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World-Wide Direct Uses of Geothermal Energy 2005

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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 2000, presented at the World Geothermal Congress 2000 (WGC2000) in Japan and subsequently updated (Lund and Freeston, 2001). This update also compares data from 1995 presented at the World Geothermal Congress 1995 (WGC95) in Florence, Italy (Freeston, 1996). As in 1995 and 2000, an effort was made to quantify geothermal (ground-source) heat pumps data. Final update papers were received from 68 countries, of which 60 reported some direct utilization of geothermal energy. Eleven additional countries were added to the list based on other sources of information. The 71 countries reporting direct utilization of geothermal energy, is a significant increase from the 58 reported in 2000 and the 28 reported in 1995. An estimate of the installed thermal power for direct-use at the end of 2004, from the current reports, is 27,825 MWt, almost a two-fold increase over the 2000 data, growing at a compound rate of 12.9% annually. The thermal energy used is 261,418 TJ/year (72,622 GWh/yr), almost a 40% increase over 2000, growing at a compound rate of 6.5% annually. The distribution of thermal energy used by category is approximately 33% for geothermal heat pumps, 29% for bathing and swimming (including balneology), 20% for space heating (of which 77% is for district heating), 7.5% for greenhouse and open ground heating, 4% for industrial process heat, 4% for aquaculture pond and raceway heating, <1% for agricultural drying, <1% for snow melting and cooling, and <0.5% for other uses.

1. INTRODUCTION

Approximately one year in advance, forms for updating the information on electric and direct-uses of geothermal energy were emailed to representatives in 90 countries in preparation for the World Geothermal Congress 2005 (WGC2005) in Turkey. The forms, consisting of eight tables, were revised versions of those utilized in the 1995 and 2000 surveys, 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 website (http://geoheat.oit.edu). These eight tables were to be completed, where applicable, and attached to the various country update papers submitted to the WGC2005. Approximately 80 countries responded with abstracts; 75 of them subsequently submitted draft papers and 68 a final paper, 60 of which had some direct utilization of geothermal energy. Unfortunately, not all countries responded in a similar manner, as some had only limited development and use data to report, while others had difficulty obtaining temperature and flow data for the various uses or were unable to locate and catalog all the direct-uses in the country. In some cases, with the help of our extensive knowledge and international experiences, reasonable estimates could be made of the various uses, especially that for geothermal heat pumps, and bathing and swimming pool heating. Reference often had to be made to other publications for data to augment the country update paper, and reports from WGC2000 were also utilized and updated where necessary. These other sources added additional countries to our list, bringing to total to 71. All data comparisons to WGC2000 as based on the report by Lund and Freeston (2001), and those for WGC1995 from Freeston (1996).

2. DATA SUMMARY

Table 1 is a summary, by country, of the installed capacity (MWt), annual energy use (TJ/yr and GWh/yr) and the capacity factor. Data on wells drilled, professional person-years and investment in geothermal projects over the past five years, were also requested; however, due to poor and variable responses, these are not reported, but can be reviewed in the individual papers submitted to WGC2005. The total installed capacity, reported at the end of 2004, for the world's geothermal direct utilization is 27,825 MWt, almost a two-fold increase over the 2000 data, growing at a compound rate of 12.9% annually. The total annual energy use is 261,418 TJ (72,622 GWh), almost a 40% increase over 2000, growing at a compound rate of 6.5% annually. Compared to ten years ago the capacity increased 12.4%/yr and the use 8.8%/yr. Thus, it appears that the growth rate has increased in recent years, despite the low cost of fossil fuels, economic down turns and other factors. It should; however, be noted that part of the growth from 2000 to the present is due, in part, to better reporting, and includes some geothermal countries that were missed in previous reports. The capacity factor is an indication of the amount of use during the year (i.e. a factor of 1.00 would indicate the system is used at a maximum the entire year, and 0.5 would indicate using the system for 4,380 equivalent full-load hours per year). The worldwide average for the capacity factor is 0.30, down from 0.40 five years ago. This decrease is due to the increased use of geothermal heat pumps that have a worldwide capacity factor of 0.17 in the heating mode without geothermal heat pumps the revised capacity factor for 2004 is 0.46.

The growing awareness and popularity of geothermal (ground-source) heat pumps had the most significant impact on the data. The annual energy use for these grew at a compound rate of 30.1% per year compared to five years ago, and 19.5% compared to ten years ago. The installed capacity grew 24.4% and 23.8% respectively. This is due, in part, to the ability of geothermal heat pumps to utilized groundwater or ground-coupled temperatures anywhere in the world.

Table 1. Summary of direct-use data from individual countries, 2005

Country	Capacity MWt	Use TJ/yr	Use GWh/yr	Capacity Factor
Albania	9.6	8.5	2.4	0.03
Algeria	152.3	2,417.0	671.4	0.50
Argentina	149.9	609.1	169.2	0.13
Armenia	1.0	15.0	4.2	0.48
Australia	109.5	2,968.0	824.5	0.86
Austria	352.0	352.0	2,229.9	0.20
Belarus	1.0	13.3	3.7	0.42
Belgium	63.9	431.2	119.8	0.21
Brazil	360.1	6,622.4	1,839.7	0.58
Bulgaria	109.6	1,671.5	464.3	0.48
Canada	461.0	2,546.0	707.3	0.18
Caribbean Islands	0.1	2.8	0.8	0.89
Chile	8.7	131.1	36.4	0.48
China	3,687.0	45,373.0	12,604.6	0.39
Columbia	14.4	287.0	79.7	0.63
Costa Rica	1.0	21.0	5.8	0.67
Croatia	114.0	681.7	189.4	0.19
Czech Republic	204.5	1,220.0	338.9	0.19
Denmark	821.2	4,360.0	1,211.2	0.17
Ecuador	5.2	102.4	28.4	0.62
Egypt	1.0	15.0	4.2	0.48
Ethiopia	1.0	15.0	4.2	0.48
Finland	260.0	1,950.0	541.7	0.24
France	308.0	5,195.7	1,443.4	0.53
Georgia	250.0	6,307.0	1,752.1	0.80
Germany	504.6	2,909.8	808.3	0.18
Greece	74.8	567.2	157.6	0.24
Guatemala	2.1	52.5	14.6	0.79
Honduras	0.7	17.0	4.7	0.77
Hungary	694.2	7,939.8	2,205.7	0.36
Iceland	1,791.0	23,813.0	6,615.3	0.42
India	203.0	1,606.3	446.2	0.25
Indonesia	2.3	42.6	11.8	0.59
Iran	30.1	752.3	209.0	0.79
Ireland	20.0	104.1	28.9	0.17
Israel	82.4	2,193.0	609.2	0.84
Italy	606.6	7,554.0	2,098.5	0.39
Japan	413.4	5,161.1	1,433.8	0.40
Jordan	153.3	1,540.0	427.8	0.32
Kenya	10.0	79.1	22.0	0.25
Korea (South)	16.9	175.2	48.7	0.33
Lithuania	21.3	458.0	127.2	0.68
Macedonia	62.3	598.6	166.3	0.30
Mexico	164.7	1,931.8	536.7	0.37
Mongolia	6.8	213.2	59.2	0.99
Nepal	2.1	51.4	14.3	0.78
Netherlands	253.5	685.0	190.3	0.09
New Zealand	308.1	7,086.0	1,968.5	0.73
Norway	450.0	2,314.0	642.8	0.16
Papua New Guinea	0.1	1.0	0.3	0.32
Peru	2.4	49.0	13.6	0.65
Philippines	3.3	39.5	11.0	0.38
Poland	170.9	838.3	232.9	0.16
Portugal	30.6	385.3	107.0	0.40
Romania	145.1	2,841.0	789.2	0.62
Russia	308.2	6,143.5	1,706.7	0.63
Serbia	88.8	2,375.0	659.8	0.85
Slovak Republic	187.7	3,034.0	842.8	0.51
Slovenia	48.6	712.5	197.9	0.46
Spain	22.3	347.2	96.5	0.49
Sweden	3,840.0	36,000.0	10,000.8	0.30
Switzerland	581.6	4,229.3	1,174.9	0.23

Thailand	1.7	28.7	8.0	0.54
Tunisia	25.4	219.1	60.9	0.27
Turkey	1,177.0	19,623.1	5,451.3	0.53
Ukraine	10.9	118.8	33.0	0.35
United Kingdom	10.2	45.6	12.7	0.14
United States	7,817.4	31,239.0	8,678.2	0.13
Venezuela	0.7	14.0	3.9	0.63
Vietnam	30.7	80.5	22.4	0.08
Yemen	1.0	15.0	4.2	0.48
GRAND TOTAL	**27,824.8**	**261,418.0**	**72,621.9**	**0.30**

The countries with the largest installed capacity and annual energy use were the USA, Sweden, China, Iceland and Turkey, accounting for about 66% of the installed capacity and 60% of the annual energy use. Sweden, a new member of the "top-five" obtained its position due to the country's increased use of geothermal heat pumps. However, if one looks at the data in terms of the country's land area or population, then the smaller countries dominate. The "top-five" then become Iceland, Israel, Switzerland, Denmark and Georgia (TJ/area), and Iceland, Sweden, New Zealand, Georgia and Denmark (TJ/population). The largest increase in geothermal energy use over the past five years are Norway, Denmark, Chile, Netherlands and Portugal; and the largest increase in installed capacity are Denmark, Norway, Netherlands, Chile and Belgium, due mostly to the increased use of geothermal heat pumps. These rankings are summarized in Table 2.

In 1985, there were only 11 countries reporting an installed capacity of over 100 MWt. By 1990, this number had increased to 14, by 1995 to 15, and by 2000 to 23. At present there are 33 countries reporting 100 MWt or more of installed capacity. In addition, 10 new countries, compared to 2000, now report some geothermal direct utilization.

3. CATEGORIES OF UTILIZATION

In Table 3 the 1995, 2000 and 2005 data are divided among the various uses in terms of capacity, energy utilization and capacity factor. The energy utilization can be seen as a bar chart as shown in Figure 1.

Table 2. Ranking (in order) of Geothermal Direct Utilization 2005

Use (TJ/yr)	Capacity (MWt)	TJ/area	TJ/population	MWt/area	MWt/population
China	USA	Iceland	Iceland	Denmark	Iceland
Sweden	Sweden	Israel	Sweden	Iceland	Sweden
USA	China	Switzerland	New Zealand	Switzerland	Denmark
Iceland	Iceland	Denmark	Georgia	Sweden	Norway
Turkey	Turkey	Georgia	Denmark	Hungary	Switzerland

% Use (TJ/yr) Increase 95-05	% Capacity (MWt) Increase 95-05	%Use (TJ/yr) Increase 00-05	%Capacity (MWt) Increase 00-05
Denmark	Canada	Norway	Denmark
Canada	Denmark	Denmark	Norway
Sweden	Sweden	Chile	Netherlands
Austria	Austria	Netherlands	Chile
Germany	Belgium	Portugal	Belgium

Table 3. Summary of the various worldwide direct-use categories, 1995-2005

	Capacity, MWt			Utilization TJ/yr			Capacity Factor		
	2005	2000	1995	2005	2000	1995	2005	2000	1995
Geothermal heat pumps	15,723	5,275	1,854	86,673	23,275	14,617	0.17	0.14	0.25
Space heating	4,158	3,263	2,579	52,868	42,926	38,230	0.40	0.42	0.47
Greenhouse heating	1,348	1,246	1,085	19,607	17,864	15,742	0.46	0.45	0.46
Aquaculture pond heating	616	605	1,097	10,969	11,733	13,493	0.56	0.61	0.39
Agricultural drying	157	74	67	2,013	1,038	1,124	0.41	0.44	0.53
Industrial uses	489	474	544	11,068	10,220	10,120	0.72	0.68	0.59
Bathing and swimming	4,911	3,957	1,085	75,289	79,546	15,742	0.49	0.64	0.46
Cooling/snow melting	338	114	115	1,885	1,063	1,124	0.18	0.30	0.31
Others	86	137	238	1,045	3,034	2,249	0.39	0.70	0.30
Total	27,825	15,145	8,664	261,418	190,699	112,441	0.30	0.40	0.41

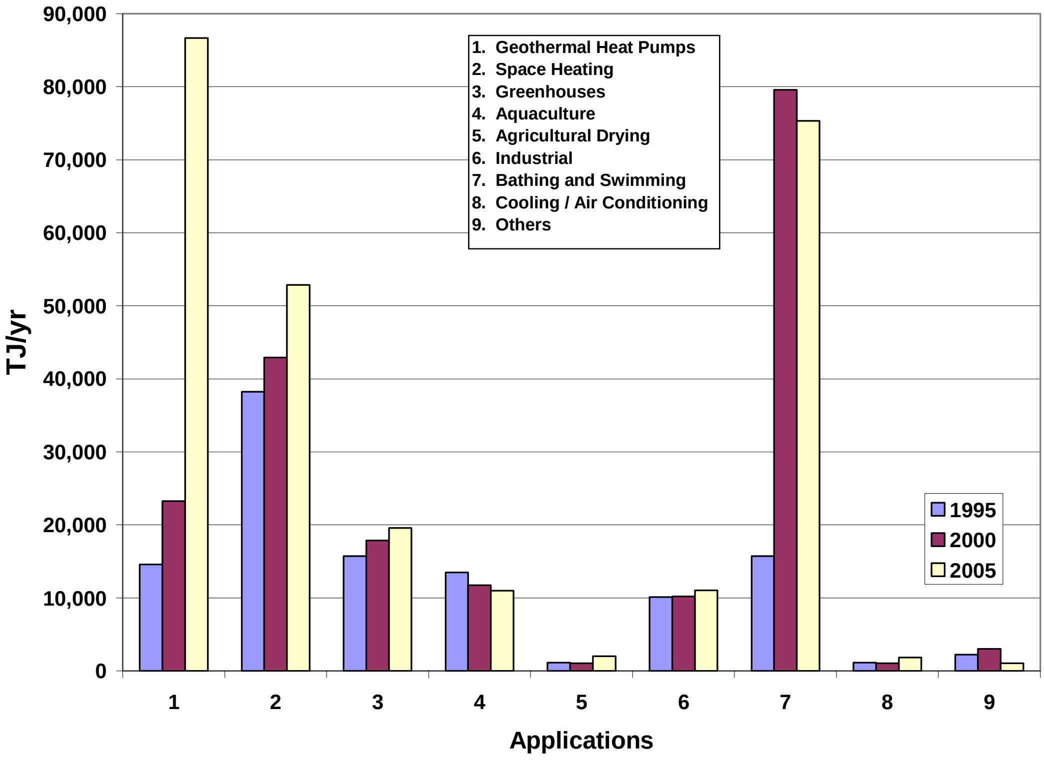
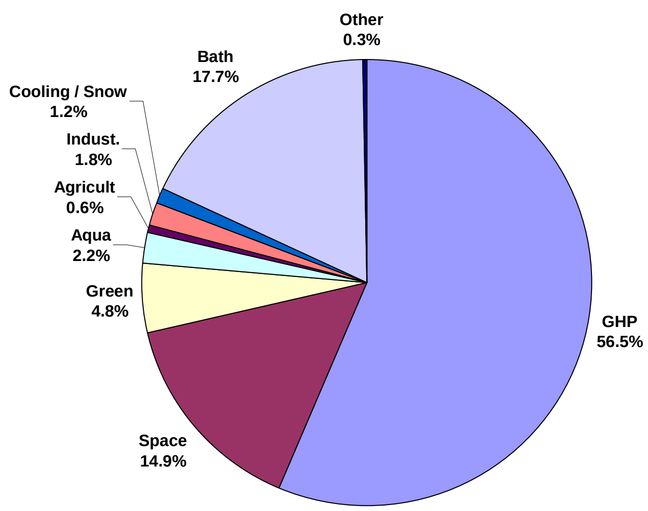
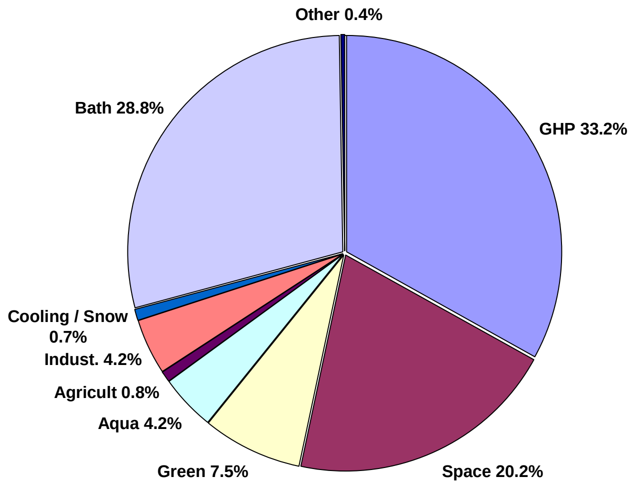


Figure 1: Comparison of worldwide energy use in TJ/yr for 1995, 2000 and 2005.



(a)



(b)

Figure 2. Categories of capacity in % for 2005 (a); and energy use in % (b), 2005.

Figure 2 presents the 2005 data in pie-chart form in percentages. We attempted to distinguish individual space heating from district heating, but this was often difficult, as reporters did not always make this distinction. Our best estimate is that district heating is 77% of total space heating energy use and 81% of the installed capacity. Snow melting represents the majority of the snow melting/air conditioning category. The Other category includes a variety of use, often not explained, but where reported, can be found described in the individual country reports that follow.

3.1 Geothermal Heat Pumps

Geothermal (ground-source) heat pumps have the largest energy use and installed capacity, accounting for 33.2% and 56.5% of the word-wide use and capacity. The installed capacity is 15,723 MWt and the annual energy use is 86,673 TJ/yr with a capacity factor of 0.17 (in the heating mode). Almost all of the installations occur in North American and Europe, increasing from 26 countries in 2000 to the present 32 countries. The equivalent number of installed 12-kWt units (typical of US and western European homes) is approximately 1.3 million, over double the number of units reported for 2000. The size of individual units; however, range from 5.5-kWt for residential use to large units of over 150-kWt for commercial and institution installation. In the United States, most units are sized for peak cooling load and are oversized for heating (except in the northern states) and, thus, are estimated to average only 1,000 full-load hours per year (capacity factor of 0.11). In Europe, most units are sized for the heating load and are often designed to provide the base load with peaking by fossil fuel. As a result, these units may operate from 2,000 to 6,000 full-load hours per year (capacity factor of 0.23 to 0.68). Unless the actual number of full-load hours was known, a value of 2,200 hours was used for energy output (TJ/yr) calculations for several of the European countries, based on reporting by Curtis, et al., (2005). The energy use reported for the heat pumps was reduced from the installed capacity based on COP (coefficient of performance) of around 3.5, which allows for one unit of energy input (usually electricity) to three and a half units of energy output, for a geothermal component of 71% of the rated capacity. The cooling load was not considered as geothermal energy use, as in this case, heat is rejected to the ground or groundwater. Cooling, however, can be considered for replacing fossil fuels and reducing greenhouse gas emission.

3.2 Space Heating

Energy use growth in space heating since 2000 is 23.2% or 4.3% annually down from the 1995-2000 period in percentages, but increasing more in absolute numbers. The installed capacity is 4,158 MWt and the annual energy use is 52,868 TJ/yr. As stated early about 77% of the annual energy use and 81% of the installed capacity is due to district heating. Iceland, Turkey, China and France are the leaders, mainly in district heating, whereas, Australia, Russia, Japan, USA and Japan dominate the individual home-heating systems use.

3.3 Greenhouse and Covered Ground Heating

Greenhouse heating energy use increased only 9.8% or1.9% annually down from the 1995-2000 period. The installed capacity is 1,348 MWt and the annual energy use is 19,607 TJ/yr. A total of 30 countries reported geothermal greenhouse heating: the leading countries being Georgia, Russia, Turkey, Hungary, China and Italy. Most countries did not distinguish between covered (greenhouses) versus uncovered ground heating, and also did not report the area heated. Several countries, such as Macedonia, reported a decrease in geothermal greenhouse use, due to economic problems. United States greenhouse growers are experiencing increased competition from import of plants from Latin America, such as roses, undermining the market. Vegetable growers in developed countries, are also experiencing economic problems due to high labor costs. Using an average energy requirement determined for WGC2000 of 20 TJ/yr/ha for greenhouse heating, the 19,607 TJ/yr gives almost an equivalent 1,000 hectares of greenhouse heated worldwide.

3.4 Aquaculture Pond and Raceway Heating

Aquaculture use of geothermal energy again decreased, as it did in 2000. The loss was 6.5% or 1.3% compounded annually. The installed capacity increased slightly, 0.4% annually, for a total of 616 MWt, with the annual energy use at 10,969 TJ/yr. Seventeen countries reported use, with the largest being USA, China, Iceland and Italy. No reason appears to explain the decrease in use; however, it is assumed economics is an important impediment for developing and maintaining the facilities, as they are very labor intensive and require management by well-trained personnel. Tilapia, salmon and trout appeared to be the most common fish raised, but unusual species such a tropical fish, lobsters, shrimp or prawns, and alligators are reported. Based on work in the United States, we calculate that is requires 0.242 TJ/yr/tonne of fish (bass and tilapia) using geothermal waters in ponds. Using the reported energy use of 10,969 TJ/yr, an equivalent 45,000 tonnes of annual production is estimated.

3.5 Agricultural Crop Drying

Fifteen countries reported the use of geothermal energy for drying various grains, vegetables and fruit crops, up from 10 in 2000. Examples are: seaweed (Iceland), onions (United States), wheat and other cereals (Serbia), fruit (Guatemala and Mexico), lucerne or alfalfa (New Zealand), coconut meat (Philippines). There is a large potential and interest using geothermal energy for drying crops in tropical regions where field spoilage occurs rapidly. A total of 2,013 TJ/yr of energy use and 157 MWt of installed capacity are reported, an increased of 14.2% and 16.2% compounded annually respectively, compared to 2000.

3.6 Industrial Process Heat

This is a category that has applications in 15 countries, down from 19 in 2000, where the installations tend to be large and energy consumption high. Examples include: concrete curing (Guatemala and Slovenia), bottling of water and carbonated drinks (Bulgaria, Serbia and the United States), milk pasteurization (Romania), leather industry (Slovenia and Serbia), chemical extraction (Bulgaria, Russia and Poland), CO_2 extraction (Iceland and Turkey), mushroom growing and laundry use (Mexico and the United States), salt extraction and diatomaceous earth drying (Iceland), pulp and paper processing (New Zealand), iodine and salt extraction (Vietnam), borate and boric acid production (Italy) and timber (New Zealand, Romania, and Mexico). A zinc extraction plant, in the Imperial Valley of southern California in the United States, did start operation, but was shut down about a short period due to economic and technical problems. The use of geothermal energy has increased slightly since 2000, with an installed capacity of 489 MWt and 11,068 TJ of energy used annually, with the highest capacity factor of all uses of 0.72.

3.7 Snow Melting and Space Cooling

There are very limited applications in this area, with pavement snow melting projects in Argentina, Iceland, Japan, Switzerland and the United States. A total of almost one million square meters of pavement are heated, the majority of which is in Iceland. A project in Argentina uses steam for highway snow melting in the Andes to keep a resort community open during winters. The power required varies from 130 to 180 W/m^2 (United States and Iceland). Space cooling is limited, only six countries reported use, amounting to 288.5 TJ/yr and an installed capacity of 55.6 MWt. Snow melting amounts to1,596.5 TJ/yr and 282.2 MWt. Heat pumps are not included, as this process returns heat to the earth.

3.8 Bathing and Swimming

Figures for this use were the most difficult to collect and quantify. Almost every country has spas and resorts with swimming pools (including balneology), but many allow the water to flow continuously, regardless of use. As a result, the actual use and capacity figures may be high. In some cases, where use was reported, no flows and temperature drops were known, thus a figure of 0.35 MWt and 7.0 TJ/yr were applied to estimate the capacity and energy use for a typical installation. Natural hot springs that are undeveloped were not included in this report. In addition to the 59 countries (up from 48 in 2000) that reported bathing and swimming use, we are also aware of developments in Malaysia, Mozambique, South Africa and Zambia, but no information was available from these countries. The installed capacity has increased 24% over the past five years, but the annual energy use has decreased by about 5%, most likely due to better reporting and change in data reporting from Japan. The data from Japan excluded the hotels and Japanese style inns that utilized hot springs water for bathing, which probably accounts for the decrease, as we attempted to include these figures in 2001 (Lund and Freeston, 2001). The 11 countries that were added to the list probably had long established facilities that were not previously reported.

3.9 Other Uses

Other uses, 86 MWt and 1,045 TJ/yr, were reported by six countries and included uses such as animal farming (Argentina and Tunisia), spirulina cultivation and desalination (Greece), and bottling, raising spirulina, producing iodine paste, and methane extraction (Bulgaria).

4. CAPACITY FACTORS

Average capacity factors were determined for each country as shown in Table 1 and for each use category as shown in Table 3. They vary from 0.03 to 0.99 for the countries and from 0.17 to 0.72 for the use categories. The lower values are for countries dominated by geothermal heat pump use as indicated by the 0.17 figure for the use category, whereas the high numbers are countries with high industrial use or continuous operation of pools for swimming and bathing. In addition, the worldwide capacity factor has dropped from 0.40 to 0.30 in the past five years, again due to the increase in geothermal heat pump use. Geothermal heat pumps have increased from 12.2% of the annual use to 33.2% since 2000. Capacity factors for the various categories of use have remaining approximately constant, except for geothermal heat pumps, as mentioned above, and for the small uses in the cooling/snow melt and others categories. The bathing and swimming use capacity factor has dropped slightly, probably due to better data reporting.

If on the other hand, we look at the capacity factors for direct-use without considering geothermal heat pumps, the values determined for 2005, 2000 and 1995 are: 0.46, 0.54, and 0.46, which are more consistent for the traditional direct heat uses of geothermal energy.

5. COUNTRY REVIEWS

The reports submitted for each country and available in the Proceedings of this Congress (WGC2005), are summarized below. All papers are referenced at the end of this paper, along with additional information from the recent literature and personal contacts to give a more complete overview of a particular country's development, program and prospect. The Congress received a total of 68 country update papers; however, a total 94 papers and personal communications were reviewed from about 80 countries, 71 of which reported some geothermal direct-use as summarized in Table 1.

5.1 Africa

Algeria: For the 2000 update Lund and Freeston (2001) used data from the 1995 update (Freeston, 1996) to obtain a set of numbers for the overall review: Thermal capacity 100 MWt, Energy use 1,586 TJ/year, Total flow 516kg/s. For this update a paper by Fekranoui and Kedaid, (2005) shows a total installed capacity of 152.3 MWt of which 2.3 MWt is for greenhouse heating, 0.1 MWt for space heating, and the rest for bathing and for balneology uses (149.9 MWt). No total energy use is given although the temperature range of the seven major spas is 98°C-37°C with flows from 80 to 8 l/s. It is reported that there are 240 hot springs and wells reported in the north of the country with 7,200 m^2 of greenhouses are heated by the albian geothermal water and a new project of heating 10,000 m^2 of greenhouses at El Qued. The geothermal water is also used for heating a building of 50 rooms. It is expected that the recent adoption of renewable energies law by government will encourage geothermal use. The authors estimate 36 TJ/yr for greenhouses, 2 TJ/yr for space heating, and 2,379 TJ/yr for bathing and swimming, based on expanding the 1995 numbers, for a total of 2,417 TJ/yr.

Egypt: There was no country update report from Egypt; however a paper by Idris (2000) and personal communications with the author describes several spas with bathing located in the country. The WGC2000 estimate of 1.0 MWt and 15 TJ/yr is assumed to still be current.

Ethiopia: The paper by Teklemariam and Beyene (2005), updates the WGC2000 paper giving details of the fields and development progress; however, there are no data on direct heat use, although it is known that there are a number of low enthalpy uses for resorts and bathing, including one in the capital, Addis Ababa. These are estimated at 1.0 MWt and 15 TJ/yr by the authors based on descriptions in Lund (1999).

Kenya: Mwangi (2005) reports that the Oserian Development Company now has a flower growing business utilizing a steam well leased from KenGen, on the Olkaria field. A heating system was installed in May 2003 and carbon dioxide from the well is also used for the flowers photosynthesis. The system started off by heating 3 hectares and is being expanded to 30 hectares. The company is planning to lease more wells for its future use. Oserian has also constructed a 1.8 MWe binary Ormat plant for use at the flower farm. Greenhouse heating amounts to 79.1 TJ/yr with a capacity of 10 MWt.

Tunisia: The geothermal resources in Tunisia were described in Ben Dhia and Bouri (1995). For the Congress in Japan in 2000 no update report was received, however a summary of greenhouse development in the Kebili region in the south of the country was used, where geothermal fluid is used for irrigation of the oasis and heating and irrigation of greenhouses (Lund and Freeston 2001). An official country update report was not available, however, Ben Mohamed (2005) reports on the further development of irrigation and greenhouse heating in Southern Tunisia. Now, 35 boreholes supply water mainly for irrigation of 16,000 hectares of oasis. About 1,500 l/s of geothermal water is exploited, 76% for oasis, 20% for 110 hectares (up from 95 ha in 2000) of greenhouses and the remainder for bathing and animal husbandry. No estimates are provided for the energy use, but the authors estimate the following based on WGC2000 data: greenhouses (24.1 MWt and 190.1 TJ/yr); bathing and swimming (0.9 MWt and 23 TJ/yr); and others (animal husbandry) (0.4 MWt and 6 TJ/yr); for a total of 25.4 MWt and 219.1 TJ/yr.

Uganda: Bahati and Tugume (2005) report on the status of geothermal developments in Uganda, which appears to be concentrated on feasibility studies for the development of a geothermal electric plant. No mention is made of direct-uses.

Zambia: Over 80 hot springs have been located in the country, Musonda and Sikazwe (2005), however we have no information on their use and there are no current plans to develop them for direct-use. A number of binary plants are being considered at some locations.

5.2 The Americas

5.2.1 Central American and the Caribbean Islands

A number of countries in Central America and the Caribbean Islands have developed geothermal electric power; however, as detailed below, only four countries and several Caribbean islands reported any geothermal direct-uses.

Caribbean Islands: Use of geothermal springs for bathing is reported on Nevis (The Baths) and on Dominica (Malgretout) (Huttrer, 2005). A total of 0.1 MWt of installed capacity and 2.8 TJ/yr are estimated for these two uses. No new uses have occurred since 1999, however, the potential for future development in this region appears good, especially on nine of the English speaking islands.

Costa Rica: The direct-use of geothermal energy has started with the heating of a few swimming pools (Mainieri, 2005). No other direct-uses are reported. Since, no data were given for the swimming pools, the authors estimate 1.0 MWt of installed capacity and 21.0 TJ/yr for three pools.

El Salvador: The authors (Rodriguez and Herrera, 2005) report that there is some potential for direct-use to dry grains and fruit, but as of yet, there is no significant activity in this area.

Guatemala: Bloteca located in the Amatitlan field, is a plant that produces concrete construction blocks and uses geothermal steam in the curing process. It has an installed capacity of 1.6 MWt and since 1998 has been using an equivalent of 40.4 TJ/yr. Adjacent to Bloteca, Agoindustrias la Laguna uses geothermal energy in a dehydration process through a downhole heat exchanger to supply heat to a fruit dehydration plant. Eco-Fruit is supplied to the local market and to a supermarket chain. This facility has an installed capacity estimated at 0.5 MWt and an annual energy use of 12.1 TJ/yr (Manzo, 2005, Meridia, 1999). The grand total is 2.1 MWt and 52.5 TJ/yr, which is considered industrial applications.

Honduras: No country update report was received from Honduras; thus, based on data from WGC2000, three pool sites were reported being heated. These were at Tamara, Gracias 1 and Gracias 2. A total of 0.7 MWt installed capacity and 17.0 TJ/yr utilization was reported, and is assumed to be the same today (Castillo and Salgado, 2000).

5.2.2 North America

Canada: The country's high temperature geothermal resource areas are predominantly in the western part of the country, principally in British Columbia and Yukon (Ghomshei, et al., 2005). Low and medium-temperature geothermal resources are present throughout Canada and growing interest in these opportunities hold promise for a bright future. Geothermal heat pumps are now in use in all Canadian Provinces, most notably in Manitoba and Ontario, where a creative financing environment has helped investors pay back the up-front capital expenditures from substantial savings in operating costs. The geothermal heat pump market has been growing in the country at the rate of 10 to 15% annually since 2000. Geothermal heat pumps are estimated to produce about 600 million kWh (2,160 TJ/yr) of energy savings, and about 200,000 tonnes in reduced greenhouse gas emissions annually. Over 30,000 units were installed by 2000 and in 2004 over 3,000 new units were installed. (An estimated 36,000 units have an installed capacity of 435 MWt – Lund, et al., 2004). About a third of all installed GHP systems are commercial/institutional or multiple residential. Direct-use applications from hot spring resorts, mainly located in the western provinces, are estimated at 100 million kWh annually (360 TJ/yr). A total of 12 major hot spring resorts in British Columbia, Yukon and Albert are reported to have individual flow rates of 6 to 32 L/s and a total installed capacity of 10 to 15 MWt. Heated water from abandoned mines is extracted to provide heat to commercial and residential uses adjacent to the mine in several areas in Canada, estimated at 26 TJ/yr with an installed capacity of 11 MWt (Jessop, 1995). The grand total for Canada is 2,546 TJ/yr and 461 MWt of installed capacity.

Mexico: In this country, geothermal energy is used mostly to generate electric energy, with some isolated direct-uses restricted to small pilot projects in the Los Azufres and Los Humeros geothermal fields (Guiterrez-Negrin and Quijano-Leon, 2005). There are also many places where hot or warm waters are used for recreation (bathing) and therapeutic purposes, but there are no coordinated efforts to promote it. Geothermal heat pumps are undeveloped in Mexico, except for some private and isolated cases with no available information. At Los Azufres, Comision Federal de Electricidad (CFE) has developed several pilot projects that include fruit drying, timber drying, greenhouse heating and space heating of a conference center and small cabins. Bathing and swimming, distributed in more than 160 sites, in 19 states in the country, account for 99.6% of the direct-use developments. A mushroom growing facility has also been developed. Space heating account for 0.5 MWt and 13.2 TJ/yr, greenhouse heating 0.004 MWt and 0.1 TJ/yr, agricultural drying 0.007 MWt and 0.2 TJ/yr, industrial applications (mushroom growing) 0.2 MWt and 4.9 TJ/yr, and bathing and swimming, 164.0 MWt and 1,913.4 TJ/yr, for a total of 164.7 MWt and 1,931.8 TJ/yr.

United States: Direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space and district heating, snow melting, agricultural drying, industrial applications and ground-source heat pumps (Lund, et al., 2005). The installed capacity is 7,817.4 MWt utilizing about 31,238 TJ/yr. Of this, 617 MWt and 9,024 TJ/yr are from traditional direct-use and the remainder from heat pumps (22,214 TJ/yr and 7,200 MWt). Most of the applications have experienced continual increase over the years; however, the largest annual growth has been in geothermal heat pumps. Space heating and agricultural drying have the largest annual energy growth rate of the direct-use categories, increasing in annual use by 9.3% and 10.4%, respectively, compounded over the past five years. From 2000, the growth rate for direct-use was 2.6% annually and heat pumps was 11.0% annually, for a combined total of 8.0% annually. The number of installed units for heat pumps is estimated at 600,000 – 12-kWt units, most of which are located in the mid-west, mid-Atlantic and southern states (from North Dakota to Florida). The traditional direct-use categories with their installed capacity and annual use are: individual space heating (146 MWt and

1,335 TJ/yr), district heating (84 MWt and 788 TJ/yr), cooling (<1 MWt and 15 TJ/yr), greenhouse heating (97 MWt and 766 TJ/yr), fish farming (138 MWt and 3012 TJ/yr), agricultural drying (36 MWt and 500 TJ/yr), industrial process heat (2 MWt and 48 TJ/yr), snow melting (2 MWt and 18 TJ/yr), bathing and swimming (112 MWt and 2,543 TJ/yr) for a combined capacity factor of 0.46. Major changes include the closing of a garlic dehydration plant and the additional of a second line to an onion dehydration plant in Nevada, the construction of a small district heating system in northern California, a greenhouse operation to raise tree seedlings added to the district heating system in Klamath Falls, Oregon and the closing of the zinc extraction plant in the Imperial Valley. Competition from cheap natural gas, import of roses from South America and dried garlic from China has contributed to the slowed growth of traditional direct-uses. There are some positive signs on the horizon with growth in space heating and greenhouse projects, along with the increased countrywide interest in geothermal heat pumps.

5.2.3 South America

Argentina: There has been an upsurge in the use of geothermal for direct-uses particularly in bathing and spa developments. Lund and Freeston (2001) reported a total installed capacity of 25.7 MWt and an annual energy use of 449 TJ/yr. Those numbers are now 149.9 MWt and 609.1 TJ/yr (Pesce, 2005). The areas of installed capacity are given, with the annual energy use estimated by the authors: space heating 22.4 MWt, (44.6 TJ/yr); greenhouse heating 21.5 MWt (21.2 TJ/yr); fish farming 7.0 MWt (8.2 TJ/yr); others (animal farming) 14 MWt (10.6 TJ/yr); snow melting 1.4 MWt (31.6 TJ/yr); and bathing and swimming 83.6 MWt (492.9 TJ/yr). Geothermal studies have been undertaken in nineteen new areas arriving to development and production stage in seven of them, prefeasibility stage in eleven and reconnaissance in one. The paper details these and gives locations and data on the fluids, etc. Geothermal resources in northwestern Argentina continue to be a major development area.

Brazil: Hamza, et al., (2005) shows that currently 360.1 MWt are installed with an annual energy use of 6,622.4 TJ/yr. Of this 355.9 MWt and 6,545.4 TJ/yr are utilized for bathing and swimming, the rest (4.2 MWt and 77.0 TJ/yr) in an industrial plant in particular for industrial wood processing and pre-heating water for use in boilers used for the production of coffee powder. About a dozen spring systems account for the bulk of this capacity with most of them located in central Brazil. The potential for large scale exploitation of low temperature geothermal water for industrial use and space heating is significant particularly in southern and southeastern parts of Brazil where cold winter seasons with temperature below 10^0C prevail under subtropical climate conditions. The paper gives information on location and characteristics of the springs.

Chile: Most of the investigations for the use and development of geothermal energy is concentrated on the high enthalpy end of the spectrum for electrical generation; however, Lahson, et al., (2005) shows that the installed capacity of direct heat as 8.7 MWt with an annual energy use of 131.1 TJ/yr for bathing and swimming. This has increased from that in Lund and Freeston (2001) of 0.4 MWt and 7 TJ/yr Most of this increase has come from further development of the bathing and swimming applications, where a total of 20 locations are described. There are additional private developments of spas, but no data are available. No other use is tabulated.

Columbia: In 2000, Alfaro and her colleagues estimated an installed capacity of 13.3 MWt and an annual use of 266 TJ/yr, Lund and Freeston (2001). They are now reporting 14.4 MWt and 287 TJ/yr, a slight increase (Alfaro, et al., 2005). The reported direct-use is entirely for bathing and swimming at 41 sites. In Columbia, the geothermal resources are still under preliminary exploration and currently there are no significant utilization developments. A description of exploration studies for the last five years is described. An inventory of hot springs is also presented with their geological setting and geochemistry of the fluids.

Ecuador: Geothermal utilization in the country is restricted to bathing resorts, balneology, mud baths and swimming pools (Beate and Salgado, 2005). A total of 22 locations are reported for an installed capacity of 5.2 MWt and 102.4 TJ/yr annual use; however, not all locations are reported. Exploration and reconnaissance studies have been carried out in Ecuador, mainly from the mid 1970s through the early 1990s; however little research as been carried out since. The production from renewable energy sources, is negligible, but is planned to increase in the future. Sites along the Ecuador-Columbia border and several other high and low-medium temperature geothermal prospects await state and private investment to be developed.

Peru: No report was filed on the utilization in Peru; however, based on personal communications with Huttrer (2000), the data reported in Lund and Freeston (2001) will be used: 2.4 MWt and 49 TJ/yr for seven spas.

Venezuela: No report was filed on the utilization in this country; however, based on a report by Urbani, (1999), Lund and Freeston (2001) estimated 0.7 MWt and 14 TJ/yr for several small spas.

5.3 ASIA

China: This country is again one of the major users of the direct-use of geothermal energy. Zheng, et al. (2005) discusses the latest developments. It appears that along with the restructuring of the economy, national investment in geothermal has decreased. However, as the living standard of the population has risen, geothermal has found favor in that the waters are used more for health, tourism, and balneology in various hot springs. Investors are looking to increase their investment, which has led to an upsurge in geothermal drilling and utilization particularly in the coastal regions of Beijing and Tianjin. The management of the resource also plays a big role particularly in the large cities. Here, efficiency in utilization has improved dramatically and environmental concerns are being addressed. For example, in Beijing the total rate of extraction of hot water has been kept stable and has even decreased slightly but energy utilization in terms of GWh produced has increased significantly. The data of Zheng, et al., (2005) shows that for the whole of China the installed capacity has risen to 3,687 MWt with an annual energy use of 45,373 TJ/yr (including 15 heat pump units ranging from 220 to 760-kW in capacity operating at an equivalent 2,880 full-load hours annually), from the 2000 (Lund and Freeston 2001) figures of 2,282 MWt and 37,908 TJ/yr an increase in annual energy use of about 20%. Geothermal space heating covers 12.7 million m^2 and greenhouse heating cover about 1.33 million m^2. There are about 1,600 public hot spring bathing houses and swimming pools, including about 430 where balneology and medical practices prevail in the country. The details of the specific uses are as follows: district heating (550 MWt and 6,391 TJ/yr); greenhouse heating (103 MWt and 1,176 TJ/yr); fish farming (174 MWt and 1,921 TJ/yr);

agricultural drying (80 MWt and 1,007 TJ/yr); industrial process heat (139 MWt and 2,603 TJ/yr); bathing and swimming (1,991 MWt and 25,095 TJ/yr); other uses (monitoring) (19 MWt and 611 TJ/yr); and heat pumps (631 MWt and 6,569 TJ/yr).

India: Chandrasekharam (2005) describes the uses and potential of the geothermal resources in the country. This includes a capacity 203 MWt and an annual energy use of 1,606.3 TJ/yr an increase from 80 MWt but a decrease from 2,517TJ/yr recorded in Lund and Freeston (2001). All the use is attributed to bathing and swimming although the text does mention the cooking of rice in large copper vessels to feed the pilgrims visiting the holy shrine at Manikaren. It is planned to utilize the waste heat from the Puga power plant, when built, for space and greenhouse heating in the Puga valley. No reference is made to the onion drying project in Andhra Pradesh and a project for removing cesium from the Puga waters.

Indonesia: The developments in Indonesia have continued to exploit the considerable resources for generation of electricity (Ibrahim, et al., 2005). There is no additional data on direct usage, only reference made to studies and research being undertaken for applications in the agriculture sector, and that development of direct utilization has taken place for more than ten years. Studies of the use of geothermal fluid for sterilizing the growing medium used in mushroom cultivation are ongoing at the Kamojang geothermal field. Reported by Lund and Freeston (2001) the use for bathing and swimming was 2.3MWt and 42.6 TJ/yr, which the authors assume has remained the same for the past five years.

Iran: This is a new country on our list of use of geothermal fluids for direct-heat purposes. Saffarzadeh and Noorollahi (2005) report that countrywide a capacity of 30.1 MWt and an annual energy use of 752.3 TJ/yr are currently used at 12 bathing and swimming sites. The prospects for further development, particularly in the north and northwest of the country, are under consideration. It is hoped that 2005 will see more detailed geoscientific studies with the drilling of exploratory wells and improvement of the current bathing and swimming facilities in the Sarein and Meshkinshar prospects. Other prospects are also under study for the application of an experimental greenhouse, fish farming, and space heating projects. An experimental heat pump is the first to be installed in the country at Tabriz in northwest Iran (Yari, et al., 2005). This unit provided a capacity of 6.3-kW with no estimate of the annual use.

Israel: The use of geothermal fluids in spas, greenhouses and for aquaculture has continued and expanded to an annual energy use of 2,193 TJ/yr. No installed capacity number are given, thus, the authors have estimated these by extending the WGC2000 data – the total is then estimated at 82.4 MWt This compares with 63.3 MWt, 1,713 TJ/yr the same parameters given in Lund and Freeston (2001). As reported in the 2001 paper, most of the fluid for the spas comes from abandoned deep oil wells. Some shallow wells were drilled for fish ponds with the greenhouse water using heat from deep water wells drilled in the Dead Sea rift and along the southern coastal plain (Levitte and Greitzer 2005). Geothermal water is used for both greenhouse and ground heating, using brackish water, with increases occurring in the Negev region (27.6 MWt and 512 TJ/yr); for fish farming which takes place in the Jordan Valley, and at Atlit-Maagan Michael along the Mediterranean coast; the latter which has increased significantly (31.4 MWt and 989 TJ/yr); and for swimming and bathing at spas at 23.4 MWt and 692 TJ/yr.

Japan: Kawazoe and Shirakura (2005) present their assessment of the direct-uses of geothermal energy in Japan. For the review they have excluded the hotels and Japanese style inns that utilize hot spring water for bathing. This makes comparison with the figures given in Lund and Freeston (2001) very difficult. The revised totals were reported as 1,167 MWt and 27,581 TJ/yr, which we believe were in error. The present authors of this paper are at this stage therefore quoting the data given in Kawazoe and Shirakura (2005). However, they do refer to a paper, New Energy Foundation (NEF)(2002), where a capacity of 409 MWt and annual energy use of 5,140 TJ/yr was estimated. The total hot springs and wells sources used for baths are reported at 16,800 by NEF. They show a total installed capacity of 413.4 MWt utilizing 5,161.1 TJ/yr of energy at a capacity factor of 0.4. Forty-one prefectures contribute to the total and usage is spread across the whole of the identified activities. The capacity and annual energy use are as follows: greenhouses (43.1 MWt and 428.5 TJ/yr); fish breeding (16.9 MWt and 212.3 TJ/yr); industrial (1.1 MWt and 27.3 TJ/yr); space heating (103.6 MWt and 1,410.0 TJ/yr); hot water supply and swimming pool (106.5 MWt and 2,583.7 TJ/yr); and, snow melting and air-conditioning (cooling) (assumed 70%-30% split since not specified) (96.7/41.5 MWt and 333.6/142.9 TJ/yr), ground heat uses, including heat pumps (4.0 MWt and 22.4 TJ/yr); and others (0.02 and 0.4 TJ/yr). Information on heat pumps was collected for 41 cases mainly from industrial companies, giving an estimated installed capacity of about 1.7 MWt (however, the 4.0 MWt stated above will be used) with additional development of this use of geothermal water planned for the future.

Jordan: Saudi and Swarieh (2005) report no further development of direct-uses of geothermal fluids since those reported in Lund and Freeston (2001). At that stage it was reported that the installed capacity was 153.3MWt and an annual energy use of 1,540TJ/yr for bathing and swimming at six sites, giving an overall capacity factor of 0.42. Future uses seems to be in connection with refrigerated warehouses using absorption refrigeration techniques for preserving fruits and vegetables or freezing fish and meat, and for fish farming and greenhouse heating.

Korea: Song, et al., (2005) estimate a capacity of 13.5 MWt and annual energy utilization of 163.3 TJ/yr for bathing and swimming at 11 sites, and an additional 3.4 MWt and 11.9 TJ/yr (in the heating mode) (4.5 TJ/yr in the cooling mode) for 30 geothermal heat pump sites, for a total of 16.9 MWt and 175.2 TJ/yr. It is expected that the geothermal heat pump will be utilized more in the future particularly for space heating and cooling applications in urban areas. A new district-heating project in the southeast of the peninsula was launched in 2003 aiming for a design of a practical system in 2005.

Mongolia: Another new country added to the direct-use list. Bignall, et al., (2005) discusses the geothermal background and potential for the country. Like many countries the numerous hot springs are utilized for heating, bathing and medicinal use. Domestic and foreign developers have conducted feasibility studies for small-scale energy development projects, as Mongolia presently depends on non-renewable sources of energy for all of its electric power requirements. National Sanatoriums (eight in total) have been constructed, which directly use thermal waters from shallow wells (typically <100m), while a further three sites use springs as popular tourist attractions. Currently despite a number of areas using geothermal heat for space and greenhouse heating, and bathing only one area, Shargaljuut, has data recorded of 1.7 MWt, with an annual energy use of 54 TJ/yr, capacity factor 1.0. However, Bingnall, et. al., do provide flow rates for the various uses along with some temperature changes ("delta T") – 15°C used. From this information, the authors are able to calculate the following approximate numbers: individual space heating (1.4 MWt and 44.0 TJ/yr); greenhouse heating (2.4 MWt and 74.0 TJ/yr); and bathing and swimming (3.0 MWt and 95.2 TJ/yr); for a total of 6.8 MWt and 213.2 TJ/yr. Bignall, et al. concluded that direct-use of the geothermal fluids could be used for district heating schemes, cashmere and wool processing, horticulture and balneology therapeutic purposes.

Nepal: Ranjit, (2005) reports a small increase in capacity and energy use since Lund and Freeston (2001). Capacity of 2.1 MWt and annual energy use of 51.4 TJ/yr compared to 1.1 MWt and 22 TJ/yr for 2001, all in the bathing and swimming category at 18 locations. There is still interest in developing the potential throughout the country. The completion of the new south-north road network is expected to open up the availability of some of the prospects in the more remote areas of the country. Also, definite governmental programs in the current Tenth Plan of Nepal (2002-2007) have yet to emerge.

Pakistan: Hossein, (2005) reviews the electrical industry in Pakistan, no direct heat is discussed.

Philippines: While the emphasis is on developing geothermal energy for the generation of electricity, Benito, et al., (2005) reports that the government is looking to increase non-power uses of geothermal energy. At present, direct-use is limited to an agriculture drying plant with a capacity of 1.6 MWt and an annual energy use of 26.9 TJ/yr, with a capacity factor of 0.52, for drying coconut meat and copra (agricultural drying) (Chua and Abito, 1994). In addition a further installed capacity of 1.7 MWt and annual energy use of 12.6 TJ/yr are estimated to be used for swimming and bathing giving totals of 3.3 MWt capacity and 39.5 TJ/yr energy use with an overall capacity factor of 0.39. There are plans to utilize geothermal for spas and balneological applications, which are being coordinated with hot spring resort owners and developers.

Saudi Arabia: Despite having a wealth of energy sources, petroleum, gas, solar, etc., there is interest in developing their considerable geothermal potential (Rehman and Shash, 2005). Currently 10 hot springs and three major harrats are of geothermal interest. Although none is being exploited at present, it is believed that some of the thermal springs can be utilized for electrical generation purposes.

Thailand: no papers was received from Thailand, so revised figures from Ramingwong, et al., (2000) are used: 1.7 MWt and 28.7 TJ/yr. A small crop drying facility and air conditioning unit using the exhaust from a 0.3 MWe Ormat plant was operating. The individual uses are: cooling (0.04 MWt and 0.3 TJ/yr); crop drying (0.04 MWt and 0.3 TJ/yr); and bathing and swimming (1.6 MWt and 28.1 TJ/yr).

Turkey: Of the 170 prospects that have been identified, 95% are in the low-to-medium enthalpy range, which is mostly suitable for direct-use applications (Simsek, et al., 2005). The installed capacity is now 1,177 MWt, up from 820 MWt in Lund and Freeston (2001) with a similar increase from 2001 of 15,756 TJ/yr to 19,623.1 TJ/yr in 2005. Most of the development has been in district heating where 65,000 residences (645 MWt and 6,015.4 TJ/yr) now have geothermal heating, along with individual space heating of 74 MWt and 816.8 TJ/yr. A total of 635,000 m^2 of greenhouses are heated by geothermal fluids, (131 MWt and 2,478.7 TJ/yr), and 327 MWt and 10,312.2 TJ/yr are utilized for geothermal heated pools for bathing and swimming. A total of 54 sites have a combined space heating and spa use of geothermal energy, and a total of 195 balneological facility use geothermal heat. About 120,000 tonnes of liquid carbon dioxide and dry ice are produced annually at the Kizildere power plant. The proven potential is calculated at 3,293 MWt, while the estimated geothermal potential for the country is estimated at 31,500 MWt, a figure which indicates 30% of the total residences in Turkey could be heated by geothermal. Targets have been set for the year 2010: 500 MWe power production and 3,500 MWt spaces heating. Increased tourism and the use of spas, together with government financial aid is seen as contributing to the achievement of these goals. Heat pumps are not currently being used, due to the high cost of electricity.

Vietnam: This is the first time we have had a report for this country. Estimates for direct-use of geothermal energy across the country indicate there are 269 geothermal prospects with surface temperatures above 30°C, with a total energy capacity of 649 MWt. Currently, a capacity of 1.4 MWt and 21.6 TJ/yr is used in a iodide salt production facility at Holvan, and 29.3 MWt and 58.9 TJ/yr for bathing and swimming at 19 sites (Cuong et al., 2005). The total direct-use is 30.7 MWt and 80.5 TJ/yr.

Yemen: No paper was submitted, thus, the 2000 figures of 1.0 MWt and 15 TJ/yr, mainly from hot springs which are used for bathing, both for health and recreation, will be used (Lund and Freeston, 2001).

5.4 Europe

5.4.1 Western and Northern Europe

Austria: Over the past 17 years a total of 63 geothermal exploration wells were drilled in the country (Goldbrunner, 2005). A large number of the wells were intended for accessing thermal water for balneology (curing, thermal spas, leisure resorts, hotels, etc.). Drilling activities focused on the Styrian Basin (SE Austria) and the Upper Austrian Molasse Basin (NE Austria). The installed capacity for direct utilization is 52.0 MWt and the annual energy use 779.9 TJ/yr. These included 45.5 MWt and 643.7 TJ/yr for district heating, 1.8 MWt and 26.4 TJ/yr for greenhouse heating, 2.1 MWt and 44.8 TJ/yr for industrial uses (assumed for CO_2 production), 2.6 MWt and 65.0 TJ/yr for bathing and swimming. Two district heating projects (Atlheim and Bad Blumau) receive cascaded water from low temperature binary power plants (105 and 110°C). The largest district-heating project in Central Europe is at Simbach-Braunau, which is a cross-border project between Austria and Germany having a capacity of 30 MWt of which 9.3 MWt is from geothermal. An assumed 25,000 geothermal heat pumps are installed, estimated to provide 300 MWt of capacity and 400 GWh/yr (1,450 TJ/yr) (Lund, et al., 2004). The totals for the country are 2,229.9 TJ/yr and 352.0 MWt.

Belgium: Only an abstract was submitted for WGC2005, thus information on geothermal uses is only estimated. The use of geothermal energy in Belgium is focused on shallow applications (Hoes, 2004). The market for geothermal heat pumps has grown significantly over the past years, with open-loop type using pumped groundwater being the most common. Most of the applications are in the eastern provinces of the country. Aquifer thermal energy storage is also being utilized in nine locations. As reported for WGC2000 (Berckmans and Vandenberge, 1998), a total installed capacity is estimated at 3.9 MWt and annual energy use of 107.2 TJ. The energy is used mainly for direct space heating, with one greenhouse, a fish farm, and swimming pool heating installations reported. 53.8 TJ/yr (2.1 MWt) is reported for space heating, 22.1 TJ/yr (0.9 MWt) for the greenhouse, 10.1 TJ/yr (0.3 MWt) for aquaculture, 13.1 TJ/yr (0.5 MWt) for agricultural drying and 8.1 TJ/yr (0.1 MWt) for swimming pools. Geothermal heat pump numbers are not reported, but are estimated to be about 5,000 units which would provide approximately 60 MWt capacity and 324 TJ/yr of utilization (assuming 1,500 full-load hours/yr) (Curtis, et al., 2005). The total for Belgium is 63.9 MWt and 431.2 TJ/yr.

Denmark: Two district heating plants using absorption heat pumps are presently in operation in the country (Mahler and Magtengaard, 2005). The plant at Thisted in northern Jutland has been operating since 1984. The plant was enlarged to 7 MWt capacity producing 80 TJ/yr of heat in 2000-2001. It presently uses 200 m^3/h of 44^oC of warm water from a depth of 1.25 km. The most recent installation, the Margretheholm Plant in Copenhagen, started operation in the fall of 2004. Absorption heat pumps will use well water directly from the sea. These wells are drilled to over two kilometer in depth and produce 73^oC water. A total of 235 m^3/h of 19% saline water will eventually produce 380 TJ/yr of heat with an installed capacity of 14.2 MWt. In addition, a total of 250 groundwater based heat pumps and 43,000 others are in operation (about 10 to 20% vertical closed-loop). They are extracting approximately 3,900 TJ/yr with an installed capacity estimated at 800 MWt (assuming 2,000 full-load operating hours/yr). The total for Denmark is 821.2 MWt and 4,360 TJ/yr.

Finland: No country update report was completed for WGC2005, thus, these estimated are based on expanded numbers from the report for WGC2000 (Kukkonen, 2000). At that time the author reported 10,000 units producing 484 TJ/yr from an installed capacity of 80.5 MWt and 4,000 equivalent full load hours per year. Based on recent data from the Finish Heat Pump Association (Suomen Lampopumppuyhdistys), heat pump sales have increased by 50 to 100%/yr over the last five years so that in 2002 there were an estimated 25,000 geothermal units installed in the country (Hirvonen, 2002). An average residence uses an average of 20,000 kWh/yr from 5 to 8-kW capacity (average COP of 3.1). Thus, the total installed capacity is 162.5 MWt using 1,220 TJ/yr of geothermal energy (based on an average of 6.5-kW capacity). Extrapolating this to 2004, the estimate values are 40,000 units using 1,950 TJ/yr from an installed capacity of 260 MWt.

France: Since 1998, the development of geothermal energy in the country has been concentrated into four areas – two of which are related to direct-use: 1) geothermal district heating systems, and 2) geothermal heat pumps (Laplaige, et al., 2005). The over 30 geothermal district heating systems are still in operation due to public-support and connections of new clients. Some 10,000 apartments have recently been connected bring the total to approximately 170,000. Geothermal heat pumps have been undergoing a regular and significant expansion in the past few years due to the influence of the French Electricity Board and the French Environment and Energy Management Agency with support from the private sector. The objective for 2010 is to equip 20% of new single-family houses, or some 40,000 units per year. Direct-use of geothermal energy includes: district heating (other than heat pumps) (243.4 MWt and 4,030.3 TJ/yr), greenhouse heating (12.6 MWt and 120.7 TJ/yr), fish farming (20.8 MWt and 309.3 TJ/yr), and bathing and swimming (15.1 MWt and 266.6 TJ/yr). A little over one million geothermal heat pump units contribute 16.1 MWt and 468.8 TJ/yr of heat energy. Of the 34 district heating systems, 29 are in the Paris Basin and 5 in the Aquitaine Basin. There are also 10 large fish farms and greenhouse complexes, and 12 swimming pool and aquatic leisure complexes. The total direct-use for the country is thus: 308.0 MWt installed capacity and 5,195.7 TJ/yr utilization.

Germany: The country has 30 geothermal direct-use installations operating with a total installed thermal capacity over 100 kWt (Schellschmidt, et al., 2005). These installations include district heating, spas with space heating, greenhouses, and individual clusters of space heat and cooling. Most of the district-heating systems are located in the Northern German Basin, the Molasse Basin in southern Germany, or along the Upper Rhine Graben. There are also numerous small- and medium-sized decentralized geothermal heat pump units with an installed capacity exceeding 400 MWt. The first geothermal plant for electric power generation in Germany, working since 2003, is located at Neustadt-Glewe with an installed capacity of 230 kWe. In addition, 10.7 MWt are used for district and space heating in a cascading mode. Fifteen projects are scheduled for completion by the years 2005-2010, yielding an estimated installed capacity of 126 MWt and electric power of 18 MWe. In addition, there are about 30,000 geothermal heat pumps installed in Germany, rated at a total of 400 MWt and providing 2,200 TJ/yr of energy from the earth. Other direct-uses contribute in the form of individual space heating 2.8 MWt and 15.1 TJ/yr; district heating of 89.8 MWt and 589.2 TJ/yr; and bathing and swimming of 12.0 MWt and 105.5 TJ/yr. The total direct-use for Germany is 504.6 MWt installed capacity and 2,909.8 TJ/yr of energy use.

Greece: The installed capacity in the country for the direct utilization of geothermal energy is approximately 75 MWt (Fytikas, et al., 2005). About half of this capacity is for thermal spas (in a few cases combined with space heating) and heating of open and closed pools. Two recent trends in Greece include the reduction in greenhouse and soil heating, even thought the latter showed a considerable increase in the previous five years, and the diversification of the uses. New uses include fish farming, spirulina growing and vegetable and fruit dehydration. Earth-coupled and groundwater (or seawater) heat pumps have shown a significant increase in the past five years, amounting to 19 large capacity units totaling 1.0 MWt and producing 5.8 TJ/yr of thermal energy, with other smaller units combining for a grand total of 4.0 MWt and 39.1 TJ/yr. Interesting direct-use applications are soil heating for growing asparagus covering about 12 ha; a tomato dehydration plant which has produced more than 15 tonnes of "sun-dried" tomatoes since 2002; a desalination plant on Kimolos Island; and cultivation of a green-blue algae spirulina utilizing the geothermal waters for both the heat and dissolved CO_2. In summary, geothermal is used for the following direct-use applications: individual space heating (1.2 MWt and 14.3 TJ/yr); greenhouse heating (22.2 MWt and 231.2 TJ/yr); fish farming (8.9 MWt and 72.0 TJ/yr); agricultural drying (0.2 MWt and 1.5 TJ/yr); bathing and swimming (36.0 MWt and 181.6 TJ/yr) and others (spirulina cultivation and water desalination of 2.3 MWt and 27.5 TJ/yr) for a grand total (including heat pumps) of 74.8 MWt and 567.2 TJ/yr.

Iceland: Geothermal resources are abundant in the country, with over half of the primary energy supply coming from this resource (Ragnarsson, 2005). The main use of geothermal energy is for space heating, used by 87% of the houses in the country. Other uses include swimming pools, snow melting, industrial applications, greenhouses and fish farming. In recent years, geothermal space heating has increased in Reykjavik, due to population increases. Several new district heating systems have come on line throughout the country, as well as small heating utilities in rural areas. Space heating is expected to increase to 92% of the houses in the country in the next few decades. Heating of swimming pools is one of the most important uses after space heating, as there are about 130 geothermally heated pools in the country. Snow melting on pavements has increased during the last two decades, using spent water from house heating at about 35^{o}C for deicing of sidewalks and parking spaces. The total area heated in Iceland is around 740,000 m^2 of which 74% is in Reykjavik. The major industrial application is the diatomite drying plant at Lake Myvatn in northern Iceland. It produces some 28,000 tonnes of diatomite filter aids for export annually. A seaweed drying plant is located in west Iceland, which produces 2,000 to 4,000 tonnes of rockweed and kelp meal annually. A salt product plant, which operates intermittently, produces salt for the domestic fishing industry and well as for export. Liquid carbon dioxide is produced from geothermal fluid that has a gas content of 1.4% by weight. The plant produces some 2,000 tonnes annually. Geothermal energy has been used in fish drying for about 25 years. The main application has been indoor drying of salted fish, cod heads, small fish, stock fish, and other products. Today about 17 small companies use geothermal energy for fish drying producing about 15,000 tonnes annually for export, mainly to Nigeria. Other smaller uses include retreading of car tires, wool washing, curing cement blocks and steam baking of bread. Geothermally heated greenhouses produce vegetables and flowers and cover about 20 hectares. An estimated 10.5 hectares of soil heating are developed to provide early thawing of the soil and bring vegetables to market sooner. Fish farming at about 50 plants produce about 4,000 tonnes annually from geothermally heated waters, the majority of which is salmon, with some arctic char and trout. Geothermal heat pumps are used on a limited basis, with only three locations reported. In summary the various direct-uses are as follows: district heating (1,350 MWt and 17,223 TJ/yr); greenhouse heating (55 MWt and 940 TJ/yr); fish farming (65 MWt and 1,680 TJ/yr); industrial process heat (65 MWt and 1,600 TJ/yr); snow melting (182 MWt and 1,150 TJ/yr); bathing and swimming (70 MWt and 1,200 TJ/yr); and geothermal heat pumps (4 MWt and 20 TJ/yr). The grand total is 1,791 MWt of installed capacity and 23,813 TJ/yr of thermal energy used.

Ireland: This country is new to the geothermal direct-use report, as nothing was reported for WGC2000, even though geothermal use, in the form of heat pumps, had been ongoing. Even though the country is “impoverished” in geothermal resources and has only normal geothermal gradient (mean of 25^{o}C/km), it does have 42 documented warm springs in the eastern and southern parts of the country ranging in temperature from 13 to 24.7^{o}C (O’Connell, et al, 2005). One warm spring has been exploited to heat a municipal swimming pool with a 100-kWt heat pump. The main geothermal energy use in the country is for space heating using geothermal heat pumps, mainly for residential use, but also covering smaller public buildings. Currently there are 1500 units installed in the 12 to 14-kWt size, but with a few larger units of about 20 MWt capacity. Growth is strong. One unusual source of energy being developed is the shallow groundwater in gravels beneath urban areas where the urban “heat island” effect gives rise to slightly enhanced groundwater temperatures. This has been utilized successfully in a small number of projects in Dublin and is currently being developed in Cork, where it has greater potential. A summary of the direct-use in Ireland is: air conditioning (0.2 MWt and 0.5 TJ/yr); bathing and swimming (0.2 MWt and 20 TJ/yr); and geothermal heat pumps (19.6 MWt and a peak use of 83.6 TJ/yr); for a total of 20.0 MWt installed capacity and a peak utilization of 104.1 TJ/yr.

Italy: Direct-uses in this country have remained almost stable over the past five years (Borhetti, et al., 2005). New developments include the Pomarance district heating system and refurbishing of the Floramiata greenhouse plant in Tuscany, as well as some activities in the geothermal heat pump section in northern Italy. If fluids above 30^{o}C are considered, the prevailing use for the heating of health spas and balneology, followed by space heating and heating of greenhouses. There are several minor industrial applications (cheese factory, boric acid and carbon dioxide production), and two aquaculture facilities. Geothermal heat pumps are being installed about 500 units per year with a total of around 6,000 units installed. Most are groundwater types, but about 100 are closed loop type. There are also several commercial applications, including the conditioning of a mattress factory. The installed capacity and annual energy use for the various use types are: individual space heating (57.6 MWt and 1,108 TJ/yr); district heating (74.2 MWt and 603 TJ/yr); greenhouse heating (94.2 MWt and 1,130 TJ/yr); fish farming (91.6 MWt and 1,488 TJ/yr); industrial process heat (10.2 MWt and 47 TJ/yr); bathing and swimming (158.8 MWt and 2,678 TJ/yr); and geothermal heat pumps (120 MWt and 500 TJ/yr). The total is then: 606.6 MWt and 7,554 TJ/yr.

Netherlands: The use of the shallow underground for extraction and storage of thermal energy were the initial investigations starting in the 1980s (van Heekeren, et at., 2005). The initial scope was to store solar energy for space heating in winter, and later this was expanded to geothermal heat pumps for both heating and cooling. These efforts were focused on large-scale applications using groundwater wells to store and extract thermal energy. In the late 1990s, borehole heat exchangers started to play a more important role using geothermal heat pumps. Geothermal installations use doublets with a range between 3.5 and 12 MWt to meet the heat demand of an equivalent 500 to 2,000 houses. Today, there are a reported 1,600 geothermal heat pump units in place with an installed capacity of 253.5 MWt and annual energy use of 685 TJ.

Norway: There is no geothermal direct heat use in the country; however, about 100 larger geothermal heat pump systems for commercial building or multi-family dwelling have been installed (Midttrømme, 2005). Traditionally, these systems are only used for heating, but some systems use the exhaust ventilation to recharge the boreholes. An increased interest in cooling in the commercial and industrial sectors is favoring ground source heat pumps and underground thermal energy storage systems. As of 2003, there were 55,100 heat pumps installed in Norway, of which 5% were geothermal (2,755). The largest installation in Europe is the heating and cooling of 180,000 m^2 of a school, shopping center, hotel, offices and residential area using 180 bores providing an output of 9 MWt heating and 6 MWt cooling (Curtis, el al., 2005). Today, the estimated number of installed units is 13,000 with a capacity of 450 MWt. Over 90% of these installations are vertical boreholes groundwater types with a single U-shaped pipe installed. No figure on annual energy use was report, but using 2,000 full load hours per year and a COP of 3.5, the annual energy use is estimated at 2,314 TJ/yr.

Portugal: Direct-use applications on the Mainland and Azores are restricted to small district heating operations, greenhouse heating and balneological applications (Carvalho, et al., 2005). District heating projects are at Chaves in northern Portugal, a S. Pedro do Sul in central Portugal and at the Lisbon Air Force Hospital. Greenhouse heating is found at S. Pedro do Sul and at Sao Miguel on the Azores. The latter greenhouse operation is a demonstration facility, where water is cascaded from the Pico Vermelho geothermal power plant. Balneological activities are quite popular in Portugal, with about 30 locations reported on the Mainland and four on the Azores. Only one geothermal heat pump operation is known, and it is presently out of service. The installed capacity and annual energy use for the various direct-use applications are as follows: district heating (1.5 MWt and 12.9 TJ/yr); greenhouse heating (1.8 MWt and 13.8 TJ/yr); bathing and swimming (27.1 MWt and 358.6 TJ/yr); and the single heat pump installation (0.2 MWt and 0 TJ/yr). The grand total is 30.6 MWt and 385.3 TJ/yr.

Spain: This is the first report on geothermal direct-use for this country, even though the low-temperature resources have been used on a limited scale for a number of years. Geothermal resources exploration started in Spain in 1974, and by today more than 70 projects have been undertaken in order to explore and assess the geothermal potential (Sanchez-Guzman and Noceda-Marquez, 2005). Low-temperature geothermal sites are currently being utilized on a small scale. Fluids are being used for heating and to provide hot water to spa buildings in Lugo, Arnedillo, Fitero, Monbrio del Camp, Archena and Sierra Alhamilla. In Orense and Lerida, geothermal waters are being used to heat homes and schools. Greenhouses are heated at Monbrio del Camp, Cartagena and Mazarron, and Zujar. The heated greenhouses cover over 10 hectares. The installed capacity and annual energy use of individual applications of direct-use are: individual space heating (4.8 MWt and 102.3 TJ/yr); greenhouse heating (14.9 MWt and 192.4 TJ/yr); and swimming and bathing (2.6 MWt and 52.5 TJ/yr). No geothermal heat pumps uses are reported. The total is 22.3 MWt and 347.2 TJ/yr.

Sweden: The country update report for this country is incomplete and only reports one large geothermal heat pumps project in Lund, which has been in operation for 20 years (Bjelm, 2005). This project delivers base load heat to a district-heating network providing about 40% of the city's energy demand with 4 MWt of installed capacity. The author also reports two other projects under exploration and completion at Scania and Malmö. However, there are many other smaller geothermal heat pump installations in Sweden as report by Curtis, et al., (2005). Heat pumps gained popularity in the country in the early 1980's and by 1985 about 50,000 units had been installed. Today about 275,000 residential units are installed and are the most popular type of heating devices for these small residential buildings with hydronic systems with an average capacity of 12-kWt and run time of 3,600 hours per year producing 7,900 GWh (28,440 TJ/yr) (Hellstrőm, 2004). In addition to the residential section, there are also some large-scale installations for district heating networks with an estimated number of units of 600 with and average run time of 4,000 hour and average unit size of 900-kWt extracting 2,100 GWh/yr (7,560 TJ/yr). The total installed capacity and annual energy use, with a seasonal performance factor of 3.0, is now estimated at 10,000 GWh/yr (36,000 TJ/yr) and 3,840 MWt (Hellstrőm, 2004).

Switzerland: Geothermal energy direct-use in the form of geothermal heat pumps is growing at a rate of up to 15% annually in the country. The reasons for this rapid market penetration are technical, economic and environmental. With over one GHP unit per two km^2, the installed density is one the highest in the world (Rybach and Gorhan, 2005). In addition, novel applications, like the use of warm tunnel waters, "geo-structures" and road and runway de-icing are emerging. Over 1,000 boreholes are drilled every year to install double U-tube borehole heat exchangers (BHE) in the ground. In 2003, a total of 550 km of BHE boreholes were drilled. Much of the support for geothermal development in Switzerland was due to the extensive energy program, called SwissEnergy, initiated by the Swiss Government in 2001. The program supports and promotes, as its central issue, the use of indigenous and renewable energy. Today, there are over 30,000 geothermal heat pump units installed in the country with an average equivalent of 1,800 full-load operating hours per year. Warm tunnel drainage waters, transported by gravity to tunnel portals, are used at various locations for space heating, and "geo-structures" which are underground building construction elements equipped with heat exchanger pipes, such as foundation piles at the new airport terminal in Zurich, are some of the recent novel applications of geothermal energy. The installed capacity and annual energy use of the various uses of geothermal energy are: district heating (6.1 MWt and 134 TJ/yr); air conditioning (2.2 MWt and 11 TJ/yr); snow melting (0.1 MWt and 0.3 TJ/yr); and bathing and swimming (40.8 MWt and 1,230 TJ/yr). Geothermal heat pumps account for 532.4 MWt and 2,854 TJ/yr. The total for the country is then: 581.6 MWt and 4,229.3 TJ/yr.

United Kingdom: The exploitation of geothermal resources in the country continues to be minimal (Batchelor, et al., 2005). There are no high temperature resources and very limited development of low- and medium-enthalpy resources. There is, however, an increasing awareness of the use of groundwater for heating and cooling domestic, commercial and public buildings, and a number of high profile projects have been undertaken. The use of flooded mine workings such as is done in Canada, is under consideration. The City of Southampton Energy Scheme remains the only major exploitation of low-enthalpy geothermal energy in the UK. The district heating system has become a combined heat and power scheme for 3,000 homes, 10 schools and numerous commercial buildings. More recently, ground source heat pumps have at last been recognized as having a role to play in the delivery of heating and/or cooling and domestic hot water. More specific, the country now understands that ground source heat pumps, connected to the UK electricity grid, offer very substantial reductions in overall carbon emissions compared to conventional fossil fueled systems. This notion has been incorporated into several official energy programs. The present estimate is that there are about 550 units installed in the country with an installed capacity of 10.2 MWt and an annual energy use of 45.6 TJ/yr based on 1,800 equivalent full-load operating hours per year.

5.4.2 Central and Eastern Europe

Albania: The paper represents a summary of the important results of the monograph: "Atlas of Geothermal Resources in Albania," published in 2004. The atlas shows that there are many thermal springs and wells of low enthalpy, with temperatures up to 65.5°C, in the country (Frasheri and Frasheri, 2005). Many abandoned oil and gas wells are being investigated for geothermal direct heat use. Thus, there are many possibilities for direct-use, especially for hotel and spa heating to develop the tourist industry. Five locations are reported using geothermal waters for bathing and balneology with a combined installed capacity of 9.6 MWt and an annual energy use of 8.5 TJ.

Bulgaria: Geothermal development in the country has not progressed significantly in the past five years. Instead, it has been a time of testing and completing new legislation concerning thermal waters and geothermal energy use (Bojadgieva, et al., 2005). Major direct geothermal uses include balneology, space heating and air-conditioning, domestic hot water heating, greenhouse and swimming pool heating, bottling of potable water and microalgae cultivation. More recently, geothermal heat pumps are being installed, mainly in the capital of Sofia starting in 1999 – about half of which are used for cooling. A total of 19 units are reported, varying between 7.2 and 45.4-kWt of installed capacity running an equivalent of 2,500 full load hours annually. Some of the more unusual uses of geothermal energy are for the production of iodine paste and methane extraction at a small plant on the Black Sea coast; 41 privately owned bottling companies; and an installation for open microalgae mass cultivation (spirulina). The summary of the various direct-uses are as follows: individual space heating (49.7 MWt and 721.6 TJ/yr); air-conditioning (9.8 MWt and 95.8 TJ/yr); greenhouse heating (16.9 MWt and 261.2 TJ/yr); bathing and swimming (25.6 MWt and 557.0 TJ/yr); others (bottling, raising spirulina, producing iodine paste, and methane extraction) (7.3 MWt and 31.5 TJ/yr); and geothermal heat pumps (0.3 MWt and 4.4 TJ/yr), for a total of 109.6 MWt and 1,671.5 TJ/yr.

Croatia: There are 28 geothermal resource reservoirs in the country, of which, 18 are being utilized (Jelic, et al., 2005). The majority of the geothermal utilizations are at spas, which usually includes hospitals and hotels, along with swimming pools and other therapeutic and recreational facilities. Except for natural springs, some of which have been used for centuries, geothermal waters supplied to these facilities are produced from shallow wells, drilled during the last few decades. Some of the water is used for balneological and recreational purposes, whereas others are used for space heating. A total of 36.7 MWt of installed capacity and 189.6 TJ/yr are used for individual space heating, and 77.3 MWt and 492.1 TJ/yr used for bathing and swimming, for a grand total of 114.0 MWt and 681.7 TJ/yr of direct utilization.

Czech Republic: Geothermal energy in the country was studied in detail over the last ten years (Myslil, et al., 2005). Geothermal energy is included in the country's energy policy as a renewable source of energy for the future period up to 2020, according to the Ministry of Industry and Business. The direct-use of thermal water in spas and swimming pools dates back several hundred years. A total of 11 major spas and thermal springs are listed, the most famous being Karlovy Vary (Karlsbad) and Marianske Lazně (Marienbad). There are over 1,000 geothermal heat pumps installed each with an average capacity of 20-kWt. One installation is in a mine for heating the mine facilities and adjacent administration buildings. The only capacity figure given is a total of 200 MWt for the heat pumps, thus, assuming a COP of 3.5 and 2,200 equivalent full-load hours per year, gives 1,130 TJ/yr as the estimated utilization. The geothermal use for the spas is estimated 4.5 MWt capacity and 90 TJ/yr (Lund, 1990). The total for the country is then: 204.5 MWt and 1,220 TJ/yr.

Hungary: During the last four years there have been 12 new geothermal developments in the country (Arpasi, 2005). The main consumers of geothermal heat remain in the agriculture industry for the heating of greenhouses, and for spas and pools. Other uses include district heating and the heating of domestic hot water. The number of organizations using geothermal heat was 130; the number of settlements using the heat was 45, and the number of spas 10. Approximately 2,655 dwelling in nine cities are heated through district heating systems. Unfortunately, many of the systems are old and outdated. Even though a Hungarian scientist, Prof. Heller, patented a geothermal heat pump in 1948, and thermal water was also used to heat the Hungarian Parliament building up to 1953, geothermal heat pumps have not been utilized to any major extent in Hungary. The total estimated installed capacity for heat pumps is 4.0 MWt, which should produce 22.6 TJ/yr. The capacity and annual use for other direct-use applications include: space heating (100.6 MWt and 1,016.7 TJ/yr) of which 80% is assumed to be district heating based on the WGC2000 country update (80.5 MWt and 813.4 TJ/yr), which gives 20.1 MWt and 203.3 TJ/yr for individual use; greenhouse heating (196.7 MWt and 1,502.5 TJ/yr); bathing and swimming (350 MWt and an estimated 5,040 TJ/yr – not reported) and other uses (not specified) (42.9 MWt and 358 TJ/yr), for a total, including heat pumps, of: 694.2 MWt and 7,939.8 TJ/yr.

Lithuania: The use of geothermal energy for district heating started in 2000 with the construction of the first geothermal demonstration plant in the country at Klaipeda on the Baltic Sea coast (Zinevicius, et al., 2005). Absorption heat pumps extract energy from 38°C water producing 215,000 MWh of energy from 41 MWt of installed capacity. Currently, geothermal investigations are being carried out in several cities and towns, mainly in the western part of Lithuania. Since 1996, more than 200 geothermal heat pumps have been installed for heating single-family houses. The installed capacity of these units, including the plant at Klaipeda, is 21.3 MWt producing 458.0 TJ/yr.

Macedonia: Geothermal development in the country has been stagnant for the past five years (Popovski, et al., 2005). The largest greenhouse project in Gevgelia, at 22.5 hectares, was abandoned and the organizational structure of the Bansko geothermal project abandoned. There have been no new investments in exploration and the development of new projects. The rice drying plant at Kotchany has been shut down. At present, seven geothermal projects and six spas use geothermal energy in the country. In the future, a "Geothermal Atlas of Macedonia" will be prepared, along with renewed interest in numerous geothermal projects such as the second phase of the Kocani geothermal system, completion of the Bansko system and reconstruction of the heating installation at the Hotel "Car Samuil" in Bansko, along with improving a number of spas. At present the installed capacity and annual energy use in Macedonia for the various uses are as follows: individual space heating (2.5 MWt and 25.8 TJ/yr); greenhouse heating (58.8 MWt and 557.5 TJ/yr);

and for balneology and hot water heating (1.0 MWt and 15.3 TJ/yr); for a total of 62.3 MWt and 598.6 TJ/yr.

Poland: Since 1992, five geothermal heating plants have been brought on-line (Kepinska, 2005). Compared to WGC2000, the installed thermal capacity and heat sales have increased significantly, especially after the extension of the Podhale project and the linking of a large number of clients in Zakopane, the main town in the region of southern Poland, as well as significant heat pump installations elsewhere in recent years. The five new space-heating plants are in the Podhale region and at Slomniki (southern Poland), Pyrzyce (NW Poland), and Mszczonow and Uniejow (central Poland). Each location uses water of different characteristics and their operations and uses of geothermal water differ. Among them are plants with some gas peaking, integrated ones with large gas contributions, and a plant integrating groundwater heat pumps with gas and fuel oil boilers. Geothermal waters are also used at seven spas. By-products, such as iodine-bromine, salts and CO_2 are extracted from geothermal waters. It is estimated that there are 8,000 ground-source heat pumps within the country with an installed capacity of at least 80 MWt and heat production of 500 TJ/yr. In addition, 23.6 MWt and 74.4 TJ/yr are attributed to absorption heat pumps at geothermal plants giving a total of 103.6 MWt and 574.4 TJ/yr for all heat pumps. Four different geothermal projects are at varies stages of development for the future. The various uses of geothermal energy in the country are as follows: district heating (59.2 MWt and 232.0 TJ/yr); greenhouse heating (along with fish farming and wood drying – not separated) (1.0 MWt and 4.0 TJ/yr); bathing and swimming (6.8 MWt and 26.9 TJ/yr); industrial applications (salt and CO_2 extraction) (0.3 MWt and 1.0 TJ/yr); for a total, including heat pumps of 170.9 MWt and 838.3 TJ/yr.

Romania: Due to problems with the economy of the country, only three new geothermal projects were completed during the last five years: one for direct heat use and two for bathing and swimming (Rosca, et al., 2005). Most of the geothermal projects completed prior to 1999 are still in operation, with some exceptions – mainly in the greenhouse area, which has decreased by almost 50%. Of the 96 direct-use wells in operation in 38 locations, 37 are exclusively used for health and recreational bathing. No geothermal heat pump use is reported. Several district heating systems, at Beius and Ramnicu Valcea, along with a hospital at Balotesti are being considering for future geothermal heat supply. Today, the various geothermal uses are as follows: district heating (57.2 MWt and 1,129.0 TJ/yr); greenhouse heating (28.3 MWt and 486.0 TJ/yr); fish farming (3.1 MWt and 65.0 TJ/yr); industrial process heat (14.1 MWt and 246.0 TJ/yr); and bathing and swimming (42.4 MWt and 915.0 TJ/yr); for a total of 145.1 MWt and 2,841 TJ/yr.

Serbia: The most common use of geothermal energy in the country are the traditional ones: balneology and recreation (Milivojevic and Martinovic, 2005). Archeological evidence indicates that the Romans developed spas in a number of localities in Serbia. Today there are 59 thermal water spas used for balneology, sports and recreation, and as tourist centers. Nine mineral water bottling companies also bottle thermal waters. Space heating is limited, and small in comparison to the potential. Geothermal waters are also used for heating greenhouses, pig farms, poultry farm, textile workshop, and industrial processes such as for carpet, leather and textile factories. A project has just been completed for drying wheat and other cereals. A small use of geothermal heat pumps is reported: nine units with an installed capacity of 6.0 MWt and producing 40 TJ/yr of heat; however, the prospects for the use of heat pumps from ground water in alluvial deposits along major rivers are very good. The prospects for using thermal water in greenhouses, aquaculture, and district heating are promising in the areas west of Belgrade. Over 40 sites with geothermal heat use are reported, the installed capacity and annual energy use for each type of use are as follows: space heating (assumed district heating) (19.7 MWt and 575 TJ/yr); bathing and swimming (36.0 MWt and 1,150 TJ/yr); agricultural drying (0.7 MWt and 22 TJ/yr); greenhouse heating (15.4 MWt and 256 TJ/yr); fish farming (6.4 MWt and 211 TJ/yr); industrial process heat (4.6 MWt and 121 TJ/yr); for a total, including heat pumps, of 88.8 MWt and 2,375 TJ/yr.

Slovak Republic: Geothermal water in the country is used in agricultural farms, for space heating, fish farming and recreational purposes (swimming pools) (Fendek and Fendekova, 2005). In 12 agricultural farms geothermal water is used for greenhouse and soil heating. This allows the early production of vegetables and flowers. The total area covered by greenhouses is about 25.86 hectares. The number of locations where geothermal water is used for space heating has increased significantly – from six in 1999 to 13 in 2004. It is used to heat hotels, blocks of flats, a hospital, a sport hall, and a miner's dressing room along with a coalmine. Eight geothermal heat pump installations are reported with a total installed capacity of 1.4 MWt and producing 12.1 TJ/yr of heat. A total of 32 individual projects using thermal energy are reported for the Slovak Republic, with a major district-heating project being proposed for the eastern city of Kosice. The individual direct-heat uses are: district heating (31.6 MWt and 576.9 TJ/yr); greenhouse heating (31.8 MWt and 502.3 TJ/yr); fish farming (4.6 MWt and 72.4 TJ/yr); and bathing and swimming (118.3 MWt and 1,870.3 TJ/yr); for a total, including heat pumps; of 187.7 MWt and 3,034.0 TJ/yr.

Slovenia: Geothermal research and development in the country in the past five years has been somewhat lower compared to the previous periods (Rajver and Lapanje, 2005). The direct-use of geothermal energy is mainly attributed to space heating, bathing and swimming (including balneology), and to a lesser extent for greenhouse heating, district heating, air-conditioning, industrial use, and geothermal heat pumps. Industrial applications include the use in a leather factory and for cooling at a cement works – however, the latter is not considered a geothermal use. Geothermal heat pumps, of the open loop system, are used for raising the thermal water temperature at spas for swimming pools and space heating. There is a low interest in geothermal heat pumps, due to the high initial cost and the low price of gas and oil in comparison. However, the number of closed loop systems has increased in recent years due to government funding and promotion of some private companies. A total of 203 installed units are reported, providing 2.3 MWt of installed capacity and producing 52.8 TJ/yr of heat energy, plus 1.6 MWt and 36.3 TJ/yr for use in heating swimming pool water, giving a total of 3.9 MWt and 89.1 TJ/yr. The individual uses in Slovenia are as follows: individual space heating (16.1 MWt and 224.1 TJ/yr); district heating (0.9 MWt and 17 TJ/yr); air conditioning (1.4 MWt and 23 TJ/yr); greenhouse heating (7.9 MWt and 99.8 TJ/yr); industrial process heat (0.8 MWt and 14.2 TJ/yr); and bathing and swimming (17.6 MWt and 245.3 TJ/yr); for a total, including heat pumps, of 48.6 MWt and 712.5 TJ/yr.

5.5 Commonwealth Of Independent States

Armenia: No report was received from this country; thus, the data from WGC2000 (Lund and Freeston, 2001) will be used. The use is based on a paper, by Henneberger, et al., (2000), that describes some resorts and health facilities using geothermal energy. However, most of these were closed or operating at a much-reduced capacity. Water from an operating well is bottled and sold as mineral water, and the same well is used during the winter season to heat a nearby guesthouse. Several warm springs and at least seven wells are located near the town of Ankavan. Spring temperatures are about 25°C, drilled to depths of 50-410 meters, have temperatures up to 42°C. Two wells produce CO_2 , one for a bottling plant and the other for a dry-ice factory. The latter well also supplies the Ankavan Sanatorium, a facility dedicated to the treatment of stomach ailments. Based on data from Henneberger (2000), it is estimated that the capacity is 1.0 MWt and the use is 15 TJ/yr used for bathing and swimming.

Belarus: Utilization of the country's geothermal energy has been identified as possible with the identification of a number of areas, particularly in the Brest depression and Pripyat Trough in the southeastern part of the country (Zui and Mikulchik, 2005). Currently only small space heating installation in the central and northeastern Belarus is operational with a total capacity of 0.5 MWt and annual utilization of about 10.0 TJ/yr. Several small heat pump systems for heating of waterworks and sewage header buildings are mentioned at five locations, with an installed capacity of 0.5 MWt and an estimated annual energy use of 3.3 TJ/yr. The total use is then: 1.0 MWt and 13.3 TJ/yr.

Georgia: Buachidze, et al., (2005) states that very little has changed since the 2000 report summarized in Lund and Freeston (2001) in which an installed capacity of 250 MWt capacity and 6,307 TJ/yr energy use was estimated from the figures supplied. In this 2005 report, Buachidze, et al. quotes 135,599 m^3 /day of fluid with a thermal capacity of 307 MWt and a 25°C ("delta T") for 206 wells and 8 springs. However, it is not known in detail how the fluid is used. District heating, agriculture, absorption heat pumps, and balneology are mentioned as users of geothermal fluids. Some detail and future plans are outlined in Vardigorel, et al. (2005) in which it is stated that over 80% of geothermal resources of the Republic are in Western Georgia. Based on the revised WGC2000 data, the following individual uses were reported: district heating (37.9 MWt and 1,045.3 TJ/yr); greenhouse heating (165.7 MWt and 4,216.5 TJ/yr); fish pond heating (25.1 MWt and 492.6 TJ/yr); agricultural drying (4.4 MWt and 120.0 TJ/yr); industrial applications (7.1 MWt and 186.3 TJ/yr); and bathing and swimming (9.8 MWt and 246.3 TJ/yr). The total is then: 250.0 MWt and 6,307 TJ/yr, which will be used for the 2005 estimate, as no updated figures are given.

Russia: In Russia more than 45% of total energy resources are used to supply heat to cities, settlements and industrial complexes. Up to 30% of these can be supplied by heat from the earth (Kononov and Povarov, 2005). So far 66 thermal water and steam hydrothermal fields have been explored in Russia. In 2001, Lund and Freeston (2001) quoted that a capacity of 308.2 MWt with an annual energy use of 6,143.5 TJ/yr of geothermal energy was used. The data reported in 2005 is 327.0 MWt and 6,135.0 TJ/yr. although in Table 7, 307.0 MWt and 6,132.0 TJ/yr are quoted with, the following individual uses: space heating (110.0 MWt and 2,185 TJ/yr); greenhouse heating (160.0 MWt and 3,279 TJ/yr); fish and cattle raising (4.0 MWt and 63.0 TJ/yr); agricultural drying (wool washing, paper production and wood drying) (4.0 MWt and 69.0 TJ/yr); industrial processes (25.0 MWt and 473.0 TJ/yr); and swimming and bathing (4.0 MWt and 63.0 TJ/yr). In addition, geothermal heat pumps were reported being used in Kamchatka (Povarov, 2000), consisting of 100 units with an installed capacity of 1.2 MWt and producing 11.5 TJ/y. These add to a total of 308.2 MWt and 6,143.5 TJ/yr, which will be used at the official numbers. Geothermal heat pumps are also being considered for the Lake Baikal region of eastern Siberia (Dorofeeva, et al., 2005). Under financial support of the GeoFund (World Bank/GEF) utilization of geothermal heat is planned for four regions of Russia: Omsk, Krasnodar Krai, Kaliningrad, and Kamchatka.

Tajikistan: The paper by Normatoov (2005) discusses and classifies the fluids available in the country; no mention is made of likely use.

Ukraine: This is a new country to report direct-use. Khvorov, et al., (2005) show that currently 10.9 MWt of geothermal energy is supplied to 9 systems, 2 of which are associated with power plant in co-generating schemes producing 0.16 MWe and 1.8MWt. However most of the units were installed between 1978 and 1998 with only 1 project coming on line in 2002. These systems generated in 2003, 33,000 MWh (118.8 TJ/yr) of heat and made it possible to save five thousand tonnes of conventional fuel and reduce CO_2 emission by 10.5 thousand tonnes. The heat iss estimated for use in individual space heating (3.5 MWt and 36.3 TJ/yr) and district heating (7.4 MWt and 82.5 TJ/yr).

5.6 Oceania

Australia: Chopa (2005) discusses Australia's use of geothermal energy. Portland, in western Victoria, continues to be the major project where four deep wells provide fluid at 56- 59°C for a district-heating scheme servicing a total building area of 18,990 m^2. As a result of a review it is intended to refurbish the system. The Portland district heating system has an installed capacity of 10.4 MWt with a annual energy of 293.8 TJ/yr. Ground- source heat pumps are also being installed. The largest installation is the Geoscience Australia building in Symonston, near Canberra, where 350 bores drilled to 100 m are used to control temperature in a building of 40,000 m^2. Inside the building, 210 water-to- air heat pumps can be independently controlled to deliver heating or cooling as required. In Tasmania, a number of commercial GSHP installations are now operating. The Monash Science Center in Melbourne uses a circulating water system connected to an adjacent artificial lake, and in New South Wales, the School of Nursing at University of Newcastle are climate controlled with a GSHP system. The Hot Dry Rock means of producing geothermal energy has been researched for some time and currently some of systems are getting close to becoming on line. Overall the total installed capacity in Australia is given as 104 MWt with 2,938 TJ/yr of annual energy use, of which 96 MWt and 2,712 TJ/yr are used for space heating, and 8 MWt and 226 TJ/yr are used for bathing and swimming. No figures are given for the geothermal heat pump capacity and use, but, based on the description in Chopa (2005), they are estimated for the building in Symonston, Canberra and for the various locations in Tasmania at about 450 units producing 30 TJ/yr from 5.5 MWt. This gives a grand total of 109.5 MWt and 2,968 TJ/yr.

New Zealand: The paper by Dunstall (2005) reports on what has been in the last five years a period of consolidation of the country's geothermal programs from a government monopoly to a privatized competitive commercial business. Tightening gas supplies and several dry autumns have highlighted the risk of dependence on limited hydro storage, which has refocused attention on renewables. For almost a decade now, the direct-use scene in New Zealand has remained static, installed capacity of 308.1 MWt and annual energy use 7,086 TJ/yr, compared to the data given in Lund and Freeston (2001) of 307.9 MWt and 7,081TJ/yr. The use is dominated by the Paper Mill at Kawerau that continues to be very successful. A new greenhouse on a much larger scale is under consideration on the site, the old one was closed to make room for a log yard. The project is at the formative stage but the plans are ambitious, a potential for a 200-500 hectares major greenhouse complex is being considered. Most of the other uses in New Zealand are very minor in comparison to the Kawerau project; however, a 5-hectare greenhouse operation with an expansion planned to 20 hectares for growing tomatoes and capsicum is in place at Mokai. The operation uses fluid from the same supply that feeds the Mokai power station. Other small-scale operations are scattered around the North Island of New Zealand, however the economic benefits are only realized when the scale and intensity of heat is high. The largest concentration of small direct-use applications remains in the City of Rotorua, where use has been quite static for the past decade or so, due to a decline in the natural features at the Whakarewarewa reserve, resulting in major restriction on use in the city. Geothermal heat pumps have made little impression on the energy market in New Zealand. So, individual space heating accounts for about 22 MWt and 700 TJ/yr, fish and animal farming 18.6 MWt and 363 TJ/yr, agriculture drying 29.3 MWt and 253 TJ/yr, bathing and swimming 28 MWt and 265 TJ/yr, and industrial process heat 210 MWt and 5,500 TJ/yr. The values for space heating and agricultural drying are probably conservative figures. In addition, 0.1 MWt and 2.5 TJ/yr is reported for the greenhouse operation at Mokai, and a similar value is estimated for the greenhouse at Taupo, bringing the total to 0.2 MWt and 5.0 TJ/yr.

Papua New Guinea: Geothermal resources on the island of Lihr are exploited to generate electricity for the gold mine (Booth and Bixley, 2005). However, on New Britain Island low enthalpy heat is used to boil megapod eggs, and the megapods (local fowl) use the hot ground to incubate the eggs, which are harvested by the locals, a tourist attraction. At Kabul during the Second World War, the Japanese used the hot springs for bathhouses, and using oil drums evaporated seawater for the salt using a combination of hot springs and solar heat. The current use is estimated at 0.1 MWt and 1 TJ/yr for bathing and swimming.

6. ENERGY SAVINGS

Using geothermal energy obviously replaces the use of other forms of energy, especially fossil fuels. The benefits, thus accrued, are for many countries, a reduced dependence on imported fuels, and, for all, elimination of pollutants such as particulates and greenhouse gases. An attempt is made here to quantify these savings of fossil fuels using a 0.35 efficiency factor if the competing energy is used to replace electricity and 0.70 if it is used directly to produce heat, such as in a furnace.

Using the 261,418 TJ/yr of energy produced, and estimating that a barrel of fuel oil contains 6.06×10^9 J, and that the fuel is used to produce replacement electricity, the saving would be 123.2 million barrels of oil or 18.4 million tonnes of oil annually. If the oil were used directly to produce energy by burning, then these values would be reduced by half. The actual savings is most likely somewhere in between these two values.

Using figures developed by Lawrence Livermore Laboratories for the U.S. Department of Energy, the following carbon savings would be realized. If electricity were produced, then the carbon savings would be 14.65 tonnes/TJ from natural gas, 62.6 tonnes/TJ from oil or 72.7 tonnes/TJ from coal, which then produces a savings in carbon production of 3.83, 16.36, or 19.00 million tonnes, respectively. Similarly, using 193 kg/MWh, 817 kg/MWh, and 953 kg/MWh for carbon dioxide emission by producing electricity from natural gas, oil and coal respectively, the saving in CO_2 emissions would be 14.02, 59.33, or 69.21 million tonnes respectively. If energy were produced by burning these fuels, the carbon and CO_2 savings would be half of these values. Again, the actual savings would be somewhere in between these sets of values and would include a mix of fossil fuels.

7. CONCLUDING REMARKS

As in 2000 and 1995, some countries stand out as major users of geothermal fluids for direct-uses; however, in most countries development has been slow. This is not surprising, since the price of oil and natural gas during the past ten years has been a major competitor for geothermal. Many countries have; however, been doing the necessary groundwork, conducting inventories and quantifying their resources in preparation for development when economics are better and fossil fuel prices are higher. We have seen many newcomers to the geothermal direct-use club, who are most welcome, and we hope to see more in the future. With the increased interest in geothermal heat pumps, geothermal energy can now be developed anywhere, for both heating and cooling.

At the moment of writing (November 2004), the cost of crude oil has risen to over US$50/barrel and natural gas prices are increasing. Thus, with the cost benefits of geothermal energy becoming more competitive with fossil fuels, and the environmental benefits better understood for renewable energy sources, increased development of this natural "heat from the earth" and domestic source of energy will certainly occur. An important task for all of us in the geothermal community is to spread the word on geothermal energy, its various possible applications, and the many environmental benefits that can accrue for its use.

Key data and explanations were frequently missing from the country update reports used in this summary, despite the fact that such essential elements were requested from the authors. In other cases, the data appeared to be in error or misreported. The authors have attempted to correct for these errors by contacting the authors or making estimates for the various missing data, and have stated so in the country summary. The use of email has certainly made this task easier.

Even with the discrepancies described above, and which we have tried to correct, preparing of this report has been a useful task, if only to demonstrate that the use of low-to-moderate temperature geothermal resources in direct heat applications, given the right environment, is viable and economic. As oil and gas supplies dwindle and increase in price, geothermal energy will become an even more economically viable alternative source of energy.

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