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Challenges and Opportunities in Nuclear Energy: Promising Option in Turkey?

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***Abstract*—**Dramatic growth in the population requires a parallel increase in the total installed capacity of electricity. Diversity, independency of resources and global warming call for installing renewable and nuclear energy plants. Several types of energy plants exist in Turkey; however, nuclear energy with its several attractive features is not utilized at all. This study presents the available energy resources in Turkey and reviews major challenges and opportunities in nuclear energy. At the end of this paper, some conclusions are stated.

***Keywords*—**Nuclear, energy resources, challenges, opportunities, Turkey.

I. Introduction

WITH a population of 74.7 million in 2011, Turkey has the largest and the youngest population in Europe. Although the remarkable growth in energy consumption in the past decade due to the large and young population base, the domestic energy generation rate still behind other Western European countries. Thus, Turkey is mainly depending on imported energy sources due to energy is one of the most important strategic requirements for developing countries [1]. Primary energy resources of Turkey include hard coal, lignite, asphaltite, oil and natural gas. Table I indicates domestic energy resource potential of Turkey.

TABLE I
Domestic Energy Resources in Turkey [19]

Source	Potential
Hard coal	1.300,0 (million tons)
Lignite	10.400,0 (million tons)
Methane from gas hydrates	14.000,0 (million tons)
Asphaltite	82,0 (million tons)
Oil	38.7 (million tons)
Natural gas	21.900,0 (million cubic meters)
Thorium	380,0 (million tons)
Uranium	9,0 (million tons)

Renewable energy resources in Turkey are; hydro, biomass, wind, biogas, geothermal and solar. Table II indicates the existing renewable energy resources in Turkey. Although renewable energy resources of Turkey have huge capacity, they cannot be fully utilized because of environmental restrictions such as climate and seasonal conditions. The Ministry of Energy and Natural Resources' Strategic Plan 2010-2014 includes the target of increasing the share of renewable energy resources to at least 30 % or 60 million tons of oil equivalent (mtoe) by the end of 2023, and that of nuclear energy to at least 10 % or 20 mtoe [2].

TABLE II
Turkey's Renewable Energy Resources

	Installed Capacity Potential	Installed Capacity	Capacity Factor	Generation (million kWh/year)
Hydro	36.000	16.934	44 %	144.000
Wind	48.000	1.587	30 %	60.000
Solar	50.000	-	20 %	7.500
Geothermal	600	94	84 %	4.400
Biomass	2.000	44	80 %	14.000
Total	136.600	18.659	-	229.900

Source: Ministry of Energy and Natural Resources, 2012 [21].

Table III indicates electricity generation according to sources. It is important to note that dependency of Turkey on natural gas is above the world average and rate of nuclear energy in electricity generation is zero. Coal is the first and gas is the second source of electricity generation in the world, however this is vice versa in Turkey.

TABLE III
Electricity Generation by Energy Resources

Resources	Turkey	World
Oil	1.0%	5.5%
Gas	46.2%	21.3%
Coal	25.9%	41.0%
Hydraulic	24.4%	15.9%
Nuclear	**0.0%**	13.5%
Other (geothermal, wind, etc.)	1.9%	2.8%
Total	212 Billon kWh	20 181 Billion kWh

Source: International Energy Agency, 2010 [20].

In Turkey, the primary energy supply per capita and electricity consumption per capita, which are development indicators, is below that of the developed countries and world in average (See Table IV). However, there is decrease in the electrical energy demand in many countries of the European Union, while there is a high rate of demand increase in Turkey. In 2010, peak demand increase was 11.8% and energy demand increase was 7.9% [3].

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TABLE IV
ELECTRICITY SUPPLY AND CONSUMPTION PER CAPITA

	2006		2007		2008	
	Supply (Teo*/person)	Consumption(kWh/person)	Supply	Consumption	Supply	Consumption
World	1.80	2659	1.82	2752	1.83	2782
OECD	4.70	8381	4.64	8477	4.56	8486
USA	7.78	13515	7.75	13616	7.50	13647
Germany	4.23	7175	4.03	7185	4.08	7148
France	4.31	7585	4.15	7573	4.16	7703
UK	3.82	6192	3.48	6142	3.40	6067
Turkey	**1.29**	**2053**	**1.35**	**2210**	**1.39**	**2400**

Source: International Energy Agency, 2010
*Teo: ton of equivalent oil (1 teo=10 Gcal=10.63 MWh)

According to Turkey's energy strategy plan (2009), total energy demand increased from 92 million tons of oil equivalent (mtoe) in 2006 to 126 mtoe in 2010, and it is expected to rise further to 222 mtoe in 2020 [4].

Güngör and Bozkurt (1999) claimed that because of the high population growth rate and rapid development and industrialization, Turkey's electrical energy demand will increase rapidly and steadily. In the forthcoming years electrical energy production based on imported sources will increase even if all the domestic sources are fully utilized [5]. Unfortunately, Turkey imports about 70% of the energy sources that are used in primary energy consumption. About 56% of the imported energy sources including oil, natural gas and hard coal are used for electricity production [6]. Moreover, Turkey is extremely dependent on Russia being the second major gas recipient after Germany [7]. On the other hand, Turkey is an energy transit country having three oil pipelines and four import pipelines which transport gas from Russia, Azerbaijan and Iran.

The significance of the study lies in the fact that nuclear power is one of the major alternative sources of energy all over the world. According to World Nuclear Association (2012), about 31 countries, 435 nuclear power plant units with an installed electric net capacity of about 368 GW are in operation and 63 plants with an installed capacity of 61 GW are in 15 countries under construction [8]. However, there is no nuclear power plant in Turkey even though it has experienced significant economic growth in last decade. Thus this study aims for investigating challenges and opportunities for a very popular yet understudied domain in Turkey.

II. ATTRACTIVE FEATURES

A. Diversity and Security

First of all, installing nuclear power plants to the system improves security and diversity of that system. In case when unexpected accidents or disasters occur, a system fed from several types of resources can be more stable and secure system. Moreover, diversity offers more alternatives for unit commitment and spinning reservoirs, thus, leading to a better economical operation of the power system for both producing companies and consumers.

B. Carbon Emission

Table V shows CO_2 emission rates of coal, oil, gas, solar, wind and nuclear energy. Renewable resources and nuclear energy present a friendly alternative solution to global warming. In fact, it is the very attractive feature of nuclear power plants that about 10-30 grams of carbon dioxide is being emitted per kWh of energy during the complete power chain. This is the same emission rate as in wind hydropower and much less than coal, oil and natural gas [9], [10]. Accordingly, as much portion of world energy consumption from renewable and nuclear resources is increased, as less contribution to global warming would be.

TABLE V
CO_2 EMISSION RATES

Energy Resource	CO_2 Emission (gram/kWh)	Normalized Rate to Nuclear (min-max)
Coal	900-1200	30-120
Oil	700-900	23-90
Gas	350-900	12-90
Solar	100-200	3-20
Wind	10-75	1-7
Nuclear	10-30	1

Source: Ministry of Energy and Natural Resources, 2012

C. Cost

The cost of nuclear energy is cheaper than the other alternatives; this has been confirmed by independent studies carried by Ontario Power Authority (OPA) and OECD. Recent worldwide trends toward higher fossil fuel prices combined with low interest rates, low inflation, increasing importance of carbon emission as a direct power generation cost, have improved the relative economics of nuclear power [11].

Tynan and Stephenson stated the following (see Fig. 1): "Although gas, coal, and nuclear are the lowest cost options according to global surveys, the discount rate plays a critical role in determining overall cost effectiveness. With the large upfront capital costs of nuclear generation development and the relatively low cost of fuel on a per kilowatt hour basis, the discount rate plays a critical role in determining the relative costs across these options. At a 5% discount rate the levelized cost of nuclear is US$29 / megawatt hour compared with $47 for natural gas. But at a 10% discount rate, nuclear generation costs $43 / megawatt hour compared with $51 for natural gas" [12].

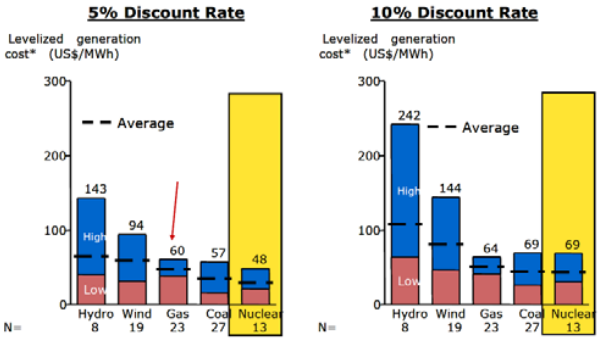

Fig. 1 Global Survey of comparative costs
Sources and notes: *Data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear, decommission cost; main assumptions- 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models. "Projected Cost of Generating Electricity 2005 Update" – Nuclear Energy Agency/ International Energy Agency

D. Other Features

The interest in nuclear power is renewed as it shows strong performance record over decades of experience and continuous improvements in its reliability, safety and decreasing operating cost. Moreover, stability of supply and KWh price are ensured and this can enable the Hydrogen Economy. In addition to the fact that nuclear plants have minimal environmental impacts, since waste volumes are small and manageable, storage of spent fuel is no longer a technical matter but a policy decision [13].

III. Issues to Consider

A. Nuclear Safety and Security

The accident of Chernobyl plant in 1986 represented the never wanted end of nuclear plants. In fact when such a disaster occurs, many lives can be lost and thousands suffer from health disorders, as well as serious environmental impacts can even add longer term concerns. In the case of Chernobyl, it was clear that mismanagement and old reactor design were the main cause. Especially after 1986 accident, international conventions and nuclear safety regime were reviewed and some were taken place to enhance the safety of nuclear activities [14].

Nuclear security in the same time is another major concern. That is, protecting nuclear facilities and controlling nuclear materials and radiological sources must be well done.

B. Nuclear Material as Radiation Source

All kinds of nuclear materials involved in a nuclear power chain may emit beta, gamma, and/or protons, neutrons, alpha-particles and fission fragments. These radiations could show hazards to the workers and the environment [15]. Hence, it is mainly a national task to ensure well management and control of nuclear materials in all stages from production to storage under an authorized regulatory system. In addition, international systems may be in parallel to national systems for a better global nuclear safety [14]-[16]. Considering the disposal of spent fuel, about 10,000 tons of annually spent fuel is a small amount when compared with 28 billion tons of carbon dioxide waste from fossil fuels directly released into the atmosphere. However, being very dangerous material, radioactive waste presents a concern to the public although experts confirm the safety of the geological disposal [9].

C. Natural Disasters

Natural disasters may threaten nuclear plants if these plants are not designed well to withstand against expected natural disasters. The Cooper nuclear power station, for instance, encountered flood waters on the MISSOURI River near Brownville in July 1993 and the operator was forced to shut down the reactor [17]. In addition, hurricanes and tornadoes form another threat to nuclear stations; Davis-Besse nuclear power station near Toledo in Ohio was hit a tornado and winds caused a loss-of-offsite power automatically shutting the reactor down [17]. Moreover, the very recent disaster in Japan (Fukushima nuclear accident in 2011) has set back the republic opinion towards nuclear energy.

IV. Conclusion

Turkey is very large country with a land area twice size of Germany and a population of 74.7million in 2011. By 2015, Turkey's population will have increased to 82.6 million, overtaking Germany as the most populous country in Western Europe. Turkey has the highest birth rate in Western Europe at 20.1 births per 1,000 inhabitants and as a result the youngest population with a median age of 27.1 years in 2006 [18]. This increasing population definitely needs that supplying energy should be in parallel with the same rate.

Increasing overall electricity generation and installing new types of power plants are required and welcomed in any supplying power system. Since the availability of nuclear energy resource is absent in Turkey, installing nuclear power plant(s) is important for diversity and national independency as well. Having very lower carbon dioxide emission rates than coal and gas plants adds another attractive feature related to the environment. Moreover, stability of energy price and constancy in generation invites investors to investment in nuclear energy.

On the other hand, this resource of energy involves challenges and issues to consider. Among of these challenges is to establish a national regulatory system based on the results of the long experience gained by other countries where nuclear energy is utilized. International or regional cooperation is required as well to ensure security and safety. In addition, disposal of radioactive wastes must be carried out very safely. Finally, natural disasters are also a very important challenge. Taking into account that Turkey is a very seismically active area, if national nuclear authority decides to construct nuclear plant(s), site must be carefully chosen and construction is established in such a way that all natural disasters are considered.

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