Renewable and Sustainable Energy Reviews 52 (2015) 572–586

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

An analysis of the current and future use of natural gas-fired power plants in meeting electricity energy needs: The case of Turkey

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ARTICLE INFO

Article history:
Received 18 July 2014
Received in revised form
17 May 2015
Accepted 25 July 2015
Available online 25 August 2015

Keywords:
Natural gas-fired power plant
Analysis of energy generation
Turkey

ABSTRACT

In Turkey as in Europe, the share of natural gas (NG) in the generation of electricity has shown a dramatic increase since the 1990s. Although Turkey faced two economic crises in the last decade, its total electricity generation has increased by 60%. NG consumption was 0.43 bcm in 1987 and reached 40 bcm by 2014. A big fraction of total electricity generation (TEG) is produced from NG. While the NG-based electricity generation was 0.2% in 1985, its share increased rapidly and it has reached to 48% of the TEG in 2014 and share of NG in total thermal power is about 60%. The goal of this paper is to review the historical development of the electricity and NG sectors, and to forecast and review the process of electricity generation with NG. Additionally, this paper compare the use of NG in electricity generation in Turkey and World, and analyze the supply–demand projections and future prospects in the field of energy. Results obtained from the present study show that a diversity of energy resources has not been achieved and as it is today in meeting the increasing energy demand, NG will continue to be a priority in the future.

Contents

1. Introduction

Energy is of vital importance in increasing life quality and in the development of nations. Energy security has become a top priority on the agenda of the World and Turkey. In this context energy has to be environmentally friendly, reliable, and abundant [1]. With today's technology electrical energy cannot be stored. So, once produced it has to be consumed. For this reason it is an industry product that has a high risk factor; however, the risk can be reduced by storing resources in electricity generation. In today's world, energy has gained more and more importance. In the near future, world energy map can change with the emergence of new actors in the energy field, wider use of renewable energy resources, the discovery of new reserves of existing fuels or discovery of new sources such as shale gas. In this case, our energy policy will need to change to keep pace with developments.

Natural gas (NG) is an extremely important source of energy to assist in creating a healthy environment as it reduces environmental

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http://dx.doi.org/10.1016/j.rser.2015.07.102
1364-0321/

pollution and has a great advantage over the use of other fossil fuels [2]. In the 1970s and 1980s the choices for most electricity generators were large coal or nuclear power plants. Due to environmental, economical, and technological changes, NG has become the fuel of choice for the generation of electricity. While coal remains the dominant fuel for power plants around the world, in recent years, NG use is increasing as the fuel of choice for power generation in many countries despite increasing costs. According to the Energy Information Administration (EIA), NG fired electricity generation is expected to increase dramatically over the next 20 years [2]. The world installed electricity capacity was approximately 4000 GW as at 2006. Gas-fired generation was around 4300 TWh in 2009 (22% of global generation) but it is expected that this value will be slightly over 7900 TWh in 2035. While electricity generation from combined cycle gas turbine (CCGT) power plants raised to 2600 TWh in 2009, it will be almost 4900 TWh in 2035 and more than 60% of this generation will consist of the gas-fired generation. However, electricity generation from open-cycle gas turbine (OCGT) power plants increased to 370 TWh in 2009, it will be over 800 TWh [3]. Global electricity generation consists of NG (21%), coal (42%), nuclear (14%) and renewable and hydro (18%). These values show that gas-fired power plants (NGFPPs) are the element of balance among age of oil, coal and renewable energy. Roughly 75% of the world's NG reserves are located in the Middle East and Eurasia. Russia, Iran, and Qatar have about 60% of the world's NG reserves. Russia is the largest exporter of NG in the world and Qatar has become the world's leading LNG exporter.

Countries are in need of obtaining a continuous, reliable, clean and cheap energy through a diversity of energy resources. There are three main ways for having “ever ready” energy resources. The first option is to determine its potential energy resources and generate energy locally in the most efficient way. The second option is to have power in the decision making process of seeking and producing energy resources abroad. The third option is to import electricity because of the failure of previously mentioned two options. If there is a necessity of importing electricity, one of the most important principles in achieving energy stability and security is to develop a diversity of resources [4]. Turkey has chosen the third option and has not achieved diversity of resources. Turkey is especially dependent on one country, Russia, for importing NG, which has caused Turkey to be at risk in terms of energy and national security. Turkey is not the only country facing this risk, and similar conditions are also faced by Hungary, Slovakia, Austria, Finland, and the Czech Republic.

Turkey's general energy and NG demand are one of the highest in the world. There is a direct relationship among NG consumption, energy consumption and economic growth. The relationship has been investigated in many studies; for G-7 countries by [5], Pakistan by [6], 67 countries by [7], general and industrial sector in Turkey by [8]. The results of the models of [5–7] revealed the causality relationship among NG consumption, economic growth and real gross fixed capital formation, and the labor force in long-run. According to [8 and 9], if the level of economic activity and energy use is tightly coupled, the economy is called energy dependent and economic growth can be affected by the energy policy. Turkey is a good example of this situation.

There has been an undeniable contribution of NG to the fast growth of Turkey's economy and it will continue in the future. The main reasons for preferring natural gas power plants (NGPPs) includes their low initial investment costs, construction time, their high electrical efficiency levels (simple cycle 35–42%; combined cycle 52–60% at full load), and their quick availability. These advantages have attracted the interest of private sector to investon NG. Energy conversion efficiency of coal-fired power plants varies between 30% and 35% ($>40\%$ shaft efficiency), while efficiency rates of natural gas combined cycle power plants (NGCCPPs) vary between 50% and 60% [10]. Cogeneration plants cycle efficiencyis between 80% and 90% (if turbine inlet air is cooled, the conversion efficiency can be increased up to 94%) [11].

Lower pollution emission rates create an environmental preference for NG. On the other hand, changes in NG prices, possible supply shortages, and dependence on importation are some disadvantages of NG. In addition, disruptions in supply can create a risk for power plants using NG. This can also affect the country's electricity generation capacity. Detailed technical and cost analyses need to be made by investors before deciding what type of power plan is attractive. A power plant that uses a simple cycle technology is a peak-load power plant, while a power plant that uses a combined cycle (CC) technology is medium-load power plant.

An accurate prediction of gas consumption is crucial and NG consumption has been analyzed with various methods and approaches by the researchers. Studies in the area of forecasting NG consumption began in the middle of last century and led to a tremendous surge in research activities in the past decade. Forecasting the consumption of NG has been studied by many researchers including: (a) for China [12], (b) for Spain [13], and (d) for European NG infrastructure [14]. Kizilaslan and Karlik [15] used seven neural network algorithms as forecasting models attempting to find the best solution for forecasting monthly NG consumption.

Forecasting the gas demand for Turkey has become a very important aspect of managing the energy policy. NG consumption in Turkey has been forecasted by using various time series methods such as exponential smoothing, winters' forecasting and Box–Jenkins methods by [16]. Additionally, the Pipeline Corporation (PPC or BOTAS in Turkish) has forecasted NG demands for Turkey.

Many researchers have studied the NG demand of Turkey. The authors in [17–19] investigated energy policies and NG consumption of Turkey. Furthermore, many researchers forecasted NG demand including: [20] used an autoregressive time series model for Turkey's residential sector, [21] used an artificial neural network (ANN) technique for Turkey and [22] used a genetic algorithm for Iran, and [23] used linear and logistic models for Turkey. Turkey's NG demand between 2013 and 2030 using linear and logistic models was forecasted by Melikoglu [23]. While forecast of BOTAS on Turkey's natural gas demand at the year 2030 is 76.4 billion m^3, in his study, it was calculated as 76.8 billion m^3 using the linear model and 83.8 billion m^3 based on the logistic model.

Electricity energy demand varies according to some parameters. The main parameters affecting energy demand are: gross national product, population and demographic variations, development in housing, industry, agriculture and transportation sectors, income per capita, climatic conditions, employment and technological development, etc. [24]. Studies concerning the energy demand and consumption forecasts of Turkey began in the 1960s [25]. Besides, reports on energy forecasts for Turkey have been officially prepared by the Ministry of Energy and Natural Resources (MENR or ETKB in Turkish). MENR has been forecasting since 1984 by using soft computing techniques. Linear regression was used by [26,27]. Other research techniques includeds nonlinear regression by [27], genetic algorithm by [28], autoregressive integrated moving average (ARIMA), seasonal ARIMA by [29]. Some additional research techniques are; ant colony optimization by [30], particle swarm optimization energy demand forecasting model by [25], fuzzy logic approach by [31] and support vector regression by [32]. All of these studies have been utilized to estimate a nationwide energy demand. Additionally, energy forecasts for Turkey were made with ANN by many researchers [33–35]. Kavaklioglu et al. [36] studied basic energy sources in Turkey at sectoral basis as transport sector and residential sector up to the year 2025.

Additionally, some scenarios were made by many researchers. Kankal et al. [37] modeled and forecasted Turkey's energy consumption using socio-economic and demographic variables and