# Geothermal Energy Use, Country Update for Turkey

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## ABSTRACT

Geothermal utilization in Turkey can be represented by a remarkable increase especially in electricity production and direct use applications. As major applications; Turkey currently has 55 geothermal power plants and 17 geothermal city heatings.

About 450 geothermal fields have been discovered (mainly by MTA (General Directorate of Mineral Research and Exploration) and private sector) in Turkey. Geothermal direct-use applications have reached 3487 MWt geothermal heating including district heating (1033 MWt), 4,3 million $m^2$ greenhouse heating (820 MWt), thermal facilities, hotels etc. heating 420 MWt, balneological use (1205 MWt), agricultural drying (1,5 MWt), geothermal cooling (0,1 MWe), (HP) heat pump (109 MWt) and ground source heat pump applications (7,6 MWt). Geothermal electricity installed capacity reached up 1282,5 MWe as at the end of 2018 (TEİAŞ 2019). Liquid carbon dioxide and dry ice production has reached factories are integrated to the Kizildere and Salavatli geothermal power plants. The issued geothermal law and incentives contributed to the increase in geothermal electricity production investments within Turkish private sector.

The total hydrothermal possible theoretical geothermal heat potential is 60.000 MWt according to heat flow maps, measured well depth temperatures and calculations made for 4 km depth. Turkey's total geothermal electricity production technical potential (hydrothermal, 0-4 km) can be estimated as 4500 MWe (36 billion kWh/year) with existing 10,5 USDcent/kWh incentive and 10 years purchase guarantee. The technical and economical EGS geothermal electricity production potantial has been projected as 20.000 MWe if the 15 USDcent/kWh incentive with minimum 15 year purchase guarantee would be possible.

## 1. INTRODUCTION

As Turkey is located on the Alpine-Himalayan orogenic belt and due to suitable geological conditions, Turkey has a high geothermal potential. The first geothermal researches and investigations in Turkey started by MTA (General Directorate of Mineral Research and Exploration) in 1960's.

Turkey has achieved important geothermal developments in last 5 years. Table 1 shows the geothermal utilization capacities as of February 2019.

Today 17 cities are heated partly with geothermal in Turkey. These geothermal district heating systems have been constructed since 1987 and many developments have been achieved in technical and economical aspects.

The first geothermal cooling application has been realized in Izmir - Balcova by Izmir Jeotermal Inc. In 2018, for cooling of 1900 $m^2$ indoor area by lithium bromide absorbtion and 90/85°C geothermal temperature regime by supplying 6/9 °C clean cold water to the coolers in the buildings.

The 2025 target of Turkey about geothermal direct use including mainly geothermal heating like district heating, greenhouse heating, thermal facilities heating and cooling and balneological use has been estimated as 7000 MWt.

About 12 % of Turkey's geothermal potential is utilized so far in direct use and electricity production in Turkey.

## 1. HIGH TEMPERATURE APPLICATIONS

As of February 2019, there exist 55 operating geothermal power plants at 26 geothermal fields in Turkey which have a total installed capacity of 1282.5 MWe (Table A and Table B). A detailed list of the existing geothermal power plants is shown in Table B.

**Table 1: Geothermal Utilization Capacities in Turkey**

| UTILIZATION | CAPACITY |
|---|---|
| GEOTHERMAL DISTRICT HEATING (CITY, RESIDENCES) | 116.000 RESIDENCES EQUIVALENCE (1033 MWt) |
| GREENHOUSE HEATING | 4,3 Million $m^2$ (820 MWt) |
| HEATING OF THERMAL FACILITIES, SPAS, THERMAL HOTELS AND TIME SHARE FACILITIES | 46.400 residences equivalence (420 MWt) |
| HEAT ENERGY OF THERMAL WATER USE IN HOTELS, SPAS AND AND TIME SHARE FACILITIES | 450 GEOTHERMAL SPA (1205 MWt) (20 Million guests/annual) |
| AGRICULTURAL DRYING | 1,5 MWt |
| GEOTHERMAL COOLING | 0.1 MWe (0,35 MWt) |
| HEAT PUMPS; GSHP | 109 MWt; 7,6 MWt |
| **TOTAL HEAT USE** | **~3487 MWt (336.000 Residences Equivalence)** |
| **TOTAL ELECTRICTY PRODUCTION** | **1282,5 MWe** (Aydın-Germencik, Denizli-Sarayköy, Manisa-Alaşehir, Manisa-Salihli, Aydın Salavatlı, Aydın-Hıdırbeyli, Çanakkale-Tuzla vd.) |
| CARBONDIOXITE PRODUCTION (Food grade Liquid $CO_2$) | 400.000 Tons/year |

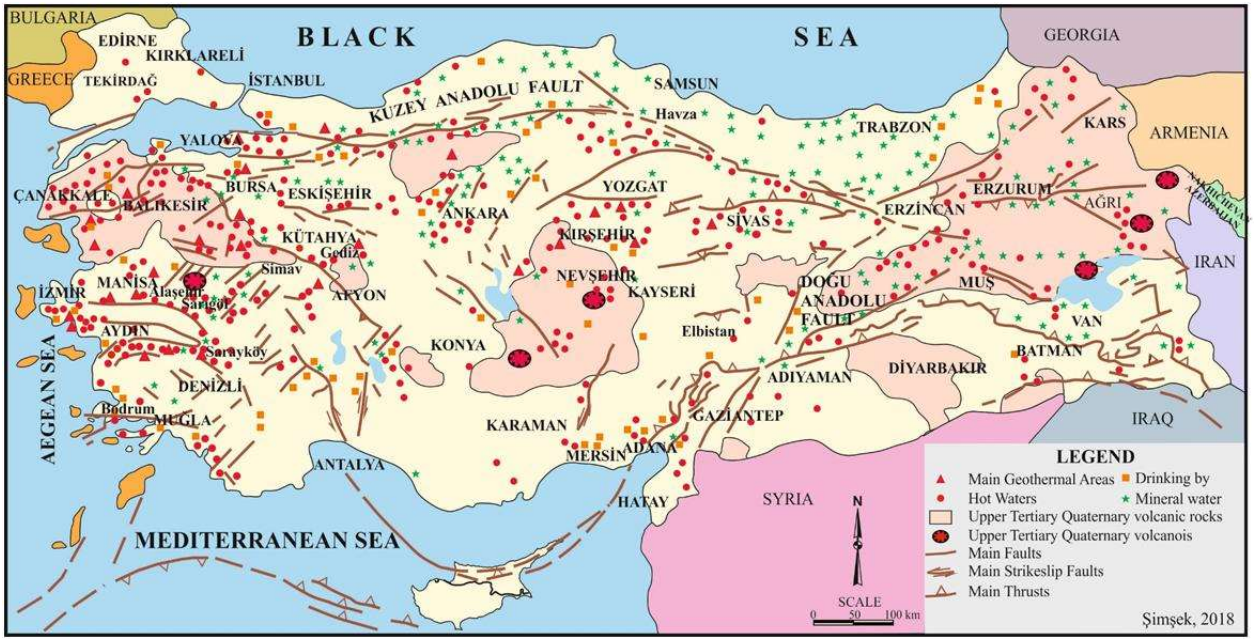


**Figure 1: Distribution of geothermal resources and the active faults of Turkey (Simsek, 2018)**

### 2.1. Deep reservoir explorations

Deep reservoir explorations are going on for electricity production purposes. For his reason deep drilling targets have reached up to 4500m. The successful results have been obtained and deep marble reservoirs discovered (about 240°C) at Kizildere and Tekkehamam geothermal fields (Simsek, 2017).

The increase of directional drillings and coil tubing operation applications are other important environmental and economic developments for the geothermal fields in Turkey.

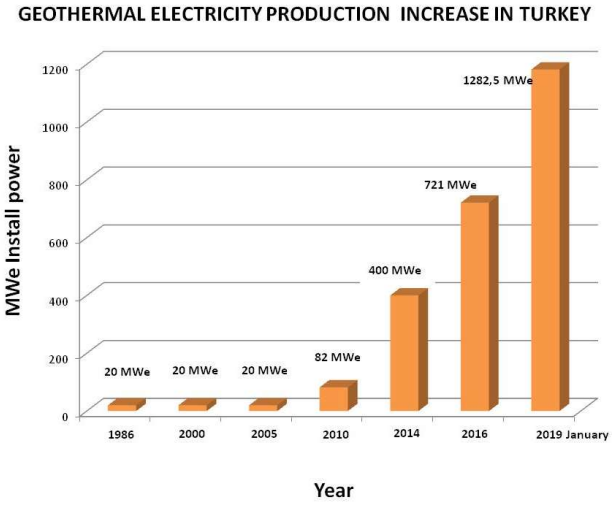


**Figure 2: Geothermal electricity production increase in Turkey (Mertoglu and Basarir, 2018)**

## 3. LOW TEMPERATURE APPLICATIONS

Today, as low as 40-45°C temperature geothermal waters are also used for space heating in Turkey without heat pumps.

The operational capacities of the city based geothermal district heating systems (GHDS) existing in Turkey are as follows: Gönen (Commissioned: 1987, 3,400 residences), Simav (1991, 14,500 residences), Kirsehir (1994, 1,900 residences), Kizilcahamam (1995, 2,500 residences), Izmir (1996, 37,000 residences), Sandikli (1998, 11,000 residences), Afyon (1996, 10,000 residences), Kozakli (1996, 3,000 residences), Diyadin (1999, 570 residences), Salihli (2002, 7,500 residences), Edremit (2003, 5,500 residences), Balikesir-Bigadic (2005, 1,500 residences), Yozgat-Sorgun (2008, 1,500 residences), Izmir-Bergama (450 residences), Izmir- Dikili (2000 residences), Denizli-Saraykoy (2,200 residences) and Balikesir-Sindirgi (2014, 300/3000 residences).

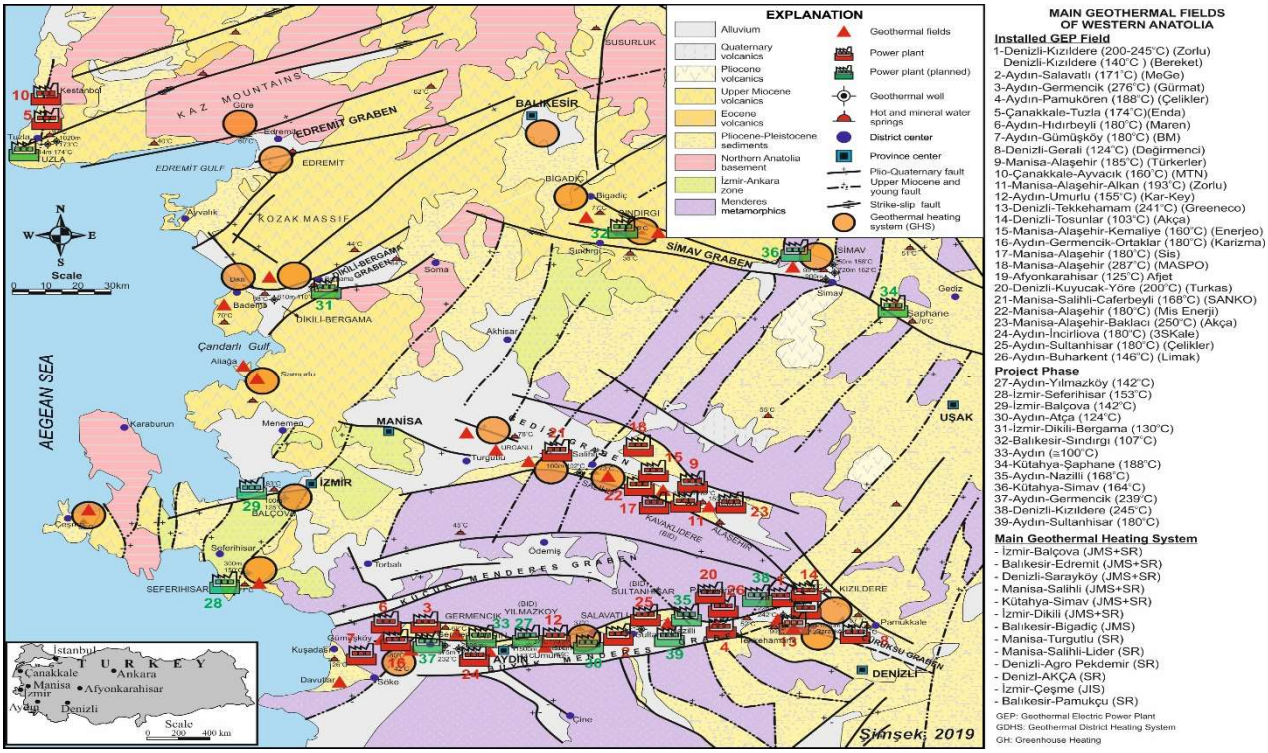


**Figure 3: Main geothermal fields of Western Anatolia (Simsek, 2019)**

Some of the existing cities heating have increased their heating capacities as it can be seen in Table D1. Geothermal greenhouse heating applications has reached 4.3 million $m^2$ during last five years.

### 3.1. Current Status on Heat Pump Applications in Turkey

Ground source heat pump (GSHP) applications in Turkey started in 2000's for residential single family houses with a total installed capacity of 586 kWt. Today, with increasing interest in renewables number of HP systems has reached to 146 with a total installed capacity of 109 MWt. Open systems using sea, lake and groundwater correspond to about 91% of total installed capacity 55% of the open systems use sea water as their source. Closed systems consist of vertical, horizontal and energy piles applications. 89 of the GSHP applications are closed systems with installed capacity of 7.6 MWt. Figure 4 shows distribution of types of GSHP systems in 2018. In recent years, as a new source waste heat from baneological use is recovered. There are 3 applications so far that corresponds to 4% of installed capacity.

Figure 5 shows tjhe distribution of GSHP applications according to type of applications. The most common application is still for single family houses with a share of 51%, but their installed capacity is only 3 MWt.

Hotel GSHP system having 45 units correspond to 65% of total installed capacity.

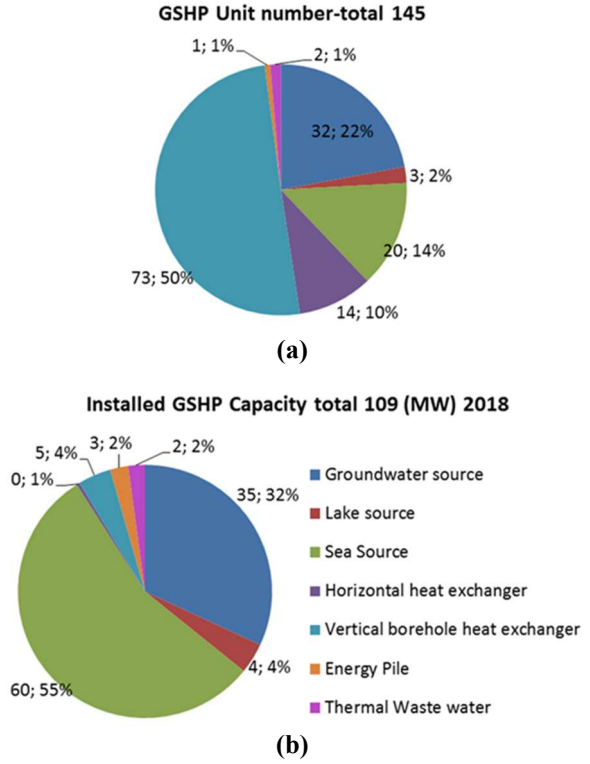


**Figure 4. Distribution of types of GSHP systems according to a) number of systems b) system capacities in 2018.**

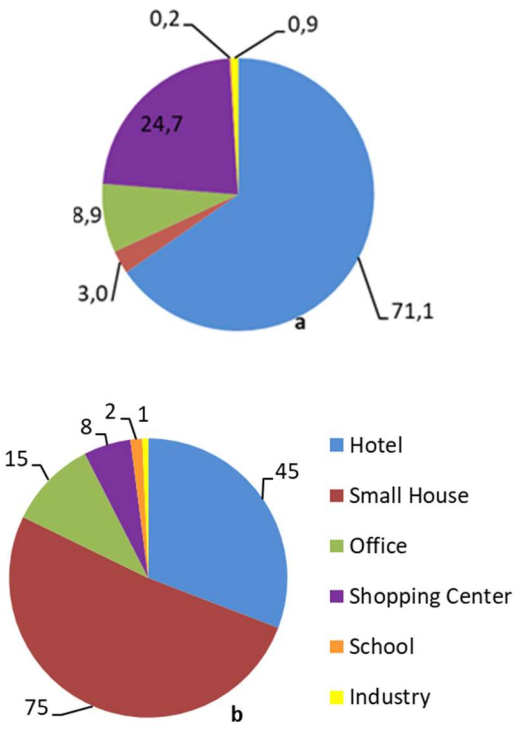


**Figure 5. Distribution of GSHP applications according to type of applications a) installed capacity and b) number of systems**

## 4. $CO_2$ EMISSION

It is known that the $CO_2$ in the geothermal fields in Turkey, are formed mostly by the marble and carbonated reservoir rocks due to the effect of the water and heat. $CO_2$ is emitting naturaly towards the atmosphere at ground surface from the reservoir. It is a natural discharge of $CO_2$ and is independent to the existence of geothermal power plants. For this reason 50-70 % decreament in the $CO_2$ amount in 11 years in the geothermal fields in Turkey has been obtained. The decreament continues.

The reasons of the decline of $CO_2$ in the geothermal fields can be explained as the following:

1) Very low $CO_2$ amount in the reinjected water, reinjection is compulsory because of maintenance of the reservoir and protect the environment.
2) The natural recharge of the geothermal reservoir is composed mostly from meteoric water.
3) Geothermal fluid production amount is over the natural recharge amount.

As a natural result of $CO_2$ decrease in the geothermal fields; The downhole pump usage in the geothermal fields will be increased. Existing $CO_2$ in the geothermal fluid is the advantage for the artesianic well flow but it is a disadvantage for the power plant (binary) electricity generation.

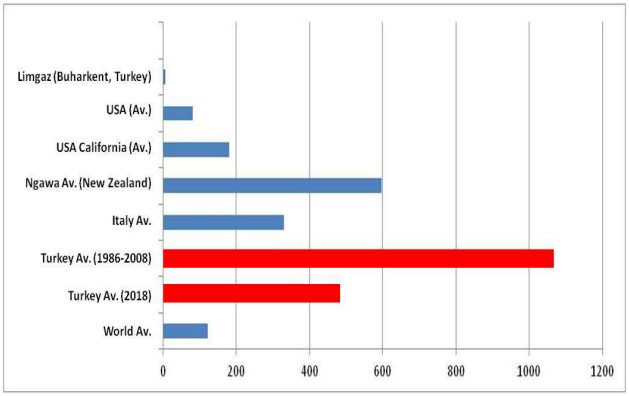


**Figure 6: Comparison of $CO_2$ emissions (Mertoglu and Basarir, 2018)**

As the result of oral communication with many geothermal power plant operators in Turkey, this decrease in $CO_2$ in geothermal reservoirs has been recognised.

The 1282.5 MWe geothermal electricity production install capacity is composed of

- about **882.5 MWe binary cycle** geothermal power plants, ORC and air cooled condenser (about 20% house consumption).

- about **400 MWe flash steam** geothermal power plant. Double flash, triple flash and integrated with the binary cycle plants, water cooled condenser (10-20% house consumption) power plants are running technical and economical feasible conditions in Turkey.

## 5. GEOTHERMAL POTENTIAL OF TURKEY

### 5.1. Geothermal Potential of Hydrothermal Systems

The total geothermal theoretical heat potential of Turkey (hydrothermal 0–3 km) has been calculated by Turkish Geothermal Association as 60'000 MWt.

The total geothermal electricity technical potential of Turkey (hydrothermal) (0–3 km) is 4500 MWe.

The 2025 target of Turkey is 2600 MWe with incentive (10.5 US $ cent/kwh feed in tariff, durations of the FIT effectiveness in 10 years).

### 5.2. EGS Potential and Projections

We estimated the EGS-Enhanced Geothermal System Electricity Production Technical Potential of Turkey (3–5 km) as 400'000 MWe.

The EGS-Enhanced Geothermal System target of Turkey (3-5 km) is 20'000 MWe. This production potential expected to be realized with the feed in tariff of 15 US $ cent/kWh for 15 years purchase guarantee.

287 °C has been measured at 2750 m depth at Manisa-Alasehir geothermal field.

High temperature geothermal field (295°C) depth as about 3000 m's discovered at Nigde province in Cental Anatolia.

## 6. CONCLUSIONS

About 450 geothermal fields have been discovered in Turkey. Rapid development at geothermal electricity installed capacity reached up 1282.5 MWe as of February 2019. The capacity has increased twice since 2016.

Geothermal direct-use applications have reached 3487 MWt geothermal heating including district heating (1033 MWt), 4,3 million $m^2$ greenhouse heating (820 MWt), thermal facilities, hotels etc heating 420 MWt, balneological use (1205 MWt), agricultural drying (1.5 MWt), geothermal cooling (0,1 MWe) and total heat pump applications (109 MWt). Geothermal electricity installed capacity reached up 1282.5 MWe as at the end of 2018 (TEİAŞ 2019). Deep reservoir explorations are going on for electricity production purposes. For this reason deep drilling targets have reached up to 4500m. The successful results have been obtained exploration of deep reservoirs.

The increase of directional drillings and coil tubing operation applications are other important environmental and economic developments for the geothermal fields in Turkey.

The EGS-Enhanced Geothermal System target of Turkey (3-5 km) is 20'000 MWe. This production potential expected to be realized during the next 20 years period.

As natural result of $CO_2$ decrease in the geothermal fields; The downhole pump usage in the geothermal fields will be increased in coming years.

Heat pump (HP) applications in Turkey started in 2000's and with increasing interest in renewables number of HP systems has reached to 146 with a total installed capacity of 109 MWt in 2018.

The 2025 target of Turkey about geothermal direct use has been estimated as 7000 MWt.

## ACKNOWLEDGEMENT

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**Tables A-G**

**Table A: Present and planned geothermal power plants, total numbers**

| | Geothermal Power Plants | | Total Electric Power in the country | | Share of geothermal in total electric power generation | |
|---|---|---|---|---|---|---|
| | Capacity ($MW_e$) | Production ($GWh_e$/yr) | Capacity ($MW_e$) | Production ($GWh_e$/yr) | Capacity (%) | Production (%) |
| In operation February 2019 | 1282,5 | 6763,15 | 87.139 | | 1,3 | |
| Under construction end of 2018 | 125 | 1013,85 | | | | |
| Total projected by 2020 | 584 | 4736,70 | | | | |
| Total expected by 2025 | 2658 | 21558,5 | | | | |
| In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2018 (indicate exploration/exploitation if applicable): | | | | | Under development:19 | |
| | | | | | Under investigation:6 | |

**Table B: Existing geothermal power plants, individual sites**

| Locality | Plant Name | Year commis sioned | No of units | Status | Type | Total capacity installed ($MW_e$) | Total capacity running ($MW_e$) | 2018 pro-duction ($GWh_e$/y) |
|---|---|---|---|---|---|---|---|---|
| Denizli (Zorlu) | Kizildere 3 | | 1 | O | 2F | 165 | | |
| Aydin (Guris) | Efeler | 2009-2018 | 5+1 | O | B+2F | 162.5 | | |
| Denizli (Zorlu) | Kizildere 2 | | 1 | O | B+2F | 80 | | |
| Aydin (Celikler) | Pamukoren | 2015 | 3 | O | B | 68 | | |
| Aydin (Guris) | Galip Hoca Germencik | 2009 | 1 | O | 2F | 47.4 | | |
| Manisa (Zorlu) | Alasehir | 2015 | 1 | O | B | 45 | | |
| Aydin (Kipas) | Maren | | 1 | O | B | 44 | | |
| Aydin (MB) | Dora 3 | 2013 | 1 | O | B | 34 | | |
| Aydin (Kipas) | Melih | | 1 | O | B | 33 | | |
| Denizli (Greeneco) | Greeneco | 2016-2018 | 4 | O | B | 51.2 | | |

**Table B (continued): Existing geothermal power plants, individual sites**

| Locality | Plant Name | Year commissioned | No of units | Status | Type | Total capacity installed ($MW_e$) | Total capacity running ($MW_e$) | 2018 production ($GWh_e/y$) |
|---|---|---|---|---|---|---|---|---|
| Manisa (Enerjeo) | Kemaliye | 2016 | 1 | O | B | 25 | | |
| Aydin (Kipas) | Mehmethan | | 1 | O | B | 25 | | |
| Aydin (Kipas) | Deniz | | 1 | O | B | 24 | | |
| Aydin (Kipas) | Ken Kipas | | 1 | O | B | 24 | | |
| Aydin (Kipas) | Kerem | | 1 | O | B | 24 | | |
| Aydin (Cevik) | Kubilay | | 1 | O | B | 24 | | |
| Manisa (Turkerler) | Alasehir - 1 | 2014 | 1 | O | B | 24 | | |
| Manisa (Turkerler) | Alasehir - 2 | | 1 | O | B | 24 | | |
| Manisa (Turkerler) | Alasehir - 3 | | 1 | O | B | 30 | | |
| Manisa (Ozmen-Sis) | Ozmen 1 | | 1 | O | B | 24+12 Under construction | | |
| Manisa Akça | Baklacı | 2018 | 1 | O | B | 19.4 | | |
| Aydin (Celikler) | Pamukoren 2 | | 1 | O | B | 23 | | |
| Aydin (Celikler) | Pamukoren 3 | | 1 | O | B | 23 | | |
| Aydin (Celikler) | Pamukoren 4 | | 1 | O | B | 32 | | |
| Aydin (Turcas) | Kuyucak | 2018 | 1 | O | B | 18 | | |
| Aydin (MB) | Dora 4 | | 1 | O | B | 17 | | |
| Denizli (Zorlu) | Kizildere | 1984 | 1 | N | 1F | 15 | | |
| Manisa (Sanko) | Sanko | 2018 | 1 | O | B | 15 | | |
| Aydin (Celikler) | Sultanhisar | 2018 | 1 | O | B | 14 | | |
| Aydin (BM) | Gumuskoy | 2014 | 2 | O | B | 13 | | |
| Aydin (Karadeniz) | Karkey Umurlu | 2016 | 1 | O | B | 12 | | |
| Aydin (Karadeniz) | Karkey Umurlu-2 | 2018 | 1 | O | B | 12 | | |

**Table B (continued): Existing geothermal power plants, individual sites**

| Locality | Plant Name | Year commissioned | No of units | Status | Type | Total capacity installed ($MW_e$) | Total capacity running ($MW_e$) | 2018 production ($GWh_e/y$) |
|---|---|---|---|---|---|---|---|---|
| Manisa (Maspo) | ALA-1 | 2018 | 1 | O | B | 10 | | |
| Aydin (Kipas) | Ken-3 | | 1 | O | B | 24.8 | | |
| Aydin (MB) | Dora-2 | | 1 | O | B | 9.5 | | |
| Canakkale (MTN) | Babadere | 2016 | 1 | O | B | 8 | | |
| Aydin (MB) | Dora-1 | 2006 | 1 | O | B | 7.95 | | |
| Canakkale (Enda) | Tuzla | 2010 | 1 | O | B | 7.5 | | |
| Denizli (Bereket) | Kizildere | 2007 | 1 | N | B | 6.85 | | |
| Denizli (Akca) | Tosunlar | 2015 | 1 | O | B | 3.81 | | |
| Afyonkarahisar (Afjet) | Afjet | 2018 | 1 | O | B | 2.76 | | |
| Aydin (3S Kale) | 3S Kale | 2018 | 1 | O | B | 25 | | |
| Denizli (Limgaz) | Buharkent | 2018 | 1 | O | B | 13.8 | | |
| Denizli (Jeoden) | Saraykoy | 2014 | 1 | N | B | 2.52 | | |
| **Total** | | | | | | **1282.5** | | |

| Key for status: | | Key for type: | | | |
|---|---|---|---|---|---|
| O | Operating | D | Dry Steam | B-ORC | Binary (ORC) |
| N | Not operating (temporarily) | 1F | Single Flash | B-Kal | Binary (Kalina) |
| | | 2F | Double Flash | O | Other |
| R | Retired | | | | |

**Table C: Present and planned deep geothermal district heating (DH) plants and other uses for heating and cooling, total numbers**

| | Geothermal DH plants | | Geothermal heat in agriculture and industry | | Geothermal heat for buildings | | Geothermal heat in balneology and other | |
|---|---|---|---|---|---|---|---|---|
| | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) |
| In operation end of 2018 | 1453 | 4600 | 820 | 2900 | 109 | 477 | 1205 | 6307 |
| Under construction end 2018 | | | | | | | | |
| Total projected by 2020 | 1800 | 5700 | 1200 | 4244 | 120 | 525 | 1400 | 7300 |
| Total expected by 2025 | 2200 | 6965 | 1600 | 5660 | 150 | 656 | 1700 | 8900 |

**Table D1: Existing geothermal district heating (DH) plants, individual sites**

| Locality / Plant Name | Year commis-sioned | CHP | Cooling * | Geoth. capacity installed ($MW_{th}$) | Total capacity installed ($MW_{th}$) | 2018 produc-tion ($GW_{th}$/y) | Geoth. share in total prod. (%) |
|---|---|---|---|---|---|---|---|
| Izmir (Balcova+Narlidere) | 1983 | N | Y, RI | 250 | | | 24.20 |
| Gonen | 1987 | N | N, RI | 19 | | | 1.84 |
| Simav | 1991 | N | N, RI | 110 | | | 10.65 |
| Kirsehir | 1994 | N | N, RI | 20 | | | 1.94 |
| Kizilcahamam | 1995 | N | N, RI | 28 | | | 2.71 |
| Afyon | 1996 | N | N, RI | 127,5 | | | 12.34 |
| Kozakli | 1996 | N | N, RI | 34 | | | 3.29 |
| Sandikli | 1998 | N | N, RI | 119 | | | 11.52 |
| Diyadin | 1999 | N | N, RI | 67 | | | 6.49 |
| Salihli | 2002 | N | N, RI | 52 | | | 5.03 |
| Saraykoy | 2002 | N | N, RI | 19 | | | 1.84 |
| Edremit | 2003 | N | N, RI | 39 | | | 3.78 |
| Bigadic | 2005 | N | N, RI | 7 | | | 0.68 |
| Dikili | 2009 | N | N, RI | 19 | | | 1.84 |
| Bergama | 2009 | N | N, RI | 3 | | | 0.29 |
| Sorgun | 2008 | N | N, RI | 19 | | | 1.84 |
| Sindirgi | 2014 | N | N, RI | 24 | | | 2.32 |
| Others | | N | N, RI | 76.5 | | | 7.41 |
| **total** | | | | **1033** | | | **100** |

* In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Only city district heating systems including, houses, governmental buildings and universtities are included in this table.

**Table E: Shallow geothermal energy, ground source heat pumps (GSHP)**

| | Geothermal Heat Pumps (GSHP), total | | | New (additional) GSHP in 2018 | | |
|---|---|---|---|---|---|---|
| | Number | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) | Number | Capacity ($MW_{th}$) | Share in new constr. (%) |
| In operation end of 2018 | 137 | 100.5 | 880.38 | 9 | 8.32 | 8.27 |
| Projected total by 2020 | 150 | 120 | 1052 | | | |

**Table F: Investment and Employment in geothermal energy**

| | in 2018 | | Expected in 2020 | |
|---|---|---|---|---|
| | Expenditures (million €) | Personnel (number) | Expenditures (million €) | Personnel (number) |
| Geothermal electric power | 5200 | 2000 | 8000 | 2400 |
| Geothermal direct uses | 1000 | 1600 | 1200 | 2000 |
| Shallow geothermal* | 32 | 26 | 48 | 36 |
| **total** | **6232** | **3626** | **9248** | **4436** |

* Only ground source heat pumps have been taken into account.

**Table G: Incentives, Information, Education**

| | Geothermal electricity | Deep Geothermal for heating and cooling | Shallow geothermal |
|---|---|---|---|
| Financial Incentives – R&D | | | |
| Financial Incentives – Investment | | | |
| Financial Incentives – Operation/Production | 10.5 USD-Cent/kWh (FIT) | | |
| Information activities – promotion for the public | | | |
| Information activities – geological information | | | |
| Education/Training – Academic | | | |
| Education/Training – Vocational | | | |

| Key for financial incentives: | | |
|---|---|---|
| DIS Direct investment support<br>LIL Low-interest loans<br>RC Risk coverage | FIT Feed-in tariff<br>FIP Feed-in premium<br>REQ Renewable Energy Quota | -A Add to FIT or FIP on case the amount is determined by auctioning<br>O Other (please explain) |