Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

Geothermal high level screening potential in global basins using E&P data

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INTRODUCTION

Traditional exploration and production data is a valuable resource for mapping geothermal potential globally due to the data's vast availability and reliability. This study utilizes an extensive subsurface temperature dataset to assess geothermal potential across four distinct geographic regions. Geothermal gradients have been calculated for all available wells with temperature data, following rigorous data quality checks and the application of a comprehensive bottom-hole temperature correction methodology. These geothermal gradients serve as the foundation for evaluating geothermal usage potential in each region, by utilizing the values to construct polygons at increasing depths, typically every 1,000 meters below the surface.

The methodology has been applied to four selected study areas: Türkiye, recognized as a well-established geothermal player; the Great Valley Basin in California, which has a rich history of traditional geothermal operations and the potential for more advanced initiatives; the Neuquén Basin in Argentina, noted for its emerging geothermal status, with ongoing projects and future development plans; and the Alberta Basin, an area with well documented yet largely untapped potential.

Geothermal wells are typically more expensive than comparable oil and gas wells. This cost premium arises from the need for specialized high-temperature equipment, longer drilling cycles, and higher daily rig rates. Geothermal projects also incur additional expenses for corrosion-resistant casing materials and specialized drilling mud, and they face higher geological uncertainty and resource confirmation risks. However, geothermal well completions are often simpler than those for complex oil and gas wells, as they do not require hydraulic fracturing, which partially offsets the higher drilling costs through reduced completion complexity.

In this study, geothermal potential estimations at various depths are integrated with additional technical data, alongside economic modelling and numerical estimations of geothermal potential. This comprehensive analysis assesses the risks associated with each study area and ultimately identifies the 'sweet spots' for geothermal development.

METHOD

A proprietary bottom-hole temperature (BHT) correction method was developed and applied to all available raw subsurface temperature data in each region. The correction method comprises several steps, building on the widely accepted Waples and Ramly (2001) and Waples et al. (2004) correction methods for single BHT readings. The United States and Canada are well known to

have an abundance of well data, often with multiple temperature readings per well. In contrast, elsewhere internationally, it is common to have only a single temperature reading available per well. Therefore, it is important that the BHT correction method is applicable to wells with single BHT readings and is consistently applied across all regions. The BHT correction results in an estimation of true formation temperature (TFT), following which a surface temperature correction is applied, and a geothermal gradient is calculated. A global raster layer of land surface and seafloor temperatures has been created by averaging seafloor temperature data from the World Ocean database and land surface temperature data from NASA, covering the period from 2000 to 2020. If a surface temperature value has not been reported by the operator, a value is drawn from this raster layer based on the specific latitude and longitude of the well.

The geothermal gradients derived from these corrections are then utilized to construct polygons at each 1,000 m interval in the subsurface, up to a depth of 5,000 m. These polygons delineate areas suitable for different geothermal usage applications, which are categorized as follows, along with their associated temperature ranges at depth:

- Ground source heat pumps only (≤ 30°C)
- Direct use applications (30-120°C)
- Marginal electricity generation (specific power plants only – 120-150°C)
- Electricity generation (≥ 150°C at depth)

Following the geothermal potential estimations, economic modelling is integrated into the analysis to produce a comprehensive risk assessment for the identification of geothermal 'sweet spots'. A simple one-well model (integrated injection and production well) was created, with average reservoir depths of 2,000 m in Türkiye, 4,000 m in the Neuquén Basin, 4,000 m in the Great Valley Basin, and 3,000m in the Aberta Basin. These depths represent ‘sweet spots’ in each region based on the modelling, where reservoir temperatures are likely to exceed 200 °C. A well lifespan of 20 years is assumed across all regions, and production and injection flow rates estimated at 50 kg/s for Türkiye, 50 kg/s for Neuquén, 60 kg/s for the Great Valley Basin, and 45 kg/s for the Alberta Basin (S&P Global, 2025). The input parameters are provided in Table 1. By leveraging cost estimation software and applying adjusted equipment factors, daily rig adjustment factors, and completion factors, geothermal well costs were estimated for each study area.

Table 1. Cost modelling input parameters for the four projects

Case	Gediz Graben, Türkiye	Neuquén, Argentina	Great Valley, USA	Alberta, Canada
Base year	2025	2025	2025	2025
Number of production wells	1	1	1	1
Number of injection wells	0	0	0	0
Reservoir average depth (m)	2000	4000	4000	3000
Production wellhead temperature (°C)	230	230	245	220
Production well flow rate (kg/s)	50	50	60	45
Plant configuration	Double Flash	Double Flash	Double Flash	Double Flash
Plant utilisation rate	90%	90%	90%	90%

RESULTS

The results for the four study areas are presented in Figure 1.

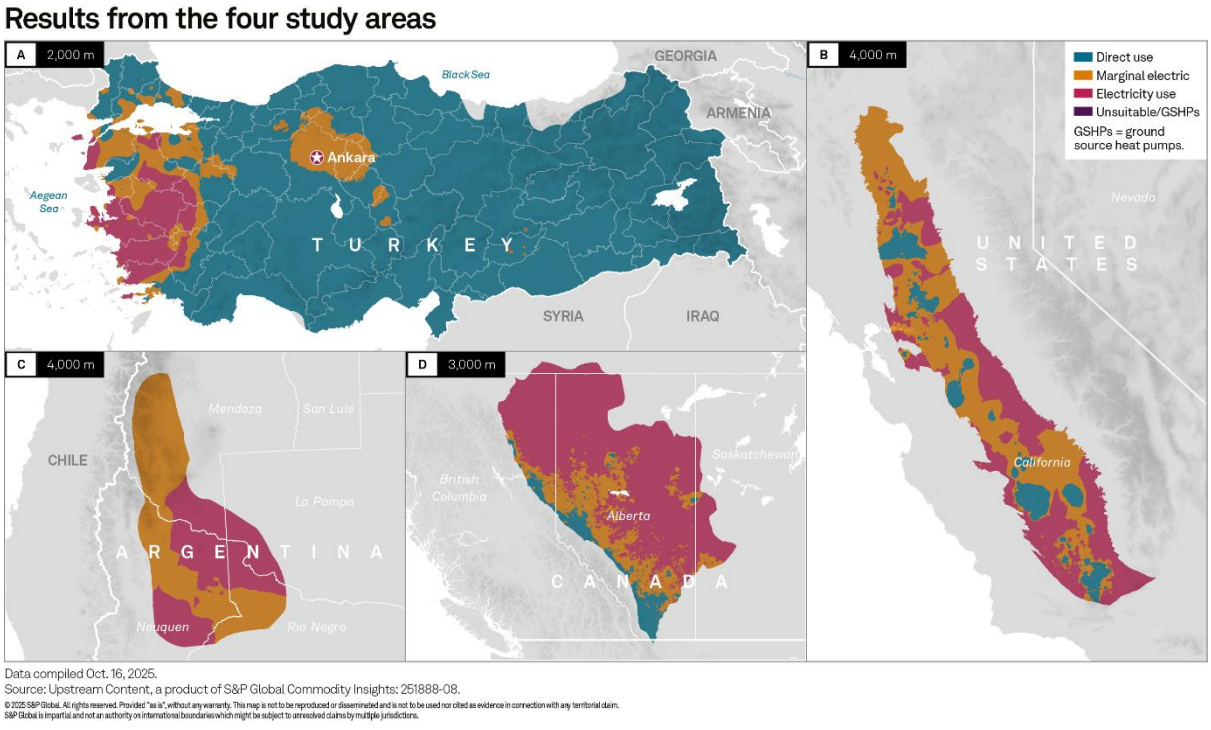


Figure 1. Polygon map of geothermal usage potential for A. Türkiye 2,000m, B. Great Valley Basin, California 4,000m; C. Neuquén Basin, Argentina 4,000m; and D. Alberta Basin, Canada 4,000m. Red indicates suitability for electricity generation applications, orange indicates the possibility for marginal electricity generation (specific power plants only), and blue indicates areas suitable for direct use.

At a depth of 2,000 meters, subsurface temperatures vary across Türkiye. Several hot spots are located in Eastern and Central Türkiye, but the highest temperatures are predominantly found in

Western Türkiye, where extensive hot spot areas exist (Figure 1). The operating geothermal power plants are situated within these hot spots in Western Türkiye.

For the Great Valley Basin California, the areas of highest temperature are located at the basin margins with a trend more extensive towards the southeast. No geothermal power plants are identified in the basin however the Geysers complex is located northwest of the region in Northern California and the extensive Salton Sea direct lithium extraction (DLE) sites are located southeast of the basin. The geothermal gradients to the south of the basins suggest a large area exists suitable for electricity generation at depths greater than 4,000m. In the Neuquén Basin the regions of highest temperature are located to the south of the basin and exploration is currently underway around the Domuyo Volcano which is situated just outside the western edge of the basin. In the Alberta Basin the hottest region is located along the northeastern edge and gradually extends southwest across the basin with depth, whilst there are no active plants in the basin the Alberta No.1 well is testing the potential around Grand Prairie to the north of the Basin.

When temperatures in these areas exceed ≥ 150°C at depth, they are designated as suitable for geothermal power generation (represented by the red areas in Figure 1). Surrounding these hot spots, areas that exhibit temperatures of 120-150°C are classified as suitable for marginal electricity generation (indicated by the orange areas in Figure 1), which can accommodate specific power plants. At 2,000 m depth, Türkiye demonstrates a technical capability for direct geothermal usage across the entire country (shown in blue in Figure 1). This suggests that Türkiye could harness widespread geothermal energy for applications such as district heating and cooling, as well as agricultural uses and balneology, among other applications.

Within the Great Valley, Neuquén and Alberta Basins the majority/significant areas of these Basins become suitable for electricity generation at depths greater than 4,000m. At depths of greater than 5,000m almost the entirety of these three basins are suitable for electricity generation.

Geothermal well costs were estimated for each study area, using the parameters outlined in the Method, the costs are summarized in Table 2. The result show that costs in Türkiye are lower than the other four regions, with operating costs at 110 $/kWh, Neuquén, Great Valley and Alberta Basins are all estimated to have operating costs in the region of 138 $/kWh

Table 2. Cost modelling results for the four regions

Case	Gediz Graben, Türkiye	Neuquén, Argentina	Great Valley, USA	Alberta, Canada
Power plant Capacity (MW)	5.41	5.41	6.59	4.64
Levelised costs of electricity (LCOE, $/kWh)	0.08	0.10	0.09	0.11
Installed cost per kw ($/kW)	5552	6863	6344	7503
OPEX per kw per kWh ($/kWh)	110	138	138	138

Combining the technical assessment of geothermal potential in these four study regions shows that Türkiye has prolific potential for geothermal energy exploration, as it is comparatively

cheaper to drill than the other study areas and has relatively shallow ‘sweet spots’. The other regions, whilst relatively underdeveloped, also possess huge potential.

This screening data can be used along with geological data from the well database to delineate regions were known reservoirs and regions of high porosity and permeability intersect these ‘sweetspots’, this analysis will further constrain the best areas in a given basin to undertake geothermal exploration.

CONCLUSIONS

Traditional E&P data provide a comprehensive high-level overview of geothermal resource potential across geologically diverse basins and countries. Based on the methodology outlined above, it is concluded that Türkiye is an exceptional candidate for geothermal energy exploration across the entire country, offering multiple applications for geothermal usage at a minimum depth of 2,000 meters.

The economic modeling for Türkiye supports this conclusion, indicating that well costs are comparatively lower than those in the Neuquén Basin the Great Valley Basin, and the Alberta Basin likely owing to the extensive geothermal exploration already underway in the region. Türkiye has established itself as a significant player in the geothermal sector, and these findings not only reinforce this reputation but also highlight additional areas throughout the country that may be well-suited for various geothermal energy applications.

For the Neuquén Basin the Great Valley Basin, and the Alberta Basin significant potential still exists however deeper wells with higher associated costs will need to be drilled to reach sufficient temperatures for direct electricity generation.

Acknowledgements

We would like to acknowledge and thank S&P Global for the use of their Upstream Content data and Questor cost estimation software.

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