. That is, it is a kind of licensing system rather than a concession award.
[18] A typical BOT, BOO or TOOR generation contract, signed between the private party and TEAS or TEDAS, includes exclusive “take or pay” obligations with fixed quantities (in general, 85% of the plant output) and prices (or price formulas) over 15-30 years. That is, under these models, the government retains most commercial risks while providing the

Current structure of the contracts concluded based on these laws acts as a major barrier to the development of competition in the electricity sector.

On 3 March 2001, Electricity Market Law (EML, No. 4628) came into force and aimed at establishing a financially strong, stable, transparent and competitive electricity market. In line with new law, TEAS was restructured to form three new state-owned public enterprises, namely Turkish Electricity Transmission Co. (TEIAS), Electricity Generation Co. (EUAS) and Turkish Electricity Trading and Contracting Co. (TETAS). The new law also created an autonomous regulatory body, namely Electricity Market Regulatory Authority.

Along the lines of developments in electricity sector, some other reforms were also introduced in other segments of the energy industry. On 2 May 2001, Natural Gas Market Law (NGML, No. 4646) also came into force and aimed at achieving similar objectives in natural gas market. It also renamed the regulatory body as Energy Market Regulatory Authority (EMRA). As a final step, Petroleum Market Law (PML, No. 5015) and Liquefied Petroleum Gas Market Law (LPGML, No.5307) came into force on 20 December 2003 and 13 March 2005 respectively and EMRA was granted the responsibility to regulate these markets as well[19].

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private sector with substantial rewards. Also the situation was worse in Turkey as, in Turkish case; there was no requirement for prequalification or even for a competitive open tender to conclude these contracts (Atiyas and Dutz, 2003), which resulted in onerous terms and high electricity prices.

[19] For a detailed discussion of the Turkish energy market reforms, see Erdogdu (2005, 2006a).

4.2. Current Market Structure

In generation, state-owned generation company (EUAS) and its affiliated partnerships were responsible for 41.6% of total generation in 2004. Power plants under autoproducer system accounted for 15.8% of total production in the same year. Those under BOT and BOO contracts also supplied another 33.8%. Table 5 presents the distribution of electricity generation by utilities in Turkish electricity market.

[*Table 5 goes here*]

In terms of installed capacity, EUAS is again in a dominant position and controlled 54.6% of total installed capacity in 2004. Power plants under autoproducer system and BOT and BOO contracts accounted for 11.9% and 23% of installed capacity respectively in the same year. Table 6 shows the breakdown of Turkey's installed capacity by utilities in 2004.

[*Table 6 goes here*]

State-owned distribution company (TEDAS) and its affiliated regional distribution companies dominate the distribution and retail supply sector. Turkey's distribution network has been divided into 21 regions, one of which is currently operating under a TOOR contract. The government's objective is to privatize the remaining 20 distribution regions by the end of 2006 (IEA, 2005).

As for the shares of primary energy resources in Turkey's gross electricity generation (see Table 7), natural gas has the highest share (41.3%) followed by hydro power (30.6), coal (22.8%), oil and naphta (5%) and renewables and wastes (0.3%).

[*Table 7 goes here*]

Turkey's rapid growth in electricity demand, which has led to almost a doubling of installed generating capacity over the past decade, is expected to continue for the foreseeable future. This could lead to building a total installed generating capacity of as much as 65,000 MW by 2010. MENR believes that this would require an investment of $3-5 billion/year (Tunc et al., 2005). Recently, TEIAS published new official demand projections up to 2015 based on two different scenarios. The government expects electricity demand to increase from 160.8 TWh in 2005 to 297.1 - 354.3 TWh in 2015 with an average annual growth rate of 6.3 - 8.4% (see Table 1).

4.3. Turkish Nuclear Energy Policy

Studies to build a nuclear power plant (NPP) in Turkey were started in 1965. Later, between 1967 and 1970, a feasibility study was undertaken by a foreign consultant company to build a 300-400 MW nuclear power plant. The nuclear power plant would have been in operation in 1977. Unfortunately, because of the problems relating to site selection and other issues, the project could not come to fruition.

In 1973, TEK decided to build an 80 MW prototype plant. However, in 1974 the project was cancelled for the reason that this project could delay the construction of a greater capacity nuclear power plant. Instead of this prototype plant, TEK had decided to build a 600 MW NPP in southern Turkey.

Site selection studies were made in 1974 and 1975 and Akkuyu (Mersin) in southern Turkey was found suitable for the construction of the first nuclear power plant. In 1976, the Atomic Energy Commission granted a site license for Akkuyu. In 1977, a bid was prepared and two companies were awarded the contract as the best bidders. Contract negotiations continued until 1980. However, in September 1980, due to the Swedish government's decision to withdraw a loan guarantee, the project was cancelled.

The third attempt was made in 1980. Three companies were awarded the contract to build four nuclear power plants. Due to Turkey's request to apply the Build Operate Transfer (BOT) model, two of the firms resigned from the bid. Although one firm accepted the BOT model, it insisted upon a governmental guarantee on the BOT credit. The Turkish government refused to give the guarantee and as a consequence the project was cancelled.

In 1992, the Ministry of Energy and Natural Resources stated in a report submitted to the government that without the installation of new energy resources before 2010, the country would face an energy crisis, suggesting that nuclear energy generation should be considered as an option.

In 1993, the High Council of Science and Technology identified nuclear electricity generation as the third highest priority project for the country. In view of this decision, the Turkish Electricity Generation and Transmission Company (TEAS) included a nuclear power plant project in its 1993 investment programme. The bid process started in 1996. Three consortiums offered proposals in 1997. After a series of delays, in July 2000, the entire nuclear programme was postponed indefinitely until economic conditions improve.

After 2001, the nuclear option has again started to be considered within the future alternative energy sources to reduce security of supply risks caused by the dominance of imported fuels and to ensure diversity in power generation (IEA, 2005). In 2004, the nuclear programme was revived by the MENR and studies were launched for a long-term and comprehensive nuclear power programme. At the end of 2005 the government again announced that it wanted to have at least three nuclear power stations with a capacity of 5.000 MW in operation by 2012. This date quickly seemed too ambitious for even the energy minister and he announced on 3 January 2006 that the launch of nuclear power would instead take place in 2015 (NEA, 2006).

In summary, today, despite several attempts in the past to build nuclear power plants, there is no nuclear power plant in operation or under construction in Turkey[20].

[20] A nuclear research reactor has been operating in Istanbul since 1962.

Founded in 1982, in Turkey, the Turkish Atomic Energy Authority (TAEK) is in charge of all regulatory activities in the nuclear field, including nuclear and radiation safety, site selection, construction, operation and decommissioning of nuclear installations and other activities involving nuclear or radioactive materials. It issues regulations and licences and conducts inspections. TAEK also conducts nuclear R&D.

While Turkey currently has surplus capacity, demand is growing quickly and the government expects it to exceed supply, potentially by 2009. Since 2001, publicly-owned generators have not been allowed to make investments in new power plants. Simultaneously, private projects have started, but there are some concerns that private investors find it difficult to compete with fully depreciated state-owned power plants. Therefore, Turkey has recently announced that it will reopen its nuclear programme in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports.

As for economics of nuclear power in Turkey, it is expected that the capital cost of a PWR[21] type nuclear power plant will range between 1.9 - 2.5 US cents/kWh in Turkey depending on finance method adapted, while its operating cost will be around 1.3 US cents/kWh. Table 8 presents the power generating costs by different energy sources.

[*Table 8 goes here*]

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[21] Pressurised water reactor is the most common type of light water reactor (LWR), it uses water at very high pressure in a primary circuit and steam is formed in a secondary circuit.

5. Policy Suggestions and Conclusion

Having reviewed the technical and economic aspects of nuclear power both in the world and in Turkey let me list some policy guidelines for energy policymakers or for anyone with an interest in nuclear-related policy matters.

First of all, all necessary steps should be taken to create a platform in which everyone with a nuclear interest may express his/her ideas with a view to reaching a consensus. That is, nuclear power development process should not rely upon purely administrative decisions, taken without public debate. Otherwise, its destiny may turn out to be that of general energy market reform process in Turkey[22], which is "uncertainty" and "deadlock".

Second, so far, Turkey has deeply experienced the tragic effects of public investments or private investments with treasury guarantees in energy sector. Therefore, the planned nuclear power plants should be owned and operated by private investors without treasury guarantees[23]. Also, private ownership of nuclear power plants (with 5.000 MW installed capacity) will contribute to the development of competitive electricity market by increasing the share of IPPs in installed capacity from 2.1% to 13.8%. On the other hand, if the planned nuclear power plants are operated by state-owned EUAS, the share of government in installed capacity will increase to 60%, meaning effectively the end of energy market liberalization process in Turkey.

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[22] For a detailed discussion of the Turkish energy market reforms, see Erdogdu (2005, 2006a).

[23] However, some non-governmental guarantees may be provided. For instance, electricity distribution companies may be required to buy a specific portion of their electricity needs from nuclear generators.

Third, Turkey should create a sound legal framework for the use of nuclear power. She should clarify the role of nuclear power in the future in terms of economic competitiveness.

Fourth, Turkish policymakers should aim at ensuring that the full, unsubsidized costs of all forms of power generation (including nuclear) are borne by generators. To the extent possible, policymakers should make sure that the full costs and benefits of environmental protection are reflected through all stages of fuel production, power generation and waste disposal, ideally through market pricing mechanisms. On the other hand, they should recognize the various effects of externalities (environmental considerations, security of supply and so on) from power generation and aim to establish procedures that would facilitate their appropriate inclusion in decision-making mechanisms. Particular attention should be devoted to evaluation of the potential energy security and environmental characteristics of nuclear power. If the market mechanism fails to include the value of positive externalities in the price signals, the government may consider providing financial support to nuclear industry. However, the support should not affect price structure and be only in the form of direct cash refunds on clearly defined bases per kWh produced, in line with estimated value of externalities.

Fifth, a fully independent nuclear energy regulator should be created to provide licences, approve suitable sites and technologies for nuclear power plants, inspect all technical issues related to nuclear power plants, and update nuclear legislation in these aspects. In this context, TAEK may be restructured by dividing it into two bodies, one which will continue nuclear energy R&D and another which will form an independent nuclear energy regulator. In terms of economic regulation, the EMRA should be responsible for the economic regulation of nuclear power plants. The quality of the persons in the position of regulators (that is, the members of the Energy Market Regulatory Board and nuclear energy regulatory board) and their staff is a critical issue as it is important for the credibility of EMRA and nuclear energy regulator that not only the members of their board but also their staff are highly qualified, which requires strict merit selection and performance management. Also, it is better to keep in mind that maintaining a stable regulatory and political environment is the key to success in nuclear regulation.

Sixth, competitive markets require clear definition and quantification of all liabilities associated with nuclear power. Therefore, responsibilities for nuclear waste management and disposal, including funding, should be clearly defined from the outset of launching a nuclear power project. Two funds, namely “radioactive waste fund” and “decommissioning fund”, need to be created for waste disposal and the eventual decommissioning of the nuclear power plants; and both of them should be managed by private parties that are expert in fund management business, not by bureaucrats.

Seventh, decisions about new nuclear power plants are likely to be strongly influenced by public opinion and political will. The lack of public acceptance undermines future possibilities for nuclear power plants. Improving the public's technical understanding of nuclear risks and enhancing their ability to weigh them against other risks is the key to improving public support for nuclear power. However, portraying the possible environmental or health effects of accidents as "zero" or as known with certainty to be negligible is not convincing and erodes credibility. It should be kept in mind that openness is an essential ingredient to foster public trust in nuclear power. Therefore, Turkey should eliminate its "culture of secrecy". Public confidence also requires trust in the involved institutions, both in the regulator and the regulated. This, in turn, also requires transparency and pro-active communication.

Eight, given current situation[24], it seems that Turkey will continue to be a "technology taker" for the foreseeable future. Therefore, R&D efforts need to focus on the acquisition and adaptation of the best available technology to suit the particular Turkish circumstances.

Finally, Turkey should separate civilian nuclear power production from military issues to the maximum extent possible and strengthen safeguards to prevent misuse of civilian nuclear materials, especially in the form of the production of military materials.

In conclusion; despite its maturity, widespread usage and steady progress, compared with other energy sources, nuclear energy has a level of public concern that makes it unique among energy sources. Many factors contribute to this, including its military origins and potential to be applied to weapons purposes, technical complexity, the long-term implications of nuclear waste, its complicated safety legal and insurance requirements, the

[24] As compared to GDP, the Turkish state energy R&D budget is one of the smallest (together with Portugal) among the IEA member countries (IEA, 2005).

consequences associated with potential accidents, the health effects of exposure to radiation and the large-scale investments required for its exploitation. Understanding these issues is vital for any evaluation of nuclear power.

I believe the nuclear option should be retained, precisely because it is an important carbon-free source of power that can potentially make a significant contribution not only to future electricity supply but also to efforts to strengthen Turkey's security of supply. However, no single technology has a clear economic advantage in all countries and specific circumstances within Turkey will determine the most economic choices. Therefore, in the long run, nuclear power should be retained in Turkey only if it has a lower cost than competing technologies. This is especially critical as electricity market in Turkey becomes progressively less subject to economic regulation.

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Table 1. Official gross electricity demand forecast: 2006–2015

Years	Scenario 1		Scenario 2	
	GWh	Growth (%)	GWh	Growth (%)
2006	171,430	-	171,430	-
2007	185,830	8.4	182,230	6.3
2008	201,440	8.4	193,711	6.3
2009	218,361	8.4	205,914	6.3
2010	236,703	8.4	218,887	6.3
2011	256,586	8.4	232,677	6.3
2012	278,139	8.4	247,335	6.3
2013	301,503	8.4	262,918	6.3
2014	326,829	8.4	279,481	6.3
2015	354,283	8.4	297,089	6.3

Source: TEIAS (2006a)

Table 2. Major nuclear power producer countries

	Nuclear Electricity Produced (2001, TWh)	(%)	Number of Reactors (2003)	(%)	Installed Capacity (2001, GW)	(%)	Nuclear Proportion in Total Domestic Generation (2001, %)
US	808	30.4	104	23.6	95	26.7	21
France	421	15.9	59	13.4	63	17.7	77
Japan	320	12.1	54	12.2	44	12.4	31
Germany	171	6.4	19	4.3	21	5.9	30
Russia	138	5.2	30	6.8	21	5.9	15
South Korea	112	4.2	18	4.1	13	3.7	40
UK	90	3.4	33	7.5	12	3.4	23
Canada	77	2.9	14	3.2	14	3.9	13
Ukraine	76	2.9	13	2.9	11	3.1	44
Sweden	72	2.7	11	2.5	9	2.5	45
Rest of the World	369	13.9	86	19.5	53	14.9	9
World Total	2654	100.0	441	100.0	356	100.0	17

Sources: Tunc et al. (2005), OECD (2003), Rosa and Rice (2004)

Table 3. World uranium production, 2001

Country	Tonne Uranium	%
Canada	12,520	35.0
Australia	7,720	21.6
Niger	3,096	8.7
Namibia	2,239	6.3
Uzbekistan	2,400	6.7
Russia (estimated)	2,000	5.6
Kazakhstan	2,018	5.6
United States	1,000	2.8
South Africa	898	2.5
China (estimated)	500	1.4
Ukraine (estimated)	500	1.4
Czech Republic	330	0.9
India (estimated)	200	0.6
France	124	0.3
Romania	115	0.3
Spain	30	0.1
Others	77	0.2
World Total	**35,767**	**100.0**

Source: (Herring, 2004)

Table 4. World uranium conversion and enrichment capacities, 1999

Country	thousand swu*/year	%
US	19,200	34.9
Russia	19,000	34.5
France	10,800	19.6
UK	1,800	3.3
Netherlands	1,500	2.7
Germany	1,100	2.0
Japan	950	1.7
Others	725	1.3
World Total	**55,075**	**100.0**

** swu means "separative work unit"*
Source: (Herring, 2004)

Table 5. Distribution of gross electricity generation in Turkey by utilities, 2004

Utilities	Production (GWh)	Contribution to Turkey's Gross Generation (%)
EUAS and its affiliated partnerships	62,638.6	41.6
Power plants under BOO model	36,645.5	24.3
Autoproducers	23,758.2	15.8
Power plants under BOT model	14,379.5	9.5
Power plants in the privatization process	5,378.6	3.6
Mobile Power Plants	1,288.0	0.9
Independent power producers (IPPs)	2,674.7	1.8
Power plants under TOOR model	3,935.2	2.6
Total Gross Electricity Generation	**150,698.3**	**100.0**

Source: TEIAS (2006b)

Table 6. Breakdown of Turkey's installed capacity by utilities, 2004

Utilities	Installed Capacity (MW)	Contribution to Turkey's total Installed capacity (%)
EUAS and its affiliated partnerships	20,109.6	54.6
Power plants under BOO model	6,101.8	16.6
Autoproducers	4,380.4	11.9
Power plants under BOT model	2,349	6.4
Power plants in the privatization process	1,680	4.6
Mobile Power Plants	780.2	2.1
Independent power producers (IPPs)	772.9	2.1
Power plants under TOOR model	650.1	1.8
Total Installed Capacity	**36,824**	**100.0**

Source: TEIAS (2006c)

Table 7. Turkey's gross electricity generation by share of primary energy resources, 2004

Energy Resource	%
Natural gas*	41.3
Hydro	30.6
Coal	22.8
Oil & Naphta	5.0
Renew. and wastes	0.3
Total	**100.0**

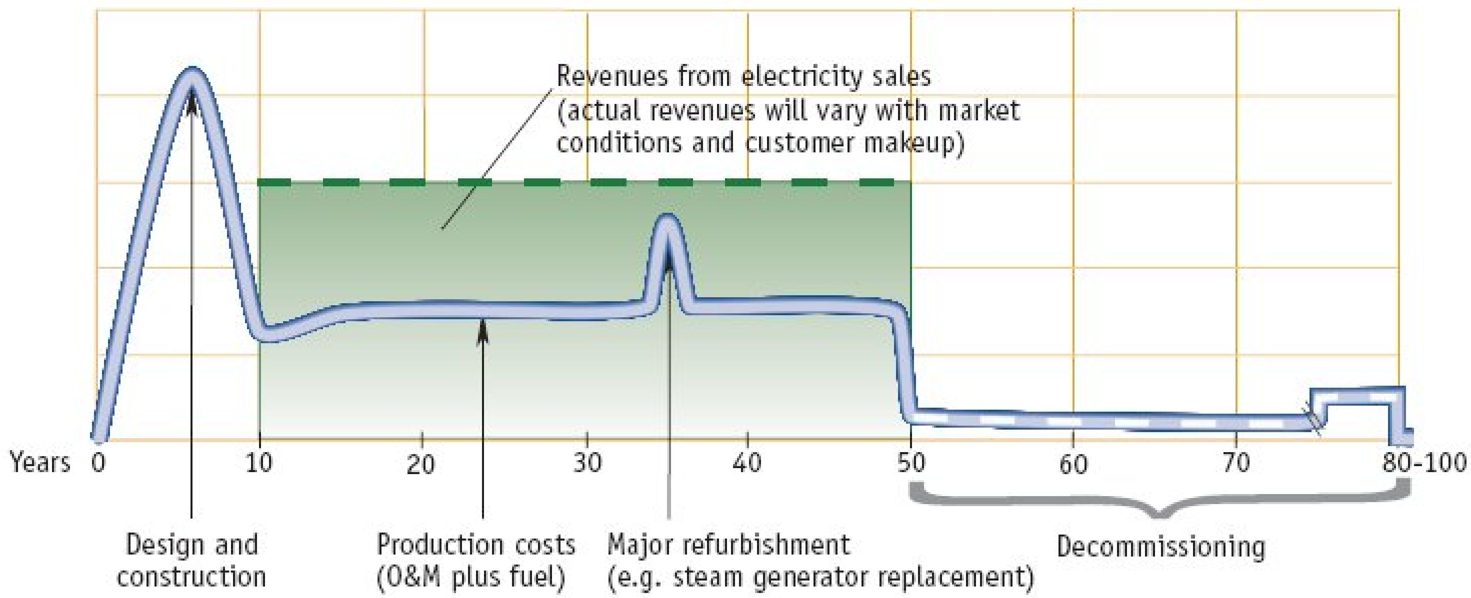
** Turkey has almost no natural gas reserves.*
Source: TEIAS (2006d)

Table 8. Power generating costs in Turkey by different energy sources

Fuel input	Total Cost (US cents per kWh)
Average hydro	0.16
Geothermal	2.46
Lignite	2.99
Fuel oil	3.14
Nuclear* (min)	**3.20**
Average thermal (EUAS)	3.56
Nuclear* (max)	**3.80**
Natural gas	3.86
Hard coal	4.37
Diesel	16.24

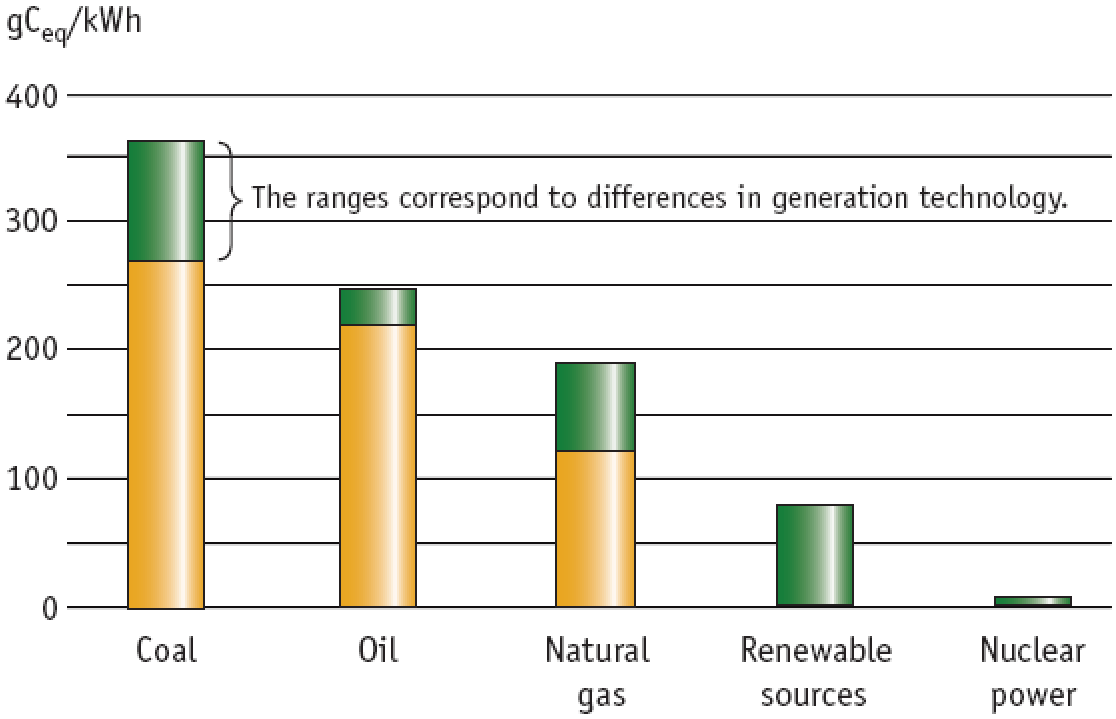
** Estimated*

Source: IEA (2005), OECD (2000, 2001)



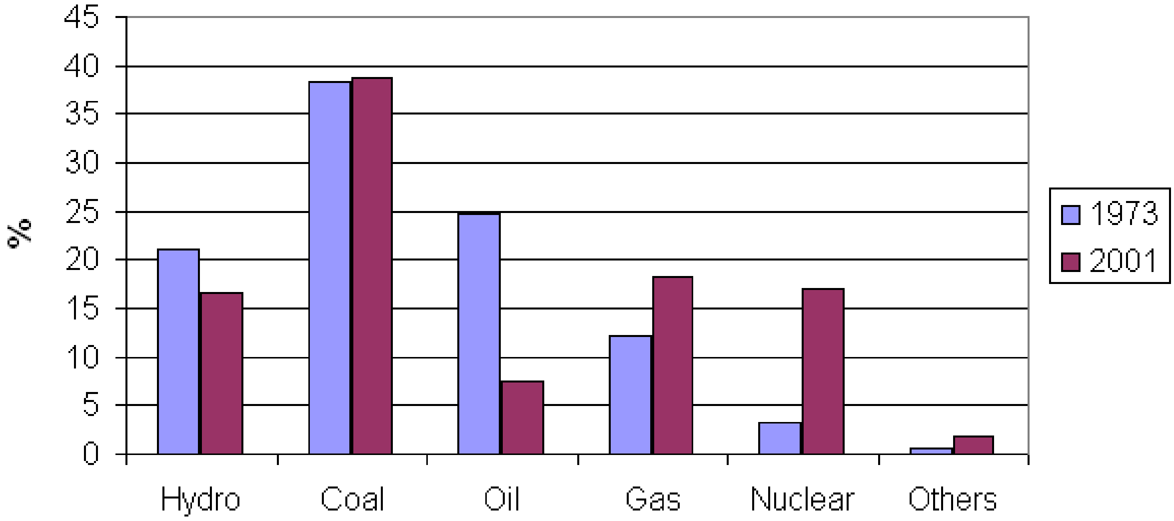
Source: OECD (2003)

Figure 1. Life cycle cash flow for a nuclear power plant



gC_{eq}/kWh: Grams of carbon equivalent per kWh of electricity produced
Source: OECD (2003)

Figure 2. Greenhouse gas emissions from electricity generation by different sources



Source: Tunc et al. (2005)

Figure 3. Fuel shares of world electricity generation in 1973 and 2001