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Power generation from geothermal resources in Turkey

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ABSTRACT

This study provides information on power generation via geothermal resources and sector development. The first instance of power generation from geothermal resources was performed by a state-owned power plant at Kızıldere-Denizli, whereas the first private sector investment was the Dora-I power plant, commissioned in 2006. Legislation regulating rights ownership and certification laws was issued in 2007. The installed capacity of the geothermal resources is 311.871 MW for 16 power plants, and power generation licenses were issued for 713.541 MW at the end of 2012. The total potential geothermal power that can be generated in Turkey is estimated to be approximately 2000 MW. The geothermal fields in Turkey produce high levels of greenhouse gases, which have been deemed highly responsible for global warming. Due to high CO_2 emissions, the geothermal energy sector risks a carbon tax in the near future. For certain geothermal resources, multiple investors produce electricity from the same resource. The sector will inevitably experience severe damage unless permanent solutions are devised for problems related to sustainably managing geothermal resources and environmental problems.

1. Introduction

Turkey's geological features offer geothermal energy opportunities. Turkey is in the central part of the Alpine-Himalayan Mountain Belt, which began to form due to closing/shrinking of the Tethys Ocean in the Late Mesozoic. High mountain ridges were formed along the northern and southern sides of Anatolia, while certain pre-Cambrian–Paleozoic metamorphic shields (i.e., the Menderes and Central Anatolian Massifs) remain at its center. The tectonic plate convergence and subduction history of the Menderes Metamorphic Massif (MMM) was developed based on data for the major flyschoidal basin and ophyolithic fields of the Izmir-Ankara range at its western and northwestern boundaries. Recent tectonics associated with westward movement of the Anatolian subplate and related N–S extension, particularly in southeastern Anatolia, caused by the Afro-Arabian Plate's northward push created several major E–W oriented grabens (Fig. 1). The faults bounding these structures created suitable conditions for the deep circulation of infiltrating meteoric waters and heating at certain depths. The tectonic forces and resulting structures are thought to be responsible for the current high heat flow in the MMM, the medium to high enthalpy geothermal systems in Western Anatolia and the many low- to medium-enthalpy systems throughout the massif, especially in the Aegean Coastal Belt (Fig. 1). The regional heat flow is approximately 100–120 mW/m^2 [1] in the MMM, which is the largest (in size and output) in Turkey. Several recent grabens have developed in the MMM, where all of the geothermal fields have medium to high enthalpy with reservoir temperatures of 120–287 °C. Büyük Menderes Graben (BMG), Gediz Graben (GG), and Simav Graben (SG) contain many medium and high enthalpy geothermal resources. The thermal fluids are composed of alkaline-bicarbonate, have high CO_2 levels and show evidence of water–rock interactions and mixing with shallow waters. The geothermal system at Tuzla is at the SW border of the young (Lower Tertiary) Kazdağ Metamorphic Massif (KMM) (Fig. 1), where Miocene volcanism shaped the Biga Peninsula following two intersecting, approximately N–S and NW–SE trending regional fracture systems. During the Pliocene, several dacitic-rhyolitic lava domes were placed along an N–S line in and north of the geothermal field. The Tuzla system is thermally recharged through an ascension of deep waters through this N–S structural discontinuity, which also explains the Pliocene lava domes in the area [2].

The power potential of 11 fields in Turkey with medium and high enthalpy is probabilistically 570 MW (P10, proven), 905 MW (P50; probable), and 1389 MW (P90, possible) [2]. Ten more fields are not studied herein but are suitable for power generation. Therefore, Turkey's total power potential can be estimated at 2000 MW.

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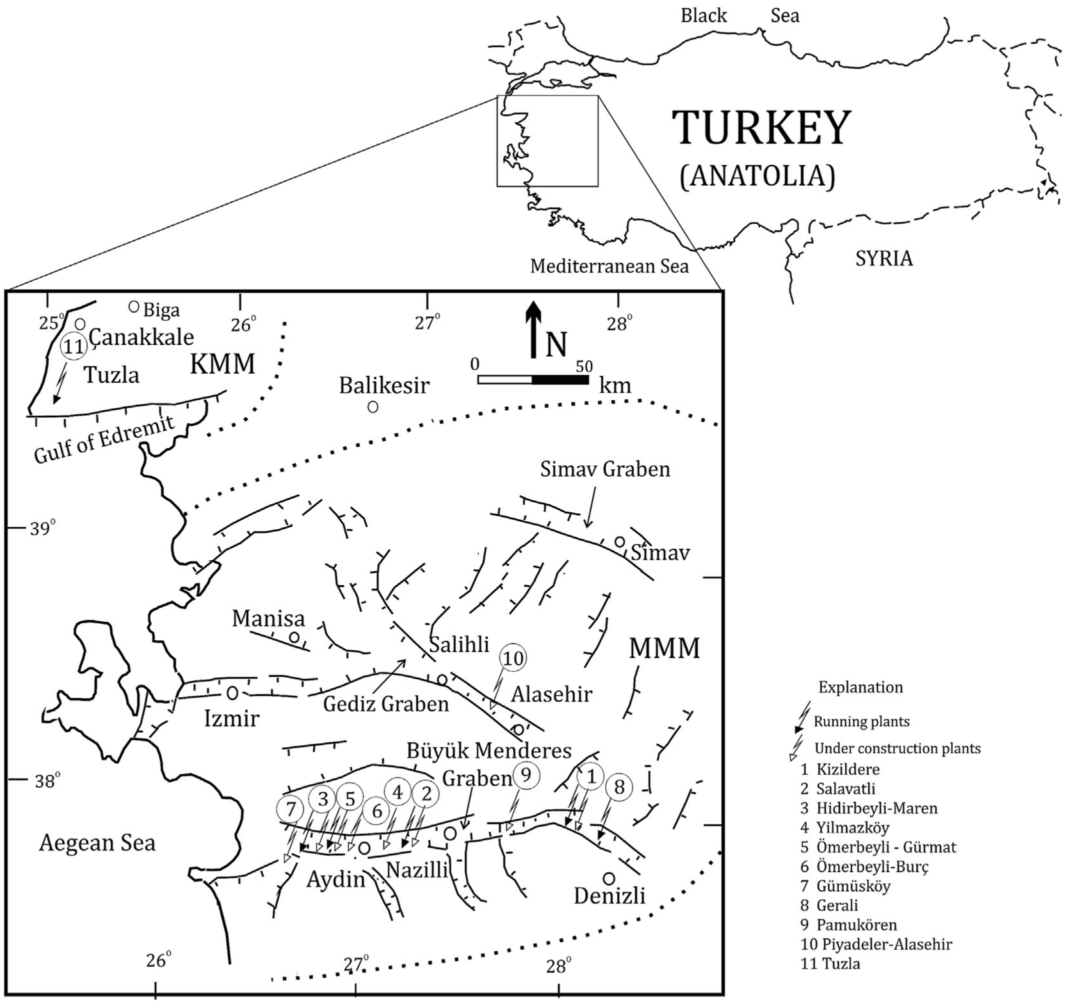

Fig. 1. Distribution of locations with geothermal resources suitable for electricity generation and current power plants in Turkey.

According to the 2012 statistics, the total power generated in Turkey is 239 billion kWh, and the total installed capacity is 57.058 MW. The distribution for power generation is 73% thermal, 24.2% hydraulic, 2.4% wind, and 0.4% geothermal power plants. The demand for power increases approximately 6.5–7.5% each year [3]. The Turkish energy market was liberated in 2001; the EMRA was established to perform a regulatory and supervisory role in the energy market. Investors must have a production license from the EMRA.

The Law of Geothermal Resources and Mineral Waters was issued in 2007 and enacted one year later in 2008, which led to an immediate issuance of approximately 3200 licenses. Almost all well-known, high enthalpy geothermal fields in Turkey were licensed by a governmental institution, namely the General Directorate of Mineral Research and Exploration (MTA). Later, these licenses and operation rights were sold by the MTA through tendering, which created approximately 600 million US dollars of income for the government. Law 6094 was enacted in 2011 and issued tariff subsidies as well as purchasing guarantees for power generation via renewable energy resources. The government announced a 10.5 ¢/kWh subsidized tariff and 10 year purchasing guarantee from the date the plants are commissioned for power generation via geothermal resources until 2020. There is also additional local product support applicable for generators, turbines, power electronics, and injectors manufactured in Turkey, which is also valid for 10 years and amounts to 2.7 ¢/kWh; thus, the subsidized tariff was increased to 13.2 ¢/kWh. The tariff and purchasing guarantee subsidies have undoubtedly eased project financing for investors. A value-added tax (VAT) and customs duty exemption for power generation investments in Turkey are also available. Due to complete liberalization of the energy market by Law 4628 in 2001, electricity can be sold and purchased on the free market.

2. Power generation development by geothermal resources in Turkey

Turkey is rich in geothermal resources. The geothermal resources are used for indoor heating, spa centers, food drying and power generation. Turkey includes 20 geothermal-based district heating systems. Nearly 80,000 residential buildings and over 2 million m^2 greenhouses are heated by geothermal energy. Direct using capacity is nearly of 800 MWt [2]. The heating time is approximately 2000 h of operation per year.

A pilot power plant was constructed in 1975 at the Kızıldere geothermal field and provided free electricity to the surrounding villages for years with a 0.5 MW capacity. The first commercial geothermal power plant in Turkey was installed in the Kızıldere geothermal field by the former Turkish Electric Authority (TEK) with the gross capacity 15 MW. No other plants were constructed in Turkey until 2006. However, the MTA continued its studies and