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National Energy Outlook of Turkey and Expectations from Nuclear Technology

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Introduction

Nuclear energy is one of the major sources of energy supply in the world contributing about one-sixth of total electricity generation. However, the future trend for nuclear energy supply seems to be uncertain, due to public opposition in some countries and economic considerations, such as higher capital costs, compared to some other power technologies. The prospects for nuclear energy depend on certain factors such as safety, the demonstration of geological disposal of high level wastes, the competitiveness of nuclear power plants and public acceptance. The ongoing debate about reducing greenhouse gases to avoid the potential onset of global warming has led to a better understanding of the advantages of nuclear power as a technology which does not emit greenhouse gases.

Energy situation in Turkey

Energy has been a priority investment sector for the Turkish government for some time and in 1986 received the second largest allocation of foreign financing among public sector investments. Although limited, Turkey has some energy sources: coal, uranium, lignite, some oil and gas deposits, and considerable potential for hydroelectricity. In the year 2000, as shown in *Figure 1*, 43.8% of primary energy consumption was met by petroleum, 26.3% by coal, and 17.7% by natural gas. During the period 1996-2000, the primary energy consumption rate increased by 4.5% per year and reached 78.8 mtoe by the year 2000. Electricity demand increased by about 8.2% per year over the same period, and reached about 128 TWh at the end of this time. The installed capacity for electricity generation was about 27 GW by the year 2000. The primary energy consumption per capita was about 1.2 toe and electricity consumption per capita was about 1966 kWh by the year 2000. The projections show that electricity consumption per capita will increase to about 3867 kWh by the year 2010 (*Figure 2*). Turkey is not rich in energy resources and import dependency was about 62% by the year 2000 (*Figure 3*) and will increase in time as energy consumption increases. It is expected that the annual electricity demand rate will increase by about 8-10% until 2010. Although the annual increase in electricity demand was about 8.2% between the periods of 1996-2000, the economic crisis in 2001 led to negative economic growth, and hence electricity demand decreased. The projections for

electricity consumption reveal that about 290 TWh will be consumed by the year 2010 and that the required installed capacity will be around 46 GW. The share of fuels for installed electricity generation capacity for the year 2000 was 41% (hydro+geothermal+wind), 26% (coal), 26% (gas), 7% (oil). CO₂ emissions were about 210 million ton in 2000 and are expected to increase to 390 million ton in 2010 (*Figure. 4*). CO₂ emissions per capita are 2.9 tons/capita in Turkey, which is much less than those of the world and OECD averages, i.e. 3.87 tons/capita and 11 tons/capita, respectively [1].

In spite of the fact that the nuclear energy contribution was planned to be 2000 MWe by the year 2015 (2.3% share of total generation) and although it was the government's firm intention to install the first NPP in Akkuyu, the government has decided to postpone the Akkuyu NPP project, following a cabinet meeting held on 25 July 2000. The government's statement on this decision made it clear that the reasons were not related to safety issues. Rather, since Turkey needed to concentrate on a programme of economic stability aimed at reducing inflation rates to reasonable figures under supervision of the IMF, the government could not afford the estimated US\$3-4 billion needed for the construction of the country's first nuclear power plant. The government also declared that the postponement of the Akkuyu NPP project did not mean that Turkey would avoid the use of nuclear energy in the future. The cabinet's announcement also included reference to the need to contribute to the technological improvements of the new generation of nuclear power plants. Finally, the announcement addressed the need to wait for the new generation nuclear reactors with reduced capital cost. In short, the reasons for the postponement of the Akkuyu NPP project can be summarized as follows.

- The financial burden of external credits could not be borne in Turkey's current economic situation.
- It would be better to wait for the new generation nuclear reactor technology with decreased capital costs.

The Turkish Atomic Energy Authority took three actions upon postponement of the Akkuyu NPP project:

- a review of the National Nuclear Energy Policy;
- participation in the International Project of the IAEA on Innovative Nuclear Reactors and Fuel Cycles (INPRO);
- application to the IAEA for participation in the Technical Working Group on Gas Cooled Reactors (TWG-GCR).

Energy policy in Turkey

Turkish energy policy is concentrated mainly on ensuring a supply of reliable, sufficient, economic and clean energy, on time, and in a way to support the targets for growth and social development. Although almost all conventional resources exist in Turkey, these resources are not sufficient to meet energy demand, except for lignite and hydro. More than half of the energy demand is met through imports to Turkey. Energy planning studies show that energy demand in Turkey will increase in parallel with the country's development and industrialization. In order to meet the demand reliably, significant increases will be needed both in energy

production and in supply in coming years. Turkish environmental policy accepts that energy policy should take into account environmental problems, and that a balance should be found between the increases in energy demand required for economic development and environmental concerns. Some of the main criteria included in the Seventh Five-Year Development Plan are given below.

- A dynamic and feasible master plan has been prepared, which accomplishes the optimum planning of resources in an economic and reliable way and minimises the environmental problems arising during the production and consumption of energy.
- It is necessary for Turkey to meet energy demand with national resources as far as possible, and to use new technologies which eliminate the adverse effects of energy production on the environment.
- According to the development plans, 'energy conservation' is one of the basic principles.

Although a member of OECD, Turkey is not a party to the United Nations Framework Convention on Climate Change (UNFCCC). Turkey's current position in this regard is that, if the agreement is to be signed, Turkey would be classified as a developed country and included in Annex 1. The convention places commitments on the developed countries in Annex 1, according to the principle of 'common, but differentiated responsibilities', and takes the view that the commitments should reflect the relative development levels of the countries. In this regard, Turkey is still in the process of rapid industrialization. Thus, the burden of the commitments imposed on Annex 1 countries is not in conformity with the social and economic circumstances and level of development of the country.

Energy sector

The 'Electricity Market Law' No.4628, published in the Official Gazette dated 3 March 2001 was enacted with the aim of unbundling electricity market activities, of enabling progress towards a liberalised electricity market and the provision of fair and transparent market regulation.

In summary, the new law includes the following key elements:

- an autonomous Energy Market Regulatory Authority, governed by a board;
- a new licensing framework for market participants;
- an energy market, comprising bilateral contracts between market participants;
- an 'eligible consumer' concept, with eligible consumers free to choose their suppliers;
- a transition mechanism to be implemented over a two-year programme in the case of electricity.

In addition, all over the world, energy sector investments are gradually being undertaken by the private sector and Turkey is also following this global trend. It is important to ensure that this transition will be smooth and effective. The purpose of this law is to ensure the formation of an electricity market which is financially strong, transparent and operates in accordance with the provisions of

private law in a competitive environment, while achieving a stable supply of adequate, low-cost, and environmentally-friendly electricity of good quality and ensuring autonomous regulation and supervision of the market. The main objective of the law is to create a competitive electricity market with the great majority of the participants in the market being private investors and most of the assets used to supply electricity being privately owned. The role of the state will be greatly reduced.

Expectations for nuclear reactor technology in future

Since Turkey's future nuclear power programme is to be dependent on nuclear policy, the Turkish Atomic Energy Authority (TAEA) has recently initiated a project to revise the nuclear policy of the country. This project includes applications in various sectors of nuclear energy, including nuclear power, and programmes associated with each sector. One of the sectors that is to be considered is 'Research and Development', which also includes innovative designs and small- and medium-sized reactors (SMRs). Cooperation with international/national groups on theoretical and experimental projects concerning SMRs and innovative technologies will lead to an increase in staff capabilities and experience in nuclear technology in Turkey. To achieve this goal, the TAEA decided to participate in the 'International Project on Innovative Nuclear Reactor Technologies and Fuel Cycles', which is coordinated by the IAEA, by sending a cost-free expert to the IAEA headquarters. The TAEA made technical contributions to the INPRO Project in 2001 and 2002. As already mentioned, the TAEA applied to the IAEA for participation in the Technical Working Group on Gas Cooled Reactors (TWG-GCR) and, in the short term, two areas of contribution seem feasible for the TAEA within the TWG-GCR:

- Cooperation with other licensing authorities in the area of licensing of GCR type of NPPs. The TAEA is a governmental organization and has the duties and responsibilities of licensing, inspection, regulation, policy making in nuclear energy and technology, research and development, and training. Since the TAEA has experience mainly in the licensing of light and heavy water types of NPP, any kind of cooperation would increase in-house expertise on licensing and/or the safety review of GCR type of reactors.
- Contribution to the safety research activities including code validation/assessment. The TAEA has some expertise on code validation/assessment on light and heavy water reactor technologies. Thus, the TAEA has the objective of developing expertise on GCR technology for code validation/assessment and plans to develop a code infrastructure in collaboration with universities. International standard problem exercises could be performed under the coordination of the IAEA and/or the OECD/NEA, based on real plant or test facility data. This might serve for the sharing of current expertise and knowledge on utilizing computer codes for GCR reactors.

The primary concern of the Turkish Atomic Energy Authority for the nuclear reactor technology includes the following subject areas.

- resources, demand and economics;
- safety; and
- environment.

Resources, demand and economics

As previously mentioned, Turkey has some energy resources, including coal, uranium, lignite, some oil and gas deposits, and considerable potential for hydroelectricity. The known uranium reserves in Turkey are reported as 9129 tons, but this reserve needs further investigation with respect to grade and feasibility. The same holds true for thorium reserves, as fertile material, which is reported as 380 000 tons. It is to be noted that Turkey should have a long-term policy for using its own natural resources for generating nuclear energy. However, today the cost of uranium favours the utilization of imported uranium fuel for short- and medium-term nuclear fuel supply. The cost of uranium is about US\$23 per kg and there is a world reserve of about 1.2 million tons recoverable at less than US\$40 per kg of uranium. The total reserve that is recoverable at less than US\$ 80 per kg of uranium is about 2.5 million tons. Assuming world wide annual consumption of uranium between 60 000 and 80 000 tons, supply requirements over 40 years can be met by primary production from reserves recoverable at less than US\$80 per kg uranium. Moreover, given the relatively low impact of the cost of uranium on energy generating cost of nuclear power plants, it can be considered that the total reserves – whatever the cost of production – is enough for a period of more than 100 years. The total uranium reserve, including probable reserves, which are recoverable at less than US\$130 per kg of uranium is estimated to be about 15 million tons, which means that this total reserve is enough for about 250 years at the current consumption rate [2]. It is well known that, even if the cost of nuclear fuel doubled from today's cost, electricity generation costs would increase by 10%, i.e. much less than those of other types of power plants. For example, in gas-fired plants generation costs are very sensitive to variations in fuel cost, and doubling the fuel cost could increase generation costs by about 100%.

The energy situation of Turkey is summarized in the first part of this paper. The projections of the Ministry of Energy and Natural Resources reveal the fact that our installed capacity and generated energy will increase fast in the coming 20 years. The required installed capacity in the year 2010 is estimated to be 59 GW with 287 TWh energy demand and these figures will increase to 116 GW and 567 TWh by the year 2020. The additional installed capacity breakdown for the next 20 years reveals that gas-fired power stations will dominate other types of technology, such as coal, hydro and nuclear. Gas used for electricity generation and heating is imported from various countries. Although the most important potential risks for gas imports for generating electricity are stability of gas prices and political conflicts, lower electricity generation costs and shorter construction periods favour the utilization of this fuel for electricity generation, as in other OECD countries. The capital cost of gas-fired plants is about US\$400-600/kW; however the cost is about US\$2000-3500/kW for current nuclear power plants [3]. It is clear that two factors must be considered for nuclear reactor designs to be able to compete with combined cycle gas stations:

- capital and generation costs
- construction period.

If the capital cost were around US\$1000/kW or less, then the financial burden would be much less than current nuclear technologies, and this would ease the

launching of nuclear power programmes, especially in developing countries. As previously explained, the main reason for postponing Akkuyu NPP project was the financial burden arising from the external credit needed for the project. The innovative nuclear reactor technologies should focus on decreasing capital cost, without compromising safety. In Turkey, after the Electricity Market Law, the private sector will lead in new investments coupled with the privatization of electricity generation plants. The range of capital cost per kW will play an important role in the selection of technology in the future, and reductions in the capital costs of nuclear power plants would favour investment in nuclear energy by private investors. Another option for private investors in Turkey would be the use of small-sized nuclear generation stations. At this point, the distributed power concept could be considered. The construction period, on the other hand, is important in developing countries, including Turkey, since energy demand increases at higher rates (8-10% per year) and delays in construction periods can sometimes lead to undesired overcapacity. In developing countries, however, the planning of new capacities is very dynamic and can change in the short term. The electricity generation cost of a nuclear power plant should be less than 4 cents/kWh if it is to compete with combined cycle gas power plants [4].

Safety

Improvement in the safety of nuclear reactors is a continuing process, in line with technological improvements and lessons learned from various developments. Indeed, the accidents at the Three Mile Island and Chernobyl nuclear power plants have led to a momentum for improving safety technology and even safety philosophy. We learned from both accidents that the *defence in depth* concept is important for safety, and that risk perception can be easily changed after one serious disaster at even one of the 438 commercial reactors in operation with their 9000 reactor-years' operating experience. The following items summarize the factors to be considered for innovative reactor technologies [4].

- Inherent safety philosophy should be applied to the design of innovative reactor technologies along with the requirement that each sequence of events leading to an accident condition should be properly evaluated.
- If core meltdown is not avoidable, then the core melt frequency should be 10^{-6} or less.
- The reactor should have a self-protection system against insertion of maximum possible reactivity.
- The licensibility of nuclear power plants is potentially very important for developing countries, due to their lack of sufficient experience in this area. In these circumstances, a licensed reference plant could be a solution for innovative designs.
- NPP developers should pay particular attention to two main areas: the development of safe and economic designs; and the provision of conditions in which the public will accept their designs as safe and economic.
- The use of passive mechanisms for heat transport and/or safety systems might be a better solution for simplifying designs, and also one which decreases the cost. However, the performance of these systems should be demonstrated

adequately against accident conditions. The use of passive systems could also improve the availability of those systems upon demand.

- Innovations in nuclear reactor technology should shorten the licensing period.

Environment

The position of TAEA is such that '*environment*' as a subject area plays an important role in the concept of '*sustainable development*'. The share of fossil fuel for energy generation in the world is about 77%, and this figure reaches 90% in some countries. The situation is no different in Turkey, and the share of fossil fuels is as high as 90% in primary energy consumption. Fossil fuels also dominate in electricity generation, i.e. about 60%. From the greenhouse gas emissions point of view, Turkey is not that critical, since, as stated earlier, CO₂ emissions per capita are only three-quarters of world average. However, in the year 2020, current installed capacity will be tripled and greenhouse gas emissions will increase accordingly. Hence, clean technologies like nuclear and renewable sources will be unavoidable in developing countries such as Turkey, if greenhouse gas emissions are to be stabilized at given levels, as international agreements and protocols (such as the Kyoto Protocol) require. However, high level radioactive waste seems to be the most important drawback of nuclear technology as far as public acceptance is considered, since no demonstration has yet been made for commercial reactor waste disposal. The position of the TAEA is that the technology for such geological disposal is available but it has to be demonstrated to the public's satisfaction. There may be two ways of approaching this problem: innovative nuclear reactor designs with levels of high level wastes which are less than those produced with current technologies; and accelerator-driven reactor systems could be used for the transmutation of long-lived wastes to short-lived isotopes.

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4. A. Tanrikut, *Nuclear Energy and Future Expectations*, The Bulletin of the Turkish National Committee of the World Energy Council (in Turkish), No.39, Ankara, December 2001.

Figure 1. Primary energy consumption in Turkey by fuel types (2000)

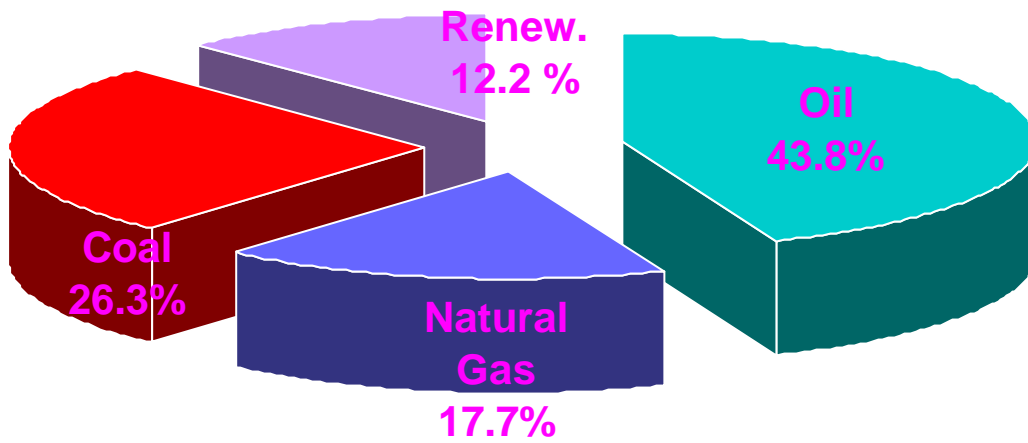


Figure 2. Projection of electricity consumption per capita in Turkey

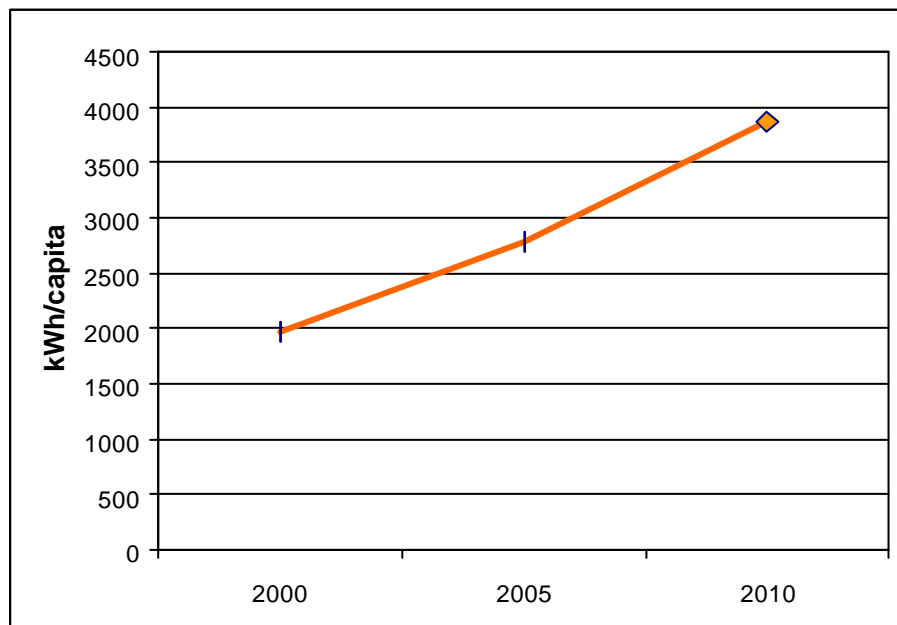
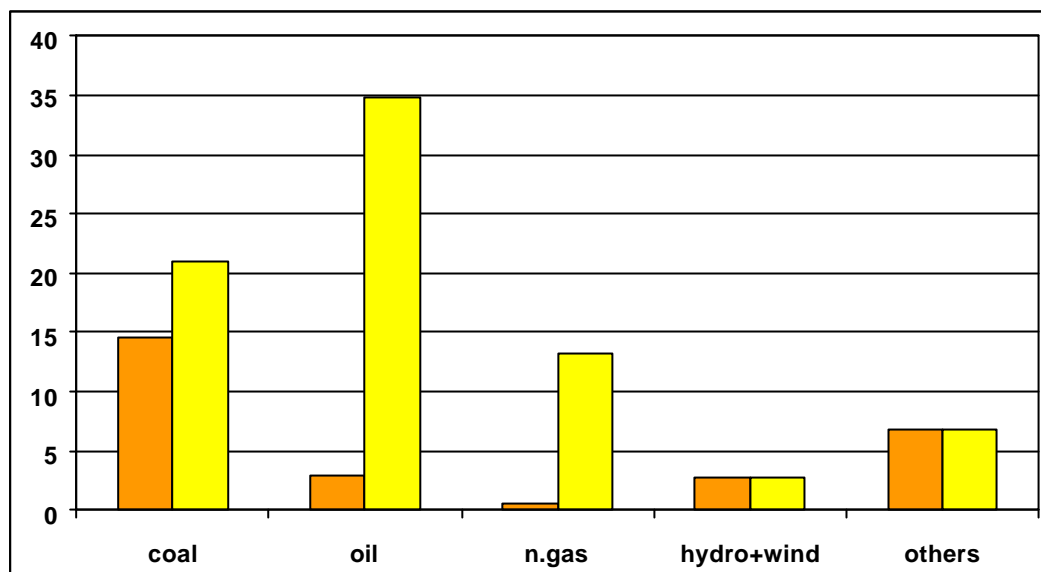


Figure 3. General energy production and consumption in Turkey (mtoe) (2000)

Figure 4. Projections of CO₂ emissions in Turkey (mton)