



Direct utilization of geothermal energy 2015 worldwide review



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ABSTRACT

This paper presents a review of the worldwide applications of geothermal energy for direct utilization, and updates the previous survey carried out in 2010. We also compare data from 1995, 2000 and 2005 presented at World Geothermal Congresses in Italy, Japan and Turkey, respectively (WGC95, WGC2000, and WGC2005). As in previous reports, an effort is made to quantify ground-source (geothermal) heat pump data. The present report is based on country update papers received from 70 countries and regions of which 65 reported some direct utilization of geothermal energy. Seventeen additional countries were added to the list based on other sources of information. Thus, direct utilization of geothermal energy in a total of 82 countries is an increase from the 78 reported in 2010, 72 reported in 2005, 58 reported in 2000, and 28 reported in 1995. An estimation of the installed thermal power for direct utilization at the end of 2014 is used in this paper and equals 70,885 MWt, 46.2% increase over the 2010 data, growing at a compound rate of 7.9% annually with a capacity factor of 0.265. The thermal energy used is 592,638 TJ/year (164,635 GWh/year), about a 39.8% increase over 2010, growing at a compound rate of 6.9% annually. The distribution of thermal energy used by category is approximately 55.2% for ground-source heat pumps, 20.2% for bathing and swimming (including balneology), 15.0% for space heating (of which 89% is for district heating), 4.9% for greenhouses and open ground heating, 2.0% for aquaculture pond and raceway heating, 1.8% for industrial process heating, 0.4% for snow melting and cooling, 0.3% for agricultural drying, and 0.2% for other uses. Energy savings amounted to 352 million barrels (52.8 million tonnes) of equivalent oil annually, preventing 46.1 million tonnes of carbon and 149.1 million tonnes of CO₂ being released to the atmosphere, this includes savings for geothermal heat pumps in the cooling mode (compared to using fuel oil to generate electricity). Since it was almost impossible to separate direct-use from electric power generation for the following, they are combined: approximately 2218 well were drilled in 42 countries, 34,000 person-years of effort were allocated in 52 countries, and US \$20 billion invested in projects by 49 countries.

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1. Introduction

Direct-use of geothermal energy is one of the oldest, most versatile and common forms of utilizing geothermal energy (Dickson and Fanelli, 2003). The early history of geothermal direct-use has been reviewed for over 25 countries in the *Stories from a Heated Earth—Our Geothermal Heritage* (Cataldi et al., 1999), that documents geothermal use for over 2000 years. The information presented here on direct applications of geothermal heat is based on country update papers published in the World Geothermal Congress 2015 (WGC2015) proceedings and covers the period 2010–2014. Papers from 70 countries and regions were received, 65 of which reported some geothermal direct-use with 17 addi-

tional countries added from other sources such as from other World Geothermal Congresses such as WGC2010, WGC2005, European geothermal meetings, and personal communications for a total of 82 countries—an increase of four countries from WGC2010 (Greenland, Madagascar, Pakistan, and Saudi Arabia). In the cases where data are missing or incomplete, the authors have relied on country update reports from the World Geothermal Congresses of 1995, 2000, 2005, and 2010 (WGC95, WGC2000, WGC2005, and WGC2010), as well as from three *Geothermics* publications (Lund and Freeston, 2001; Lund et al., 2005, 2010), *European Geothermal Congress* (2007, 2013), and personal communications. Data from WGC2015 are also compared with data from WGC95, WGC2000, WGC2005, and WGC2010.

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Table 1
Summary of direct-use data worldwide by region and continent, 2015.

| Region/Continent (# countries/regions) | MWt | TJ/year | GWh/year | Capacity factor |
|--|--------|---------|----------|-----------------|
| Africa (8) | 140 | 2,538 | 705 | 0.575 |
| Americas (16) | 19,610 | 99,899 | 27,752 | 0.162 |
| Central America and Caribbean (5) | 9 | 181 | 50 | 0.634 |
| North America (4) | 19,031 | 91,442 | 25,403 | 0.152 |
| South America (7) | 570 | 8,276 | 2,299 | 0.460 |
| Asia (18) | 25,369 | 260,198 | 72,283 | 0.325 |
| Commonwealth of Independent States (5) | 399 | 7,094 | 1,971 | 0.564 |
| Europe (32) | 24,863 | 214,093 | 59,475 | 0.273 |
| Central and Eastern Europe (15) | 2,819 | 26,220 | 7,284 | 0.295 |
| Western and Northern Europe (17) | 22,044 | 187,873 | 52,191 | 0.270 |
| Oceania (3) | 504 | 8,816 | 2,449 | 0.555 |
| Total (82) | 70,885 | 592,638 | 164,635 | 0.265 |

Table 2
Worldwide leaders in the direct utilization of geothermal energy.

| MWt | TJ/year |
|-----------------|------------------|
| China (17,870) | China (174,352) |
| USA (17,416) | USA (75,862) |
| Sweden (5,600) | Sweden (51,920) |
| Turkey (2,937) | Turkey (45,892) |
| Germany (2,849) | Iceland (26,717) |

2. Data summary

Table 1 is a summary, by region and continent, of the installed thermal capacity (MWt), annual energy use (TJ/year and GWh/year) and the capacity factors to the end of 2014. Table A1 in the Appendix is a similar summary by individual countries. The total installed capacity, reported through the end of 2014 for geothermal direct utilization worldwide is 70,885 MWt, a 46.2% increase over WGC2010, growing at an annual compound rate of 7.9%. The total annual energy use is 592,638 TJ (164,635 GWh), indicating a 39.8% increase over WGC2010, and a compound annual growth rate of 6.9%. The worldwide capacity factor is 0.265 (equivalent to 2321 full load operating hours per year), down from 0.28 in 2010, 0.31 in 2005 and 0.40 in 2000. The lower capacity factor and growth rate for annual energy use is due to the increase in geothermal heat pump installations which have a low capacity factor of 0.21 worldwide. The growth rates of installed capacity and annual energy use over the past 20 years are shown in Fig. 1.

The five countries with the largest direct-use (with heat pumps) installed capacity (MWt) are: China, USA, Sweden, Turkey and Germany accounting for 65.8% of the world capacity, and the five countries with the largest annual energy use (with heat pumps) (TJ/year) are: China, USA, Sweden, Turkey and Iceland accounting for 63.2% of the world use. However, an examination of the data in terms of land area or population shows that the smaller countries dominate, especially the Nordic ones. The “top five” then become for installed capacity (MWt/population): Iceland, Sweden, Finland, Norway, and Switzerland; and for annual energy use (TJ/year/population): Iceland, Sweden, Finland, New Zealand, and Norway. The “top five” in terms of land area for installed capacity (MWt/area) are: Switzerland, Netherlands, Iceland, Sweden and Austria; and in terms of annual energy use (TJ/year/area) are: Switzerland, Iceland, Netherlands, Sweden and Hungary. The largest percent increase in geothermal installed capacity (MWt) over the past five years was in: Thailand, Egypt, India, Korea (South), and Mongolia; and in terms of annual energy use (TJ/year) over the past five years was in: Thailand, Egypt, Philippines, Albania, and Belarus. Most of these increases were due to geothermal heat pump installations or better reporting on bathing and swimming use. See Tables 2–5. In 1985, only 11 countries report an installed capacity of more than 100 MWt. By 1990, this number had increased to 14, by 1995–15, by 2000–23, by 2005 33 countries, and by 2010–36 coun-

Table 3
Worldwide leaders in direct utilization of geothermal energy in terms of population (per 1000).

| MWt/population | TJ/year/population |
|--------------------|--------------------|
| Iceland (6.26) | Iceland (82.04) |
| Sweden (0.57) | Sweden (5.30) |
| Finland (0.28) | Finland (3.29) |
| Norway (0.25) | New Zealand (1.90) |
| Switzerland (0.22) | Norway (1.61) |

Table 4
Worldwide leaders in direct utilization of geothermal energy terms of land area (per 100 km²).

| MWt/area | TJ/year/area |
|------------------------|-------------------------|
| Switzerland (4.20) | Switzerland (28.67) |
| The Netherlands (2.16) | Iceland (25.94) |
| Iceland (1.98) | The Netherlands (19.41) |
| Sweden (1.24) | Sweden (11.54) |
| Austria (1.08) | Hungary (11.04) |

Table 5
Worldwide leaders in direct utilization of geothermal energy in terms of the largest increase since 2010 (%).

| MWt | TJ/year |
|------------------|-------------------|
| Thailand (4,959) | Thailand (1,393) |
| Egypt (580) | Egypt (487) |
| India (272) | Philippines (213) |
| S. Korea (265) | Albania (166) |
| Mongolia (196) | Belarus (156) |

Table 6
Worldwide leaders in direct utilization of geothermal energy without geothermal heat pumps.

| MWt | TJ/year |
|-----------------|------------------|
| China (6,089) | China (74,041) |
| Turkey (2,894) | Turkey (44,932) |
| Japan (2,086) | Iceland (26,700) |
| Iceland (2,035) | Japan (25,630) |
| India (986) | Hungary (9,573) |

tries. As of the end of 2014, there were also 36 countries reporting over 100 MWt.

The five countries with the largest direct-use (without heat pumps in MWt) in installed capacity are: China, Turkey, Japan, Iceland, and India accounting for 68.3% of the world capacity. The five countries with the largest annual energy use (without heat pumps in TJ/year) are: China, Turkey, Iceland, Japan, and Hungary accounting for 68.0% of the world use. See Table 6.

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