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# World-wide direct uses of geothermal energy 2000☆

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**Abstract**

The worldwide application of geothermal energy for direct utilization is reviewed. This paper attempts to update the previous survey carried out in 1995 (Freeston, 1995) and presented at the World Geothermal Congress 1995 in Florence, Italy. For each of these updates since 1975, the recording of data has been similar, but not exactly the same. As in 1995, an effort was made to quantify geothermal heat pump data and the investment in geothermal energy development. Final update papers were received from 60 countries, of which 55 reported some form of geothermal direct utilization. Three additional countries were added to the list based on other sources of information. An estimate of the installed thermal power at the beginning of 2000 (1995 values in brackets) from the current reports is 15,145 MWt [8664 MWt] utilizing at least 52,746 kg/s [37,050 kg/s] of fluid, and the thermal energy used is 190,699 TJ/yr [112,441 TJ/yr]. The distribution of the thermal energy used by category is approximately 42% for bathing and swimming pool heating, 23% for space heating, 12% for geothermal heat pumps, 9% for greenhouse heating, 6% for aquaculture pond and raceway heating, 5% for industrial applications, 2% for other uses, and less than 1% each for agricultural drying, snow melting, and air conditioning. The reported data for number of wells drilled was 1028, the work by professionals over the five-year period was 3363 person-years, and the total investment over the same five years was 841 million US$, indicating minimum values. © 2001 CNR. Published by Elsevier Science Ltd. All rights reserved.

*Keywords:* Direct use; Low enthalpy; Spas; Balneology; Space heating; Aquaculture; Greenhouses; Heat pumps; Crop drying; Industrial; Snow melting

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## 1. Introduction

Approximately one year in advance, forms for updating the information on electric and direct uses of geothermal energy were mailed to representatives in 85 countries in preparation for the World Geothermal Congress 2000 (WGC2000) in Japan. The forms, consisting of eight tables, were revised versions of those utilized in the 1995 survey, especially in terms of how to make the necessary calculations for installed power and energy utilized. The tables were also made available on the Internet through the Geo-Heat Center web site. These eight tables were to be completed, where applicable, and attached to the various country update papers submitted to WGC2000. Approximately 75 countries responded with abstracts; 65 of them subsequently submitted draft papers and 60 a final paper, 55 of which had some direct utilization of geothermal energy. Unfortunately, not all countries responded in a similar manner, as some had only limited exploration data to report, while others had difficulty obtaining temperature and flow data for the various uses. In some cases, with the help of our extensive knowledge and international experience, reasonable estimates could be made of various uses, especially that for geothermal heat pumps, pools and resorts. Reference often had to be made to other publications for data to augment the country update papers. These other sources added three more countries to the list.

The assumptions used in the analysis were similar to those used in previous surveys, with the methods of calculation listed at the top of the various tables:

Installed thermal power (MWt) = $m$ (kg/s) × ($T_i - T_o$) (°C) × 0.004184
Energy used (TJ/year) = annual average flow rate (kg/s) × ($T_i - T_o$) (°C) × 0.1319
Capacity factor = TJ/year × 0.03171/MWt
where $m$ = maximum flow rate, $T_i$ = inlet temperature, and $T_o$ = outlet temperature.

Both swimming pools and other aspects of balneology are included where they are identified. Heat pumps, as in 1995, are included and they make a significant contribution to the totals.

## 2. Data summary

Table 1 is a summary, by country, of the peak flow rates, capacity, annual energy utilization (in TJ/year and GWh/year) and capacity factor, wells drilled, professional person-years and investment reported by the various authors. There are 58 countries reporting use, as compared to 28 in 1995 and 24 in 1985. The maximum total flow rate is at least 52,746 kg/s, an increase of 42.4% over 1995; total capacity is 15,145 MWt, a 74.8% increase over 1995; energy utilization is 190,699 TJ/year (52,976 GWh/year), a 69.6% increase over 1995. These numbers correspond to a 7.3% annual compounded growth for flow rate, an 11.8% annual compounded growth for capacity, and an 11.1% annual compounded growth for utilization over

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