Turkey

Characterizing the declining CO_2 emissions from Turkish geothermal power plants

Terms of Reference

February 28, 2019

1. Background

Turkey is the 17th largest economy in the world and the 6th largest in Europe. With a growing economy and population, Turkey's energy demand is projected to increase by approximately 7 per cent each year until the year 2023. While domestic resources currently provide around 26 per cent of the total energy demand, the remaining three fourths are being imported. Increase in domestic energy generation and diversification of energy supply are therefore among the priorities of Turkish energy policy.

In order to reduce the risk associated with external energy dependence and to create a more sustainable energy model, the Government has been promoting renewable energy and has set ambitious objectives that rely on exploitation of domestic resources. According to the National Renewable Energy Action Plan (REAP) for the period of 2013-2023, the country is planning to increase the share of renewable energy in electricity generation to at least 30% of the total 100 GW of installed power generation projected by 2023.

Turkey is endowed with vast geothermal resources that range in temperature from just above ambient to more than 240°C and that are thus suitable for different utilization technologies. During the last decade, the geothermal power sector in Turkey has been the fastest growing geothermal market in the world. Starting from 15 MW of installed capacity in 2007, the sector has grown to almost 1,350 MW in November 2018, far exceeding the goals of the government to reach 1,000 MW by 2023. The growth of the geothermal power sector in Turkey is expected to continue at a robust rate, at least in the intermediate term.

Turkish geothermal fluids are characterized by unusually high CO_2 content due to the unusual geologic setting of the geothermal fields in the country. The Turkish geothermal systems occur in intraplate extensional setting where carbonate rocks are commonly the dominant host rock type. Carbonate rocks, composed of calcium and magnesium carbonates ($CaCO_3$ and $MgCO_3$) release CO_2 to the fluid at high temperatures. The high CO_2 content of the geothermal fluids results in very high CO_2 emissions from Turkish geothermal power plants. Typical emission factors at power plant *at commissioning* are in the range from 1,000 to 1,300 g/kWh, i.e. in the same range or even higher than from coal fired power plants and almost 10 times higher than the global average emission factor for geothermal projects of 121 g/kWh.

Despite the high initial CO_2 emission factors most, if not all, Turkish geothermal power plants have experienced gradual decline of CO_2 emission with time based on available data. Although the rate of the decline is different between different fields, it is typically in the range of 10% per year to more than 50% per year in the most extreme cases. The declining CO_2 content of the fluid is generally linked to degassed brine that is reinjected into the reservoirs.

The high CO_2 emission values for Turkish geothermal power plants have caught the attention of the global geothermal community and raised serious concerns among international financing agencies about the environmental impact of geothermal power generation. During the preparation of the Geothermal Development Project the World Bank team was aware of the high CO_2 emissions from Turkish geothermal power plants and this influenced the design of the project. The World Bank team also intended to use the information collected through the project to improve the understanding of how the CO_2 emissions from

Turkish geothermal power plants would evolve over time. The unequivocal pattern of declining CO_2 emissions described in the preceding paragraphs suggests that there is now sufficient volume of data available to launch an independent scientific study to gather and analyze the available information on declining CO_2 levels in Turkish geothermal reservoirs.

2. Objectives

The objective of this study is to identify the parameters that affect the rate of CO_2 decline in different reservoirs in Turkey during utilization and develop a methodology to allow prediction of the average life-time emission factors for geothermal projects in the country within defined uncertainty limits.

3. Scope of Work

In this study, production data from number of geothermal fields in Turkey will be analyzed. The study will at least analyze data from the five projects currently financed under the World Bank's Geothermal Development Project and will ideally include further 5 to 10 projects that will be identified in partnership with JESDER. The exact number of projects included in the study, and thus the scope of the work, will depend the willingness of geothermal power producers to share data for the study and the recommendations of the consultant regarding the number of data sets needed to obtain a statistically reliable result.

In this project the consultant shall:

- At inception, provide a complete list of parameters and data sets needed to understand the relationship between the decline of CO_2 concentration in geothermal fluids and production and reinjection, such as:
    - Time series of production and injection rates for individual wells and cumulative production and reinjection rates for the reservoirs;
    - CO_2 concentration in total discharge from production wells;
    - total CO_2 emission rates from power plants;
    - chemical monitoring data showing return of reinjected brine to production wells, e.g. Cl concentration of geothermal fluid and reinjected brine over time;
    - data on temperature and pressure conditions in the reservoir;
    - data on well-head pressure
    - data to quantify the volume of the reservoirs, e.g. aerial extent, thickness, porosity;
    - etc.
- Develop a standard request to developers to seek the data (listed above) necessary to carry out the study,
- Identify the number of projects to include in the study to ensure statistically significant results taking into account the variability in temperature and pressure conditions, reservoir and power plant size, variability in CO_2 content and decline rate and the length of the production history,
- Support the World Bank team and JESDER in communicating with project developers to seek appropriate data for the study, particularly in following up for details,
- Develop a simple predictive model based on analysis of the data collected from project developers that allows prediction of CO_2 emissions from geothermal power plants over the project lifetime with defined certainty limits,
- Assess how declining CO_2 content of the fluid will affect reservoir pressure and well productivity over the life time of the power projects

- Develop a tool, or a set of equations, to calculate CO_2-contnent predictions into the future as well as average values for project.
- Prepare a manuscript suitable for publication in an international, peer-reviewed scientific journal describing the results of this study,
- Prepare an editable power point slide deck describing the methodology of the study and the resulting predictive model,
- Present the results at an event attended by Turkish geothermal sector actors.

4. Methodology

This study is a desktop study, i.e., the consultant shall work with data that have been collected already by project developers.

The consultant shall, in the technical proposal, present a detailed modeling methodology describing what data need to be collected from developers and how they will be analyzed to develop a predictive model for CO_2 emissions from geothermal power plants.

5. Schedule and Deliverables

This assignment is expected to take approximately six months to complete. The four key deliverables expected for this study are

- *Inception report (2 w preparation – 2 w review/approval)*
- *Data request (1 w preparation – 1 w review/approval)*
- *Interim report with preliminary results of data analysis and predictive modeling (6 w preparation – 2 w review/approval)*
- *Final report including manuscript for a peer reviewed publication and a power point presentation with main results (4 w preparation – 2 w review/approval)*

6. Consultant Qualifications

The consultant needs to have the following qualifications

- Strong experience in geothermal reservoir modeling
- Strong experience in interpretation of geochemical data for reservoir studies
- Good communication skills and experience in presentation of scientific results in written and oral form
- Experience in writing articles for publication in peer reviewed journals
- Close familiarity with the geothermal sector in Turkey and geothermal energy technologies in general

Interested candidates are asked to send a CV, highlighting experiences related to this assignment, and a cover letter with a brief methodology proposal to Thrainn Fridriksson at the World Bank (tfridriksson@worldbank.org) before March 15.