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A multi-criteria and multi-expert decision aid approach to evaluate the future Turkish power plant portfolio

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ABSTRACT

The study presents recent developments in the Turkish power market and introduces an Analytic Hierarchy Process model to evaluate and compare the relative overall attractiveness of power plant options for Turkey. The developed model incorporates technical characteristics, resource availability, socio-economic, environmental, cost, political, legal and organisational aspects, for evaluating and prioritising power plant types (biomass, coal, geothermal, hydro, natural gas, nuclear, petroleum, solar and wind). The study incorporates perspectives of different experts that represent various stakeholders of the Turkish power sector. The study reveals that supply reliability, investment costs and contribution to national economy are perceived as most important factors, whereas waste disposal and decommissioning costs are perceived as least important factors. Considering the overall weights, the most attractive power plant types for the Turkish power market are coal, hydro and natural gas power plants. The study indicates that Turkey should drastically decrease the installed capacity share of traditionally dominant power plants (to 58% from 89% in 2016) and fossil fuel power plants (to 40% from 56% in 2016), and increase the share of renewable power plants (to 52% from 44% in 2016), indigenous resource based power plants (to 67% from 56% in 2016) and nuclear power plants.

1. Introduction

The Turkish electricity sector has a huge potential for new investments because of a fast growing demand. According to the demand projections from the Turkish Ministry for Energy and Natural Resources (MENR, 2017c), the gross electricity demand in Turkey will more than double in 2030 (Deloitte, 2016). According to the Vision 2023 targets, the installed generation capacity in Turkey is growing by more than 50% between 2016 and 2023 (ISPAT, 2017). In fact, except for 2001 and 2009, the demand for electricity in Turkey has been steadily rising over the last 42 years (Yavuzdemir and Gökgöz, 2015). Between 2000 and 2016, the average annual growth rate of the gross electricity demand was 7.3%, which resulted in an electricity demand of 278 TWh in 2016 (Yavuzdemir and Gökgöz, 2015; Deloitte, 2016). This high growth rate has made Turkey one of the fastest growing energy markets in the world (ISPAT, 2017). According to the International Energy Agency (IEA), Turkey will likely experience the fastest medium-to-long term growth in energy demand among all IEA member countries (IEA, 2016).

In parallel to the growing demand, the Turkish power market structure has changed drastically over the last 30 years. Yılmaz and Uslu (2007a) present the implemented policies in the Turkish energy sector between 1923 and 2003. In 1984, the monopoly of Turkish Electricity Authority (TEK) came to the end by law and in 1993, TEK was divided into two public companies, namely the Turkish Electricity Generation and Transmission Company (TEDAS) and the Turkish Electricity Distribution Company (TEAS) by decision of the Council of Ministers (Önol et al., 2017). Deloitte (2016) provides a timeline and status of the liberalisation process of the Turkish power market from 2001 to 2016. The privatisation process of the power market started in 2001 with the adoption of Electricity Market Law 4628, which was later amended by Law 6446. Law 4628 is based on a license model whereby companies effectively rent the right of operating an asset that they have bought or built (McKeigue et al., 2009). This legislation redefined the state organisations that control generation, transmission, and distribution assets to facilitate their privatisation, construct an electricity trading mechanism (independent energy exchange market established in 2015), and create an independent body to regulate the electricity market (Energy Market Regulatory Authority, EMRA). TEAS was split into individual bodies for generation (EUAS), distribution and trading (TETAS), and transmission (TEIAS) and their assets were unbundled to

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accelerate their privatisation. 21 distribution regions that operate under distribution license from EMRA were created and privatised (Tunç and Paksoy, 2017). The law also privatised the majority of power plants hold by EUAS. The EUAS power plant portfolio includes 56 small and 27 big hydropower plants with a total installed capacity of 3.7 GW and 18 thermal power plants with a total installed capacity of 11.8 GW. In October 2015, 55 small hydropower plants and 10 thermal power plants were privatised via bids. The privatisation process in not yet finalised as 26% of the installed capacity is still owned by EUAS (EPDK, 2017).

Another important market transformation was initiated in 2005 by the adoption of Law 5346 for the Utilisation of the Renewable Energy Resources for the Electricity Energy Production (TR, 2005). This law, together with its 2011 amendment, provides strong incentives for investments in generation capacity for renewable energy resources, for example, by setting floor prices, priority dispatch, feed-in tariffs (plants commissioned before 2021 (IEA, 2016)) and feed-in premiums (Tunç and Paksoy, 2017). As part of the Renewable Energy Action Plan (MENR, 2014), Turkey has set ambitious energy targets for 2023 ("Vision 2023") in which it aims to increase the total share of renewable energy in energy production to 30% by increasing the installed capacity of hydro, wind, geothermal, solar and biomass power plants to 36 GW, 20 GW, 1 GW, 5 GW (ISPAT, 2017) and 2 GW respectively (Melikoglu, 2017b). Additional targets for 2023 are to increase the coal power plant capacity to 30 GW (Melikoglu, 2017b). Based on an expected installed power plant capacity of 120 GW in 2023, the renewable energy and thermal power plant capacity share is expected to be 53% and 47% respectively.

Besides the significant changes and transformations in the Turkish electricity sector, power plant investments have also changed during the last 30 years. Fig. 1 illustrates the evolution of the yearly added installed power plant capacity for each power plant type between 1985 and 2016. On average, 2 GW of new capacity has been added annually to the total installed power plant capacity. Between 1985 and 2000, the investments in new power plants were mainly made in hydro, natural gas and lignite power plants. Between 1985 and 1986, 1994–1995 and in 2006, the newly installed capacity was dominated by lignite power plants. The majority of the power plant investments between 1987 and 1993 were made in hydropower plants, whereas between 1996 and 1999 and 2002–2005, investments in natural gas power plants dominated. Following the intensive construction period of 1987–1993, there have been intensive investments in hydropower plants since 2000 and got boosted after 2010. Fig. 1 also shows that the installation of renewable power plant capacity increased significantly after the adoption of Law 5346 in 2005. Between 2010 and 2016, the annual increase of newly installed capacity for hydropower was over 1 GW. A similar boost

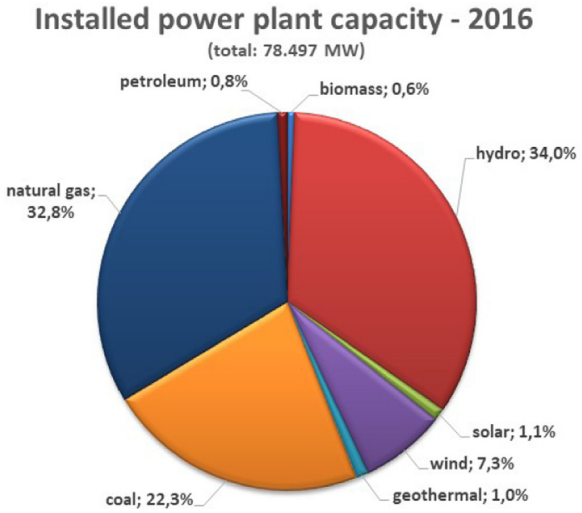

Fig. 2. Installed power plant capacity share for Turkey in 2016 (MENR, 2016).

in installed capacity was observed for wind power plants with an average annual increase of 0.7 GW as of 2008. The newly installed capacity for solar power plants rose very mildly as of 2005 but increased significantly after 2014 (0.8 GW in 2 years) and the installed capacity of biomass fuelled power plants rose steadily but mildly after 2009 (on average 0.06 GW per year). After 2009, significant investments have been made in new natural gas power plants (on average 1.5 GW per year) and hard coal power plants (on average 0.7 GW per year). Between 2015 and 2016, coal and wind power plant had the highest increase in installed capacity.

The total installed capacity of power plants has been rising steadily in Turkey. Between 2000 and 2016, the average annual growth of the installed power plant capacity was 11.8%, which resulted in a total installed power plant capacity of 78,5 GW in 2016 (MENR, 2016). Fig. 2 reveals that the majority of the installed power plant capacity of Turkey stems from hydro, natural gas and coal power plants with a share of 34%, 33% and 22% respectively. The thermal power plant capacity is 56% of the total installed capacity in 2016, whereas the renewable power plant capacity (hydro, wind, geothermal, biomass and solar) is 44%.

However, Turkey's resources of fossil fuels, especially those of oil, natural gas and hard coal, are very limited and its dependency on foreign imports is very high (Balat, 2010). On the other hand, diversity in primary energy sources needs to be maintained in order to sustain energy security. The main underlying reasons requiring the effort to

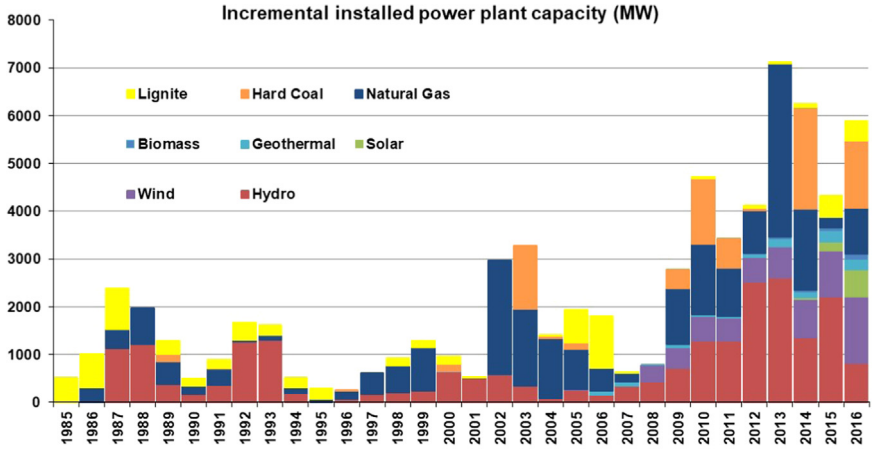

Fig. 1. Incremental installed power plant capacity evolution based on fuel type during the period 1985–2016 (derived from the data obtained from (TEIAS, 2010; Deloitte, 2016; EPIAS, 2016; MENR, 2016).