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THE BOTTOM LINE

Türkiye[1] has substantial geothermal potential, and the country's government is committed to exploiting it, both for economic reasons and to meet its obligations as a signatory of the Paris Agreement on Climate Change. Türkiye has more than 400 known geothermal fields in 63 different provinces. The country's total estimated geothermal potential is more than 60,000 megawatts thermal. Developing that potential could create more than 120,000 direct jobs, with ample opportunities for women's participation.

The Turkish government has set an ambitious goal of 11,150 MWt in direct uses of geothermal energy by 2025. Meeting that goal will require raising awareness, building capacity, ensuring a favorable regulatory environment, and increasing access to funding for both public and private entities.

The World Bank is supporting the Turkish government's efforts through the Geothermal Development Project and the recently approved Climate Smart and Competitive Agricultural Growth Project.

Opportunities for Direct Uses of Geothermal Energy in Türkiye

What is the potential for the direct use of geothermal energy in Türkiye?

The potential is very great indeed

Geothermal energy is extracted from thermal sources in the earth. It can be used directly to supply heat or extract gas and minerals—or indirectly to generate electricity. The earth's crust will provide heat for billions of years, so with proper resource management geothermal energy can be used sustainably for a very long time.

The use of geothermal energy depends on its source temperature, which can range from 20˚C to more 300˚C. When the temperature is below 100°C, it is more suitable for direct uses. Those uses include district heating systems; space heating and cooling; thermal baths at spas; and geothermal greenhouses and food-drying facilities; and extraction of chemicals and minerals from geothermal fluids (figure 1). Geothermal fluids with temperatures higher than 100°C can be put to direct use, but, depending on the market conditions, it may be more economical to use them to produce electricity. When demonstrating the feasibility of a geothermal project involving direct use, a market analysis should be done to evaluate the domestic and export markets for the planned products.

Located in a tectonically active zone, Türkiye has more than 400 known geothermal fields in 63 different provinces (MTA 2019). Low-temperature resources with temperatures ranging from 20°C to 120°C are widespread. The country's total estimated geothermal potential is more than 60,000 megawatts thermal (MWt) (Şener et al. 2022). Of that, the potential for direct applications is approximately 15,000 MWt; the potential for electricity generation is 4,500 megawatts electric (MWe), assuming a 10 percent conversion factor. The higher-temperature resources are concentrated at the country's western and eastern ends.

1. On June 1, 2022, the United Nations accepted the Turkish government's position that Turkey should henceforth be known as Türkiye.

Oumaima Idrissi is an intern at the World Bank.

Almudena Mateos Merino is a senior energy specialist at the World Bank.

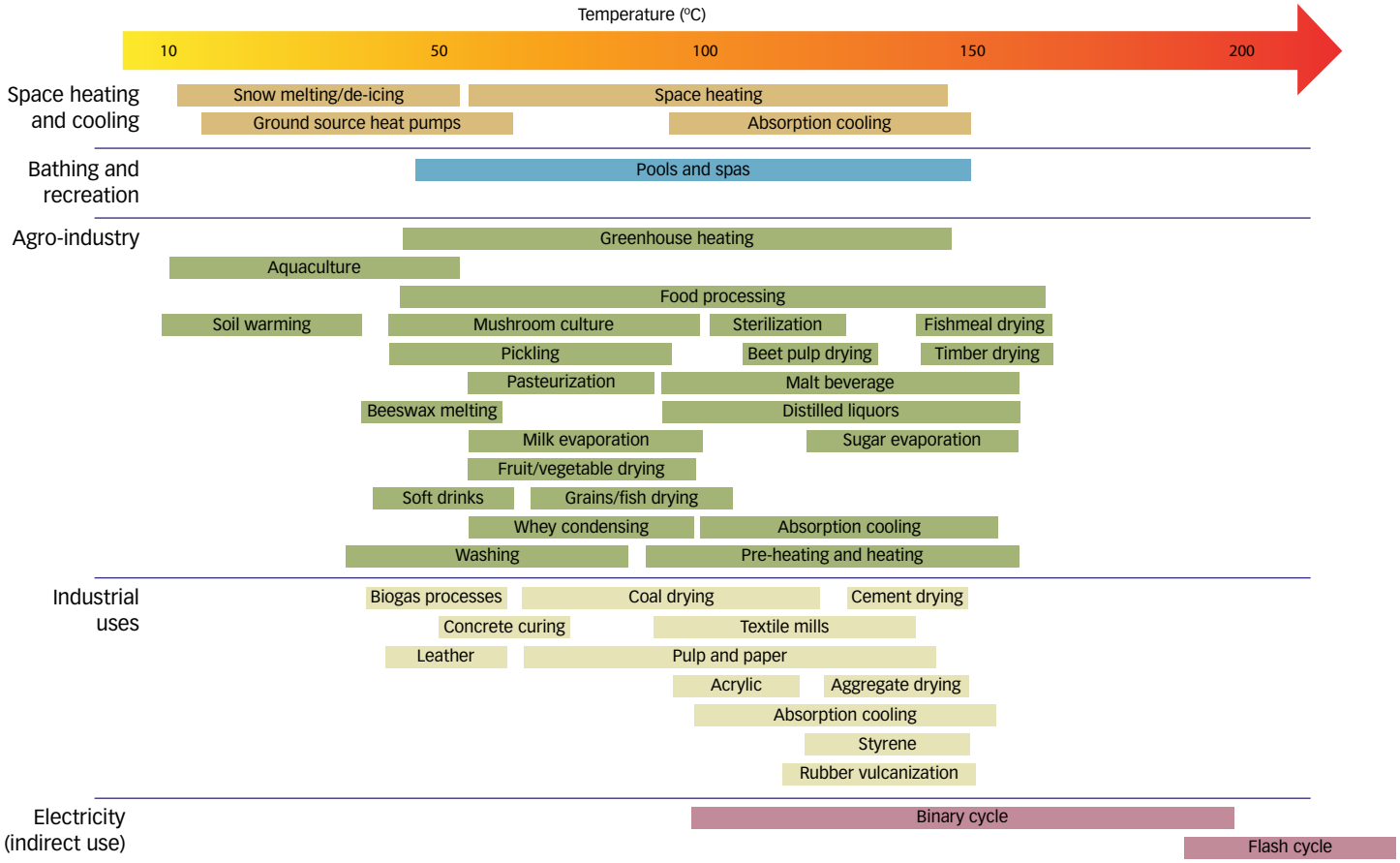
Alper Baba is a professor at the Izmir Institute of Technology.

Elin Hallgrimsdottir is a senior energy specialist at the World Bank.

A. Yasemin Orucu is a senior energy specialist at the World Bank.

Geothermal electricity generation in Türkiye has grown rapidly in the last decade, from 30 MWe in 2008 to 1,665 MWe by the end of 2021, an average annual increase of almost 40 percent. The increase in direct uses has been much slower, from 2,886 MWt in 2015 to 5,113 MWt in 2022.

Figure 1. Examples of direct uses of geothermal energy



Source: ESMAP 2022.

How does Türkiye compare with other countries in direct use of geothermal energy?

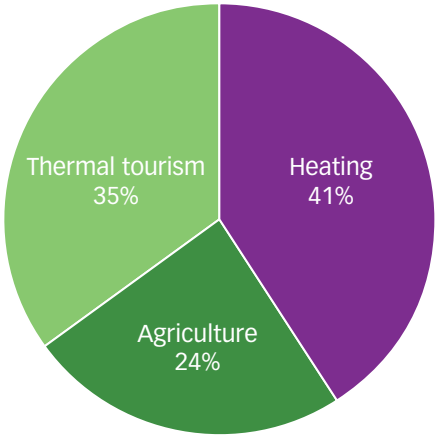
Türkiye is among the global leaders in direct uses

In 2019, the installed capacity for direct use of geothermal energy in 88 countries was 108 GWt, an increase of 52 percent since 2015 (Lund and Toth 2020). Driving the increase was the widespread installation of ground source heat pumps. China, not known for high-temperature geothermal resources, accounts for about 41 percent of the total installed capacity. Türkiye is in fifth place with 3 percent. Others in the top ranks are the United States (21 percent), Sweden (7 percent), Germany (5 percent), France (3 percent), Japan (3 percent), and Iceland (2 percent).

Geothermal electricity generation in Türkiye has grown rapidly in the last decade, from 30 MWe in 2008 to 1,665 MWe by the end of 2021, an average annual increase of almost 40 percent. The increase in direct uses has been much slower, from 2,886 MWt in 2015 to 5,113 MWt in 2022, an average annual increase of 11 percent (Şener et al. 2022). The major uses of that capacity were heating (district heating systems, individual homes, thermal space heating), at

Figure 2. Direct uses of geothermal energy in Türkiye in 2022

Total installed capacity: 5,113 MWt



Source: Adapted from Şener et al. (2022).

Türkiye has a wide network of thermal baths and hot springs, including 520 geothermal spas that receive about 23 million visitors annually, consume the production of 1,763 MWt of installed geothermal capacity, and generate approximately $3 billion in revenues.

41 percent; thermal tourism (bathing, swimming, spas), at 35 percent; and agriculture, at 24 percent (figure 2). Each of these major uses, as well as nascent industrial applications, is described briefly below. The information is drawn largely from Şener et al. (2022).

Heating—including district heating, residential heating, hotels, and ground source heat pumps—accounts for 2,110 MWt of Türkiye's installed geothermal capacity. District heating alone accounts for 1,422 MWt. Currently 18 district heating systems are in operation in 17 cities, some using water as cool as 40–45°C to serve the equivalent of 156,744 residences. Approximately 680 MWt is used to heat hotels and other spaces equivalent to 48,600 single-family residences. Given the cold winters in some parts of Türkiye, geothermal energy could play an important role in decarbonizing the heating sector. Ground source heat pumps can provide both heating and cooling, but their use in Türkiye is still limited (8.5 MWt in 2022).

Absorption cooling systems are another option, although only one such system is present in use in Türkiye: Balçova's (İzmir) 45 kW cooling unit, which is part of the city's geothermal district heating system. The cooling system was commissioned in 2018 to cool 1,900 m^2 of indoor area by absorption of lithium bromide and utilization of geothermal resources having a 90°C inlet temperature and 85°C outlet temperature. The result is a 6°C inlet cooling temperature for the coolers in the buildings, which return to the system at 9°C.

In 2020 Balçova's installed geothermal heating capacity was 250 MWt. The system can provide heat to 50,500 residences. By 2022, 76 percent of the installed capacity was being used, providing heat for 38,460 residences. Through the use of geothermal energy for heating and cooling, emissions of approximately 77,106 metric tons of CO_2 are prevented annually, compared with the use of natural gas.

Thermal tourism. Türkiye has a wide network of thermal baths and hot springs, including 520 geothermal spas that receive about 23 million visitors annually, consume the production of 1,763 MWt of installed geothermal capacity, and generate approximately $3 billion in revenues (figure 3a).

The Kozaklı district of Nevsehir province is the most famous location for geothermal health facilities in Türkiye. It also has the most thermal tourism facilities, which provide an important source of income and employment for the district. Nevsehir province is the largest single component of the Konya Plain Project region, containing 19 of the 50 thermal tourism and health facilities in the KOP region (Çarıkcı et al. 2021). Together these facilities can sleep 7,947 people in 3,243 rooms.

Agriculture and agribusiness. Greenhouses (1,230 MWt) and food drying facilities (9.5 MWt) account for nearly all of the 1,240 MWt of installed capacity dedicated to agriculture and agribusiness in Türkiye (figure 3b). In 2020 Türkiye's greenhouses covered 79,000 hectares, of which only 450 hectares were heated with geothermal energy, suggesting a vast potential for expansion (HortiDaily 2019). Three food-drying facilities presently use geothermal energy: Sandıklı (Afyon), Seferihisar (İzmir), and Karakurt (Kırşehir).

The Sultan Greenhouse in Aydın-Salavatlı is an example of a cascaded system, as the greenhouse uses geothermal fluid from the Dora-2 geothermal power plant before the fluid is reinjected.[2] The fluid is supplied to the facility at about 80°C and used to heat 4.2 hectares of greenhouse with a heating capacity of 16 MWt. The

2. Cascaded utilization is a way to implement multiple direct use applications, and often indirect applications by employing a central geothermal source in a cascade sequence.

Given the cold winters in some parts of Türkiye, geothermal energy could play an important role in decarbonizing the heating sector. Ground source heat pumps can provide both heating and cooling, but their use in Türkiye is still limited.

Figure 3. Three applications of geothermal energy

a. Thermal facilities at Kestanbol hot springs

b. Greenhouse in Dikili geothermal field

c. Linde gas production facility in Denizli

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greenhouse also uses CO_2 from the power plant to enrich the soil. Thirty-six of the 40 employees are women (Business News 2018).

The Kırşehir geothermal vegetable and fruit drying facility was established in 2012 in the town of Karakurt, with the cooperation of the Kırşehir Municipality and Provincial Special Administration. In an indoor area of 200 m^2, the facility's six employees dry approximately 39 metric tons of produce per month—eleven types of fruit and two types of vegetables. The thermal energy required is obtained from the Karakurt 1 (K1) well, which is 147 meters deep and has a flow rate of 12 liters per second at a temperature of 52°C (Boyaci, Boyaci, and Gürdal 2018).

Industrial applications. In their first years of operation, Türkiye's geothermal power plants emit considerable amounts of CO_2. Emissions drop considerably with use, often resulting in a need to install pumps to extract the fluid (Idrissi et al. 2021). The CO_2 released from the plants can be utilized in methanol production (Carbon Recycling International n.d.) or in the food industry, as described below.

One of the leading providers of industrial and medical gases in Türkiye is Linde Gas, based in Germany. The company has a cascade facility in Denizli with a daily capacity of 240 metric tons of gas (figure 3c). The plant uses the CO_2 released during operation of the Zorlu Energy geothermal power plants. The gases are purified, liquefied, then stored in specialized vessels for used on demand in liquid or gaseous form. Linde is also building pipelines to supply CO_2 for the geothermal agricultural industrial area of Sarayköy. Through pipelines, the CO_2 will be pumped to greenhouses in the industrial area to increase production. Liquid CO_2 is used in greenhouses and in carbonated beverages.

Industrial applications of geothermal energy, though still in a nascent stage, have received increased global attention in recent years, including in Türkiye. Mineral extraction from geothermal fluids is today used in food supplements (e.g., GeoSilica Iceland n.d.), algae production in Türkiye (Richter 2017), cosmetics (Blue Lagoon Iceland n.d.), or extraction of lithium (Cantù 2021).

Is there interest in further development of geothermal energy in Türkiye?

Interest in geothermal is strong—but obstacles must be overcome

Potential community benefits of direct use projects include increased demand for local resources, low emissions of greenhouse gases, creation of local employment, greater energy independence, opportunities for women's employment, and increased food security.

For this Live Wire, the World Bank and a consulting firm surveyed Turkish developers and other stakeholders in direct uses of geothermal energy to understand their views of the benefits of direct uses and the obstacles to realizing those benefits. The survey consisted of questionnaires and interviews touching on investment interests, market and workforce challenges, and management of gender equality.

The survey revealed deep interest in developing and exploiting geothermal resources for direct uses, both as stand-alone projects and in connection with power generation (so-called cascaded utilization). Interest is expected to increase, especially in district heating, agriculture, and thermal tourism, following the implementation of pending energy legislation that is expected to establish a framework for ownership and extraction of heat resources.

The stakeholders identified several potential community benefits of direct use projects, apart from financial gains. These include increased demand for local resources, low emissions of greenhouse gases, creation of local employment, greater energy independence, opportunities for women's employment, and increased food security.

Many of these benefits will materialize automatically as local resources are developed. However, even though Türkiye has a well-developed geothermal sector, there is ample room for improvement in gender equality, and advancing equality will need specific attention. An assessment of gender gaps in the Turkish geothermal sector carried out by the World Bank (2021) revealed that geothermal companies in the country employ few licensed female engineers. More than half of the companies surveyed employed none. In addition, almost half of the surveyed companies have no female managers. The dearth of gender disaggregated data makes it difficult to analyze gender inequality in terms other than employment numbers. Assuming that the technical potential of direct uses is fully developed with the current balance of applications, it is estimated that more than 120,000 direct jobs, both skilled and unskilled, could be created, generating ample opportunities for women's participation.

But even where a suitable geothermal resource is available, the viability of projects depends on the existence of an adequate enabling environment. The key challenges identified in the survey of Turkish developers were as follows:

- Limited access to finance and grants
- Inadequate price and incentives
- An unsupportive legal framework
- Limited willingness of local authorities to participate in projects
- Cumbersome licensing procedures
- Drawn out permitting procedures (environmental and social).

Addressing some of these challenges will require government leadership to ensure that a strong legal and regulatory framework is in place to govern permitting, land planning, and industrial and rural development. Responsibility for surmounting other challenges will fall to developers or require joint efforts. Environmental and social assessments constitute a good example of joint responsibility between government and developers. Developer-specific challenges often stem from the particular circumstances of a given direct use project. Those circumstances may pose idiosyncratic questions of permitting and licensing, as well as particular financial, technical, environmental, and social challenges that must be managed.

In some regions of Türkiye geothermal power plants are viewed negatively by the local communities. However, the survey showed that views improve as people become more familiar with the multiple uses of geothermal. This process of improvement was observed in the communities surrounding the thermal baths at Pamukkale (in Denizli province). However, in regions where geothermal energy was used solely for electrical generation, communities viewed projects more negatively—and those views were more resistant to change.

All stakeholders agreed that one of the main challenges they faced was access to financing. If the current estimated direct use potential were to be fully developed by 2050, an estimated annual investment of about USD 445 million would be required. The total investment over a 30-year period would therefore amount to approximately USD 14 billion (or USD 700 per MWt).

What is the Turkish government doing to scale up the direct use of geothermal energy?

The government is engaged in multiple projects to exploit the country's geothermal potential

Türkiye ratified the Paris Agreement on Climate Change in October 2021 and followed by announcing a target of net-zero emissions by 2053. Further development of renewable energy, including geothermal (both for electricity and heat), will be essential to meet this ambitious target.

Türkiye ratified the Paris Agreement on Climate Change in October 2021 and followed by announcing a target of net-zero emissions by 2053. Further development of renewable energy, including geothermal (both for electricity and heat), will be essential to meet this ambitious target. The Ministry of Agriculture and Forestry is supporting the use of geothermal heat for greenhouses. In 2020, the Ministry established Türkiye's first geothermally heated Agricultural Organized Industrial Zone (OIZ) in Dikili, İzmir; in February 2022 it approved a grant for the previously established Kadıköy Specialized OIZ project, which envisages the use of geothermal energy in greenhouses in Aydın.

The Turkish government has provided various incentives for investments in agricultural activities, including the machinery and equipment components of greenhouses and drying units. For example, Ziraat Bank, a state-owned bank tasked to support the agriculture sector, provides subsidized loans for greenhouse investments at below-market interest rates. If a greenhouse uses geothermal energy, even lower interest rates are available. Women or young investors can receive additional subsidies. The government is also working on a law to promote the development of direct use, especially in greenhouses and district heating.

The World Bank is supporting the Turkish government's efforts to scale up geothermal through the Geothermal Development Project and the recently approved Climate Smart and Competitive Agricultural Growth Project (TUCSAP). The original Geothermal Development Project, approved in 2016, included two credit lines totaling USD 250 million for the Development and Investment Bank of Türkiye (TKYB) and the Industrial Development Bank of Türkiye (TSKB). The credit lines were to be used to support capacity-related drilling and construction of geothermal facilities, both for power generation and direct use applications. The USD 300 million in additional financing approved in December 2021 goes a step further in addressing the limited availability of financing for direct use projects by earmarking a minimum of 10 percent of the loan for such projects. The additional financing instrument is also accompanied by a grant from the Energy Sector Management Assistance Program to support the preparation of prefeasibility reports, business plans, market analyses, and feasibility reports for direct use projects.

The Geothermal Development Project also includes an innovative risk-sharing mechanism financed by a USD 39.8 million grant from the Clean Technology Fund. The objective of the risk-sharing mechanism is to increase private sector investment in geothermal exploration in Türkiye by providing partial coverage of drilling costs in case of unsuccessful wells, both for electricity generation and direct use projects. Several applicants to the second round have requested support for heat and hybrid (power and heat) projects.

The TUCSAP project, approved by World Bank's board of directors in March 2022, will help the Ministry of Agriculture and Forestry expand the use of geothermal energy in clustered greenhouse production. Through a USD 30 million investment, the project will support pilot investments by one or two special agribusiness zones (TDİOSB in the Turkish acronym) to build basic enabling infrastructure for greenhouse production, including geothermal heating power and related basic infrastructure (electricity, water, etc.). These moves are designed to facilitate subsequent investments by private operators. Project funds will be provided to TDİOSB as loans.

These engagements demonstrate that the Turkish government is supporting the scaling up of direct uses of geothermal energy. An ambitious goal of 11,150 MWt by 2025 has been set (Mertoglu, Simsek, and Basarir 2021). Meeting that goal will require raising awareness, building capacity, ensuring a favorable regulatory environment, and increasing access to funding for both public and private entities.

This Live Wire was peer reviewed by Luz Berania Diaz Rios, Megan Meyer, and Joeri Frederik de Wit.

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