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Towards More Geothermal Power in Turkey

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ABSTRACT

The energy policy of the Turkish government has two main priorities, namely (a) maximizing exploitation of domestic primary energy resources, and (b) securing sufficient, reliable and affordable energy to a growing economy in an environmentally sustainable manner.

In this context, the government of Turkey has put in place a supportive legal framework to facilitate geothermal development. A critical milestone was the Geothermal Law of 2007. This set out the rules and principles for effective exploration, development, production and protection of geothermal and natural mineral water resources. In 2010 an amendment to the Renewable Energy Law established a feed-in tariff of 105 USD/MWh for geothermal power, for a 10-year period from the commissioning date, with an addition of up to 27 USD/MWh, for a 5-year period from the commissioning date, to reward the use of locally produced equipment. This is guaranteed for geothermal power plants being commissioned until 31/12/2020.

Geothermal resources in Turkey are used for power production, as well as for space heating and tourism related applications. The installed capacity of geothermal power plants in Turkey has grown rapidly in recent years. From some 15 MWe in 2006 to 1,336 MWe in June 2019. This rapid growth has led the government to increase the target of developing 1,000 MWe geothermal electric generation capacity by 2023 to a target of 2,000 MWe. However, this growth has been restricted to Western Turkey; the vast majority of the capacity development has taken place in the Menderes and Gediz Grabens.

The key research question of this paper is: how can Turkey attract new investments and further accelerate the installed capacity in geothermal for power generation? Thereupon, this paper will assess the current situation of geothermal in Turkey and point out the potential and the geographical hotspots, which should be focused upon to further develop geothermal power. The literature on investments in geothermal power will be assessed, leading to an estimate of the reasonable installed capacity per drilled production well. A simple business model needed for profitable investments will be discussed. Financial support in the form of a risk sharing mechanism (RSM), which has recently been launched in Turkey will be crucially important.

1. INTRODUCTION

The energy policy of the Turkish government has two main priorities, namely (a) maximizing exploitation of domestic primary energy resources, and (b) securing sufficient, reliable and affordable energy to a growing economy in an environmentally sustainable manner.

In this context, the government of Turkey has put in place a supportive legal framework to facilitate geothermal development. A critical milestone was the Geothermal Law of 2007. This set out the rules and principles for effective exploration, development, production and protection of geothermal and natural mineral water resources. In 2010 an amendment to the Renewable Energy Law established a feed-in tariff of 105 USD/MWh for geothermal power, for a 10-year period from the commissioning date, with an addition of up to 27 USD/MWh, for a 5-year period from the commissioning date, to reward the use of locally produced equipment. This is guaranteed for geothermal power plants being commissioned until 31/12/2020.

Geothermal resources in Turkey are used for power production, as well as for space heating and tourism related applications. The installed capacity of geothermal power plants in Turkey has grown rapidly in recent years. From some 15 MWe in 2006 to 1,282 MWe produced by 48 power plants in 2018. Moreover, power plants with a total installed capacity of 354 MWe are under construction and another 400 MWe has obtained a pre-license, as of JAN 2019. This rapid growth has led the government to increase the target of developing 1,000 MWe geothermal electric generation capacity by 2023 to a target of 2,000 MWe (JD, 2019). However, this growth has been restricted to Western Turkey; the vast majority of the capacity development has taken place in the Menderes and Gediz Grabens.

The key research question of this paper is: how can Turkey attract new investments and further accelerate the installed capacity in geothermal for power generation?

The outline of the paper is as follows. Section 2 will assess the current situation of geothermal in Turkey and point out the potential and the geographical hotspots, which should be focused upon to further develop geothermal power. The literature on investments in geothermal power will be assessed in Section 3, leading to an estimate of the reasonable installed capacity per drilled production well. A simple business model needed for profitable investments will be discussed in Section 4. Financial support in the form of a

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risk sharing mechanism (RSM), which has recently been launched in Turkey will be crucially important. Section 5 draws the main conclusions.

2. ASSESSMENT OF THE CURRENT SITUATION OF GEOTHERMAL IN TURKEY

As of end June 2019, there is about 1,336 MWe of installed capacity in geothermal power in Turkey (TEIAS, 2019). Table 1 shows the breakdown of installed capacity of geothermal by province for most of this capacity. We can see from the table that the highest installed capacity is in Aydın followed by Denizli and Manisa. These provinces are the hot spots for geothermal development in Turkey. In addition, some geothermal power plants are also found in Çanakkale and Afyonkarahisar. A map with key geothermal locations is presented in Figure 1. Hence, the hotspots for geothermal can be found in the Menderis and Gediz grabens in the provinces of Aydın, Denizli and Manisa.

Table 1 Distribution of installed capacity of geothermal power in Turkey as of early 2019

PROVINCE	SUM OF MWE
AYDIN	744.0
DENIZLI	322.7
MANISA	221.0
ÇANAKKALE	15.5
AFYONKARAHISAR	2.8
TOTAL	**1306**

Source: EA (2019)

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

Sources: Aksoy (2014), Kilic (2016).

Karamanderesi (2013) presents the key geographical characteristics of geothermal reservoirs in Turkey. Well-known geothermal fields are Kızıldere, Germencik, Salavatlı, Alaşehir-Alkan, Salihli-Caferbeyli, MDO-1 well, Sandıklı AFS wells, Afyon geothermal area, Çanakkale Tuzla, but also in central and eastern Anatolia.

Mertoglu, Simsek and Basarir (2015) reports on the geothermal potential in Turkey. These are reported as 4,500 MWe for power generation[2] with well depths up to 3 km, whereas the potential of direct use has been increased from 31,500 to 60,000 MWth. An important step for accelerating geothermal development has been the geothermal law No 5686 of 2007. Together with the FIT for

[2] Melikoglu (2017) also uses the number of 4,500 MWe of geothermal power potential in Turkey.

geothermal power production, the installed capacity has increased substantially. The geothermal potential in Turkey is also studied in detail by Korkmaz, Serpen and Satman (2014). They arrived at lower estimate for geothermal power potential, namely 2,263 MWe. In 2017, Turkey has entered the so-called 1 GWe country club with respect to geothermal power installed capacity; where Turkey is ranked fourth in the world after USA (3,591 MWe), Philippines (1,868 MWe) and Indonesia (1,809 MWe) (TGE, 2019).

Ates and Serpen (2016) focus on which technology to choose to optimally fit the characteristics of the geothermal reservoirs. Based on a model simulation analysis the authors conclude that a model using single flash and binary cycle processes together to be an optimal choice for many reservoirs in Turkey.

3. LITERATURE ON INVESTMENTS IN GEOTHERMAL POWER

ESMAP (2012) provides a handbook into the planning process and financing geothermal power projects. The following graph shows how risks develop over time in the project cycle, where the need for financial support such as RSM is particularly important during the exploration phase.

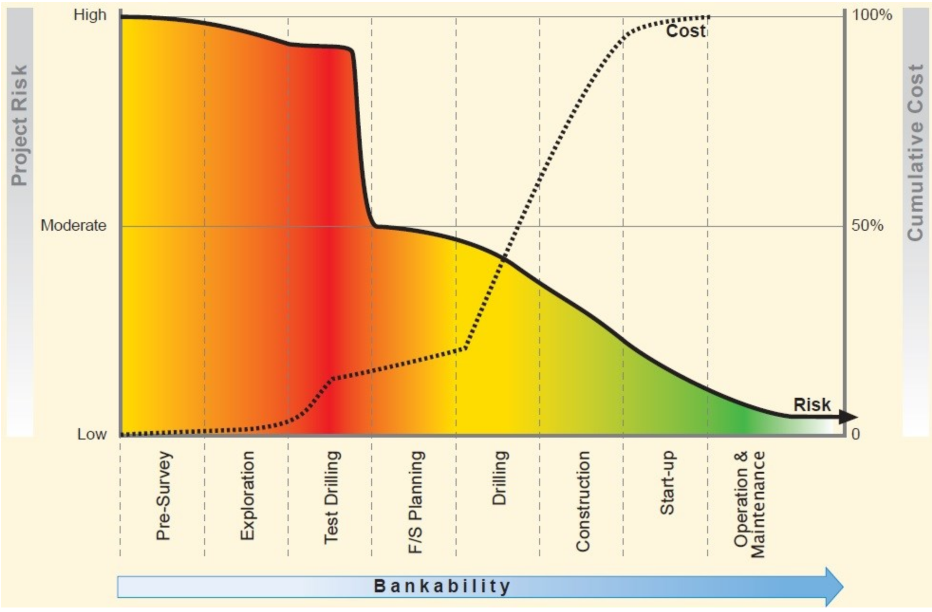

Figure 2: Project Cost and Risk Profile at Various Stages of Development

Source: ESMAP (2012).

Pater Salmon et al (2011) provide a guidebook into recent trends in geothermal power finance, based on experiences in the USA. Figure 2 summarizes the main results.

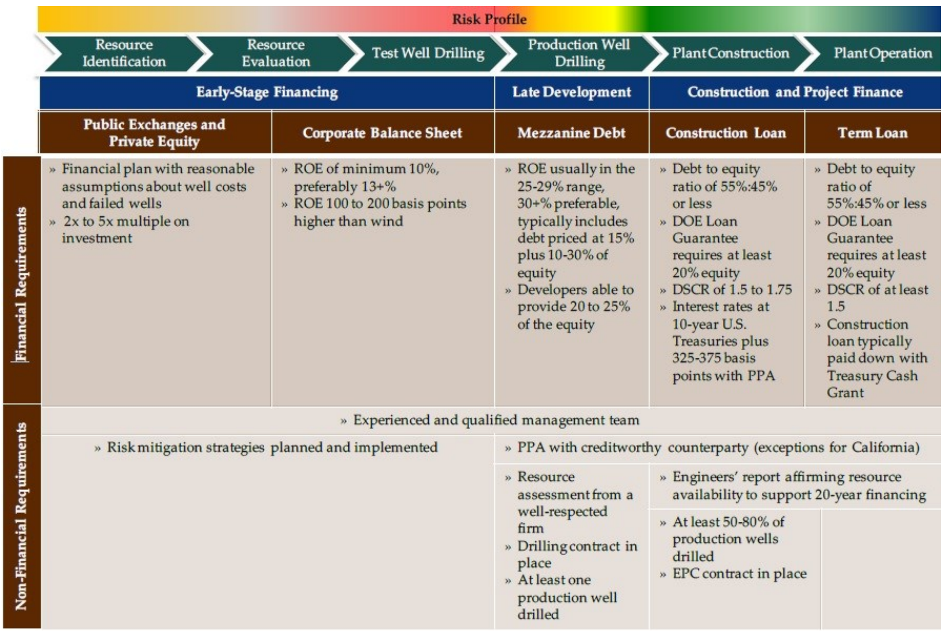

Figure 3: Key information for financing the development of geothermal power plants

IFC (2013) focusses on success criteria for geothermal wells, developing a database of wells from all around the world, covering 2,613 wells. The main conclusion is that 78 percent of the drilled wells were considered successful. However, the success for the first well is determined at only 50%, whereas the success rate for consecutive wells after one successful well is going up quickly. The average capacity per well is 7.3 MWe in that study, but averages vary significantly between different geothermal areas and resource types. The total dataset is skewed with a few very large wells. It is better to consider the modal average capacity which is 3 MWe. That geothermal field are generally small is also confirmed by WEC (2016).

Olivier and Stadelmann (2015) present a very detailed case study of one particular power plants in Turkey: Gumuskoy, which is the first geothermal power plant where the exploration costs and risks has been borne by the investor. In the end the risk taking appetite of the investor paid off and this project led to a profitable enterprise.

4. A SIMPLE BUSINESS MODEL FOR PROFITABLE INVESTMENTS

Financial modelling of geothermal power plants has been undertaken by various authors. Gunnlaugsson (2012) presents financial detail of a large geothermal power plant in Iceland. Ngugi (2014) has built a financial model for geothermal power projects in Kenia. Chatenay and Johannesson (2014) compare the economics of geothermal power plants to other power generation technologies.

In order to build a simple financial model relevant for Turkey, the following bullet summarise the key assumptions:

- Key drivers of profitability are the CAPEX and OPEX. These are taken as 4000 USD/kWe net installed capacity for CAPEX and 100,000 USD/MWe net installed capacity for OPEX.
- The net installed capacity is taken as 5 MWe.
- A flat 80% availability is assumed, which is equal to 7008 running hours.
- We assume 115 $/MWh for the first 10 years and 75 $/MWh for the next 15 years, all assumed to be in nominal USD.
- Depreciation and amortization are assumed to be 10%.
- The loan is dispatched in 2 years and paid back in 11 years in equal installments.
- Interest payments for first two years are added to the CAPEX as financing costs.
- The projections are done in nominal USD.

The result of the financial model with these assumptions is as follows: the profitability in terms of project internal rate of return or project IRR is 10.8%. This is a sufficiently high rate of return. However, the key driver of this result is the ability to benefit from the going FIT, which means that the project needs to be commissioned until end 2020. Also, if some of the drilled wells are not successful, this may add to the cost of the investment and lower the overall profitability considerably. To have an insurance against this risk there is a need for a RSM, which is currently available in Turkey.

5. CONCLUSIONS

Turkey has entered the so-called 1 GW country club with respect to geothermal power installed capacity. Moreover, Turkey is ranked fourth in the world after USA (3,591 MWe), Philippines (1,868 MWe) and Indonesia (1,809 MWe) (TGE, 2019). The development of geothermal installed power capacity in Turkey, has gone quicker than expected, driven by a favorable regime with feed-in tariffs (FIT), namely 105 $/MWh for 10 years, which may be increased with another 27 $/MWh for 5 years for including local equipment in the investment. However, these projects need to be completed until end-2020. Initially the official target was to reach 1 GW until 2023; this has been revised to 2 GW until 2023, in line with recent developments. Turkey has an extensive potential for geothermal for power, estimated to 4.5 GW. To reach this potential, the current FIT will regime will need to be extended to projects that will be commissioned from 2021 onwards.

Also new areas need exploration which may be suitable for geothermal power development. Here the literature shows that the largest risk of the investor is during exploration. Moreover, the likelihood of drilling a successful well increases as more wells are drilled in the same location. Also, according to IFC (2013), across all resource types, the average size of a successful production well has been estimated to be around 3 MWe globally and Turkey is no exception on this. Here, to facilitate exploration drilling in new areas, there is a need for a Risk Sharing Mechanism (RSM), which is currently an ongoing project in Turkey funded by the Clean Technology Fund through the WB.

BRIEF CVS OF THE AUTHORS

Wietze Lise is Principal Consultant at ÅF-Mercados EMI, Ankara since February 2012, heading Energy Markets Unit. Experienced in European and Turkish power and gas markets. Twenty-three years of experience, gained at several leading consultancy energy and environmental companies. He worked in multidisciplinary teams, and acquired, produced and managed various projects. Published about forty and widely cited scientific articles in various international journals. Holding an MSc in Applied Mathematics from Twente University, Holland and a PhD in Economics from Delhi School of Economics, India.

Bjarni Richter is a Geothermal Expert and consultant with broad practical experience in geothermal surface- and sub-surface exploration, well logging, including lithology, alteration and mineral identification, interpretation of geophysical data, borehole temperature and pressure data, good knowledge on technical aspects of drilling, well design and drilling programs. Experience in geothermal exploration, well siting and conceptual modelling. Knowledge of resource assessment. Work experience in marine geology including projects in petroleum exploration and Law of the Sea related studies. Experience in planning and carrying out field surveys and drilling campaign. Good experience in project management, marketing and business development.

Dadi Thorbjörnsson is a Geothermal expert and consultant with broad practical experience in geothermal studies, project management and consultation. The experience includes geochemical studies such as sampling, chemical modelling and interpretation, environmental studies such as chemical and physical impacts of geothermal utilization (including drilling and testing geothermal wells), well testing, tracer flow testing of geothermal wells, conceptual model-ling based on various geoscientific data, geochemical reservoir monitoring, hydrogeological studies. Several years of project management experience including management of drilling projects, reservoir monitoring projects, conceptual modelling, environmental studies, well testing, resistivity studies and seismic studies.

Helga Tulinius is a Senior Geophysicist and geothermal expert focusing on geophysics and reservoir engineering. Main projects involve project management and resource assessment. The geothermal experience spans a wide field of expertise, such as in project management, conceptual geothermal reservoir modeling, geothermal high and low temperature well testing, bore hole logging, and most types of geophysical surveys both in Iceland and abroad. She previously worked with Mannvit Engineering, the National Energy Authority, Iceland, and the Authority's Geothermal Division, mainly as a geophysicist, reservoir physicist, and borehole logger.

Gudni Axelsson is Director of geothermal training and research and senior geothermal reservoir engineer at Iceland GeoSurvey (ÍSOR). He has a PhD in geophysics from Oregon State University, USA. Gudni has worked at ÍSOR, and its predecessor Orkustofnun, since 1985. He specializes in geothermal reservoir physics, including testing, monitoring and modelling of geothermal reservoirs, as well as having a long experience in geothermal resource management, including monitoring, reinjection, tracer tests and sustainable utilization. He has e.g. worked on geothermal projects in Iceland, China, The Philippines, Turkey, Kenya, Central-America and Europe. Gudni has been involved in world-wide geothermal training and technology transfer for close to 35 years, in particular through the United Nations University Geothermal Training Programme.

Ralf Brauchler has received an MSc and PhD in Geology at the University of Tübingen, Germany. He was employed at the Institute for Applied Geology of the University of Göttingen, Germany, where he set up and managed the research group on geohydraulics. He contributed significantly to the advancement of hydraulic and tracer tomographic techniques for the reconstruction of hydraulic properties in unconsolidated sediments and fractured rocks. His work on this topic is documented in a large number of scientific publications in renowned international journals and book contributions. From 2010 to 2014, he worked as a research associate and lecturer at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. He joined AF-Consult in 2014 as Group Manager Hydrogeology and Waste Disposal.

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