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Direct Utilization of Geothermal Energy 2010 Worldwide Review

John W. Lund[1], Derek H. Freeston[2], Tonya L. Boyd[1]

[1]Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, Oregon, USA

[2]Geothermal Institute, University of Auckland, Auckland, New Zealand

john.lund@oit.edu

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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 2005, presented at the World Geothermal Congress 2005 (WGC2005) in Turkey and subsequently updated in Geothermics (vol. 34) (Lund, Freeston and Boyd, 2005). This update also compares data from 1995 and 2000 presented at two World Geothermal Congresses in Italy and Japan (WGC95 and WGC2000). As in previous reports, an effort is made to quantify ground-source (geothermal) heat pump data. This report is based on country update papers prepared for WGC2010 and other sources of data available to the authors. Final update papers were received from 70 countries of which 66 reported some direct utilization of geothermal energy. Twelve additional countries were added to the list based on other sources of information. The 78 countries having direct utilization of geothermal energy, is a significant increase from the 72 reported in 2005, the 58 reported in 2000, and the 28 reported in 1995. An estimate of the installed thermal power for direct utilization at the end of 2009, for this current reports is 50,583 MWt, almost a 79 % increased over the 2005 data, growing at a compound rate of 12.3% annually with a capacity factor of 0.27. The thermal energy used is 438,071 TJ/year (121,696 GWh/yr), about a 60% increase over 2005, growing at a compound rate of 9.9% annually. The distribution of thermal energy used by category is approximately 49.0% for ground-source heat pumps, 24.9% for bathing and swimming (including balneology), 14.4% for space heating (of which 85% is for district heating), 5.3% for greenhouses and open ground heating, 2.7% for industrial process heating, 2.6% for aquaculture pond and raceway heating, 0.4% for agricultural drying, 0.5% for snow melting and cooling, and 0.2% for other uses. Energy savings amounted to 307.8 million barrels (46.2 million tonnes) of equivalent oil annually, preventing 46.6 million tonnes of carbon and 148.2 million tonnes of CO_2 being release to the atmosphere which includes savings in geothermal heat pump cooling (compared to using fuel oil to generate electricity).

1. INTRODUCTION

Direct-use of geothermal energy is one of the oldest, most versatile and also the most common form of utilization of geothermal energy (Dickson and Fanelli, 2003). The early history of geothermal direct-use has been well documented for over 25 countries in the *Stories from a Heat Earth – Our Geothermal Heritage* (Cataldi et al., 1999), that documents geothermal use for over 2,000 years. The information presented here on direct applications of geothermal heat is based on country update papers submitted for the World Geothermal Congress 2010 (WGC2010) and covers the period 2005 to 2009. Papers from 70 countries have been received, 66 of which reported some geothermal direct-use with 12 additional countries added from other sources for a total of 78 countries – an increase of six countries from WGC2005 (Bosnia & Herzegovina, El Salvador, Estonia, Morocco, South Africa and Tajikistan). In the case where data are missing or incomplete, the authors have relied on country update reports from the World Geothermal Congresses of 1995, 2000 and 2005 (WGC95, WGC2000, WGC2005), as well as from two *Geothermics* publications (Lund and Freeston, 2001, and Lund et al., 2005), and personal communications. Data from WGC2010 are also compared with data from WGC95, WGC2000 and WGC2005.

2. DATA SUMMARY

Table 1 is a summary, by country, of the installed thermal capacity (MWt), annual energy use (TJ/yr and GWh/yr) and the capacity factor to the end of 2009. The dataset on wells drilled, professional person-years and investment in geothermal projects during 2005-2009 is incomplete, but significant information can be obtained from the individual papers submitted to WGC2010. The total installed capacity, reported through the end of 2009 for geothermal direct utilization worldwide is 50,583 MWt, a 78.9% increase over WGC2005, growing at an annual compound rate of 12.33%. The total annul energy use is 438,071 TJ (121,696 GWh), indicating a 60.2% increase over WGC2005, and a compound growth rate of 9.89%. The worldwide capacity factor is 0.27 (equivalent to 2,365 full load operating hours per year), down from 0.31 in 2005 and 0.40 in 2000. The growth rate of installed capacity and annual energy use over the past 15 years is shown in Figure 1. The lower capacity factor and growth rate for annual energy use is due to the increase in geothermal heat pump installations which have a low capacity factor of 0.19 worldwide.

Table 1. Summary of direct-use data worldwide, 2010.

Country	Capacity, MWt	Annual Use, TJ/yr	Annual Use, GWh/yr	Capacity Factor
Albania	11.48	40.46	11.2	0.11
Algeria	55.64	1,723.13	478.7	0.98
Argentina	307.47	3,906.74	1,085.3	0.40
Armenia	1	15	4.2	0.48
Australia	33.33	235.1	65.3	0.22
Austria	662.85	3,727.7	1,035.6	0.18
Belarus	3.422	33.79	9.4	0.31
Belgium	117.9	546.97	151.9	0.15
Bosnia & Herzegovina	21.696	255.36	70.9	0.37

Brazil	360.1	6,622.4	1,839.7	0.58
Bulgaria	98.3	1,370.12	380.6	0.44
Canada	1126	8,873	2,464.9	0.25
Caribbean Islands	0.103	2.775	0.8	0.85
Chile	9.11	131.82	36.6	0.46
China	8,898	7,5348.3	20,931.8	0.27
Columbia	14.4	287	79.7	0.63
Costa Rica	1	21	5.8	0.67
Croatia	67.48	468.89	130.3	0.22
Czech Republic	151.5	922	256.1	0.19
Denmark	200	2,500	694.5	0.40
Ecuador	5.157	102.401	28.4	0.63
Egypt	1	15	4.2	0.48
El Salvador	2	40	11.1	0.63
Estonia	63	356	98.9	0.18
Ethiopia	2.2	41.6	11.6	0.60
Finland	857.9	8370	23.25.2	0.31
France	1345	12,929	3591.7	0.30
Georgia	24.51	659.24	183.1	0.85
Germany	2,485.4	12,764.5	3,546.0	0.16
Greece	134.6	937.8	260.5	0.22
Guatemala	2.31	56.46	15.7	0.78
Honduras	1.933	45	12.5	0.74
Hungary	654.6	9767	2,713.3	0.47
Iceland	1,826	24,361	6,767.5	0.42
India	265	2,545	707.0	0.30
Indonesia	2.3	42.6	11.8	0.59
Iran	41.608	1,064.18	295.6	0.81
Ireland	152.88	764.02	212.2	0.16
Israel	82.4	2,193	609.2	0.84
Italy	867	9,941	2,761.6	0.36
Japan	2,099.53	15,697.94	7,138.9	0.39
Jordan	153.3	1,540	427.8	0.32
Kenya	16	126.624	35.2	0.25
Korea (South)	229.3	1,954.65	543.0	0.27
Latvia	1.63	31.81	8.8	0.62
Lithuania	48.1	411.52	114.3	0.27
Macedonia	47.18	601.41	167.1	0.40
Mexico	155.82	4,022.8	1,117.5	0.82
Mongolia	6.8	213.2	59.2	0.99
Morocco	5.02	79.14	22.0	0.50
Nepal	2.717	73.743	20.5	0.86
Netherlands	1,410.26	10,699.4	2,972.3	0.24
New Zealand	393.22	9,552	2,653.5	0.77
Norway	3,300	25,200	7,000.6	0.24
Papua New Guinea	0.1	1	0.3	0.32
Peru	2.4	49	13.6	0.65
Philippines	3.3	39.58	11.0	0.38
Poland	281.05	1,501.1	417.0	0.17
Portugal	28.1	386.4	107.3	0.44
Romania	153.24	1,265.43	351.5	0.26
Russia	308.2	6,143.5	1,706.7	0.63
Serbia	100.8	1,410	391.7	0.44
Slovak Republic	132.2	3,067.2	852.1	0.74
Slovenia	104.17	1,136.39	315.7	0.35
South Africa	6.01	114.75	31.9	0.61
Spain	141.04	684.05	190.0	0.15
Sweden	4,460	45,301	12,584.6	0.32
Switzerland	1,060.9	7,714.6	2,143.1	0.23
Tajikistan	2.93	55.4	15.4	0.60
Thailand	2.54	79.1	22.0	0.99
Tunisia	43.8	364	101.1	0.26
Turkey	2,084	36,885.9	10,246.9	0.56
Ukraine	10.9	118.8	33.0	0.35
United Kingdom	186.62	849.74	236.1	0.14
United States	12,611.46	56,551.8	15,710.1	0.14
Venezuela	0.7	14	3.9	0.63
Vietnam	31.2	92.33	25.6	0.09
Yemen	1	15	4.2	0.48
Total	**50,583**	**438,071**	**121,696.0**	**0.27**

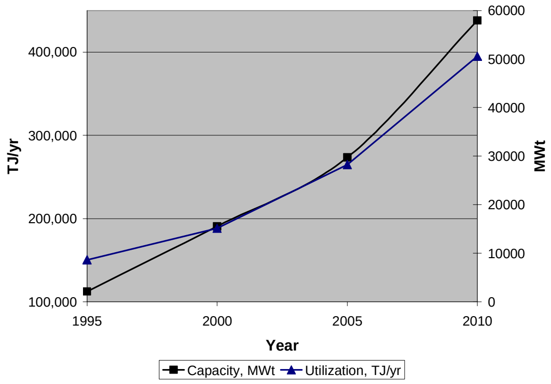


Figure 1. The growth rate of the installed capacity and annual utilization from 1995-2010.

The growing awareness and popularity of geothermal (ground-source) heat pumps have had the most significant impact on direct-use of geothermal energy. The annual energy use for these units grew 2.45 times at a compound annual rate of 19.7%. The installed capacity grew 2.29 times at a compound annual rate of 18.0%. This is due to better reporting and to the ability of geothermal heat pumps to utilize groundwater or ground-coupled temperatures anywhere in the world (see Table 2).

The five countries with the largest installed capacity are: USA, China, Sweden, Norway and Germany accounting for 60% of the world capacity, and the five countries with the largest annual energy use are: China, USA, Sweden, Turkey, and Japan, accounting for 55% of the world use. Japan and Germany are new members of the “top five” as compared to WGC2005. However, an examination of the data in terms of land area or population shows that the smaller countries dominate, especially the Nordic ones. The “top five” then become for installed capacity: (MW/population) Iceland, Sweden, Norway, New Zealand and Switzerland; (MW/area) Denmark, Netherlands, Iceland, Switzerland and Hungary. For annual energy use: (TJ/yr/population) Iceland, Norway, Sweden, Denmark and Switzerland; (TJ/yr/area) Netherlands, Switzerland, Iceland, Norway and Sweden. The largest increase in geothermal installed capacity (MWt) over the past five years are: United Kingdom, Korea, Ireland, Spain and Netherlands; and the largest increase in annual energy use (TJ/yr) over the past five years are: United Kingdom, Netherlands, Korea, Norway and Ireland. All of these increases are due to geothermal heat pump installations.

In 1985, only 11 countries reported an installed capacity of more than 100 MWt. By 1990, this number had increased to 14, by 1995 to 15, by 2000 to 23, and by 2005 33 countries. At present (December, 2009), there are 36 countries reporting over 100 MWt, an increase of 3 countries over 2005.

3. CATEGORIES OF UTILIZATION

In Table 2 the 1995, 2000, 2005 and 2010 data are divided among the various uses in terms of capacity, energy utilization and capacity factor. This distribution can also be viewed as bar charts in Figure 2. Figure 3 presents the 2010 data in pie-chart form in percentages. An attempt was made to distinguish individual space heating from district heating, but this was often difficult, as the individual country reports did not always make this distinction. Our best estimate is that district heating represents 85% of the installed capacity and 84% of the annual energy use, similar to WGC2005. Snow melting represents the majority of the snow melting/air-conditioning category. "Other" is a category that covers a variety of uses: frequently the data sources do not provides details; but include animal husbandry.

Table 2.Summary of the various categories of direct use worldwide, referred to the period 1995-2010.

Capacity, MWt

	2010	2005	2000	1995
Geothermal Heat Pumps	35,236	15,384	5,275	1,854
Space Heating	5,391	4,366	3,263	2,579
Greenhouse Heating	1,544	1,404	1,246	1,085
Aquaculture Pond Heating	653	616	605	1,097
Agricultural Drying	127	157	74	67
Industrial Uses	533	484	474	544
Bathing and Swimming	6,689	5,401	3,957	1,085
Cooling / Snow Melting	368	371	114	115
Others	41	86	137	238
Total	**50,583**	**28,269**	**15,145**	**8,664**

Utilization, TJ/yr

	2010	2005	2000	1995
Geothermal Heat Pumps	214,782	87,503	23,275	14,617
Space Heating	62,984	55,256	42,926	38,230
Greenhouse Heating	23,264	20,661	17,864	15,742
Aquaculture Pond Heating	11,521	10,976	11,733	13,493
Agricultural Drying	1,662	2,013	1,038	1,124
Industrial Uses	11,746	10,868	10,220	10,120
Bathing and Swimming	109,032	83,018	79,546	15,742
Cooling / Snow Melting	2,126	2,032	1,063	1,124
Others	956	1,045	3,034	2,249
Total	**438,071**	**273,372**	**190,699**	**112,441**

Capacity Factor

	2010	2005	2000	1995
Geothermal Heat Pumps	0.19	0.18	0.14	0.25
Space Heating	0.37	0.40	0.42	0.47
Greenhouse Heating	0.48	0.47	0.45	0.46
Aquaculture Pond Heating	0.56	0.57	0.61	0.39
Agricultural Drying	0.42	0.41	0.44	0.53
Industrial Uses	0.70	0.71	0.68	0.59
Bathing and Swimming	0.52	0.49	0.64	0.46
Cooling / Snow Melting	0.18	0.18	0.30	0.31
Others	0.73	0.39	0.70	0.30
Total	**0.27**	**0.31**	**0.40**	**0.41**

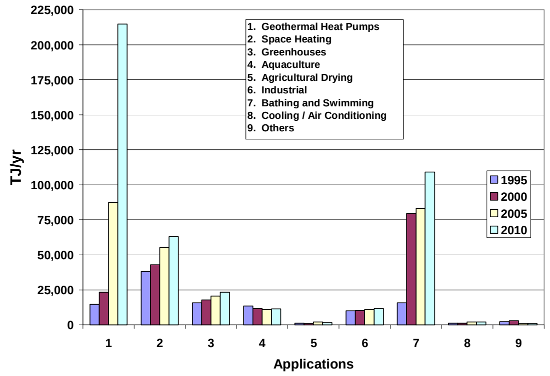
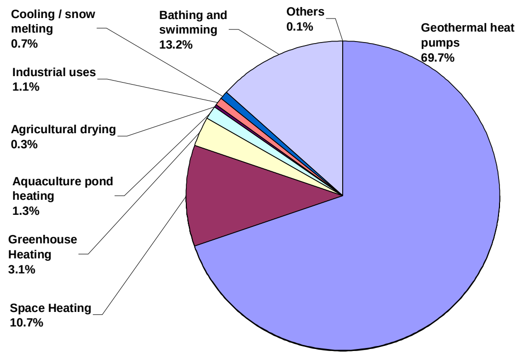
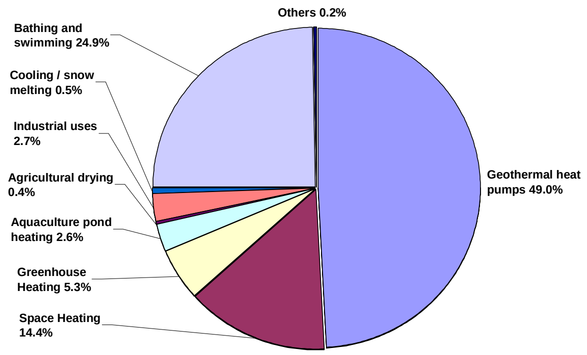


Figure 2. Comparison of worldwide energy in TJ/yr for 1995, 2000, 2005 and 2010.



(a)



(b)

Figure 3. Geothermal direct applications worldwide in 2010, distributed by percentage of total installed capacity (a) and percentage of total energy use(b).

3.1 Geothermal Heat Pumps

Geothermal (ground-source) heat pumps have the largest energy use and installed capacity, accounting for 69.7% and 49.0% of the worldwide capacity and use. The installed capacity is 35,236 MWt and the annual energy use of 214,782 TJ/yr, with a capacity factor of 0.19 (in the heating mode). Almost all of the installations occur in North American, Europe and China, increasing from 26 countries in 2000, to 33 countries in 2005, to the present 43 countries. The equivalent number of installed 12 kW units (typical of

US and Western European homes) is approximately 2.94 million, over double the number of units report for 2005, and four times the number for 2000. The size of individual units; however, ranges from 5.5 kW for residential use to large units of over 150 kW for commercial and institutional installations.

In the United States, most units are sized for peak cooling load and are oversized for heating, except in the northern states; thus, they are estimated to average only 2,000 full-load hours per year (capacity factor of 0.23). 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 be in operation up to 6,000 full-load hours per year (capacity factor of 0.68), such as in Nordic countries. Unless the actual number of full-load hours was reported, a value of 2,200 hours was used for energy output (TJ/yr) calculations, and higher for some of the northern countries, based on reports by Curtis et al. (2005).

The energy use reported for the heat pumps was deduced from the installed capacity (if it was not reported), based on an average coefficient of performance (COP) of 3.5, which allows for one unit of energy input (usually electricity) to 2.5 units of energy output, for a geothermal component of 71% of the rated capacity [i.e. (COP-1)/COP = 0.71]. The cooling load was not considered as geothermal, as in this case, heat is discharged into the ground or groundwater. Cooling; however, has a role in the substitution for fossil fuels and reduction of greenhouse gas emissions and is included as discussed in Section 6.

The leaders in installed units are the United States, China, Sweden, Norway and Germany.

3.2 Space Heating

Space heat has increased 24% in installed capacity and 14% in annual energy use over WGC2005. The installed capacity now totals 5,391 MWt and the annual energy use is 62,984 TJ/year. As stated previously about 85% of the installed capacity and 84% of the annual energy use is in district heating (24 countries). The leaders in district heating annual energy use are Iceland, China, Turkey, France and Russia, whereas, Turkey, Italy, United States, Japan and Georgia are the major users in the individual space heating sector (a total of 27 countries).

3.3 Greenhouse and Covered Ground Heating

Worldwide use of geothermal energy used for greenhouse heating increased by 10% in installed capacity and 13% in annual energy use. The installed capacity is 1,544 MWt and 23,264 TJ/yr in energy use. A total of 34 countries report geothermal greenhouse heating (compared to 30 for WGC2005), the leading countries being: Turkey, Hungary, Russia, China and Italy. Most countries did not distinguish between covered greenhouses versus uncovered ground heating, and only a few reported the actual area heated. The main crops grown in greenhouses are vegetables and flowers; however, tree seedlings (USA) and fruit such as bananas (Iceland) are also grown. Developed countries are experiencing competition from developing countries due to labor costs being lower – one of the main costs of operating these facilities. Using an average energy requirement, determined from WGC2000 data of 20 TJ/year/ha for greenhouse heating, the 23,264 TJ/yr corresponds to about 1,163 ha of greenhouses heated worldwide – a 16.3% increase over 2005..

3.4 Aquaculture Pond and Raceway Heating

Aquaculture use of geothermal energy has increased slightly over WC2005, reversing a downward trend from WGC1995; however, it is still down when compared to WGC1995. The increase over the past five years has been 6% for the installed capacity and 5% for annual energy use. The installed capacity is 653 MWt and the annual energy use is 11,521 TJ/yr. Twenty-two countries report this type of use, the main ones being China, USA, Italy, Iceland, and Israel. These facilities are labor intensive and require well-trained personnel, which are often hard to justified economically, thus the reason why the growth is slow. Tilapia, salmon and trout seem to be the most common species, but tropical fish, lobsters, shrimp, and prawns, as well as alligators also being farmed. Based on work in the United States, we calculate that 0.242 TJ/yr/tonne of fish (bass and tilapia) are required, using geothermal waters in uncovered ponds. Using the reported energy use of 11,521 TJ/yr, an equivalent 47,600 tonnes of annual production is estimated a 5.8% increase over 2005.

3.5 Agricultural Crop Drying

Fourteen countries report the use of geothermal energy for drying various grains, vegetables and fruit crops compared to 15 for WGC2005. Examples include: seaweed (Iceland), onion (USA), wheat and other cereals (Serbia), fruit (El Salvador, Guatemala and Mexico), Lucerne or alfalfa (New Zealand), coconut meat (Philippines), and timber (Mexico, New Zealand and Romania). A total of 127 MWt and 1,662 TJ/yr are being utilized, a decrease from WGC2005, mainly due to the shutting down of an onion and garlic dehydration plant in Nevada, USA.

3.6 Industrial Process Heat

This is a category that has applications in 14 countries, down from 15 in 2005 and from 19 in 2000. These operations tend to be large and of high-energy consumptions. Examples include: concrete curing (Guatemala and Slovenia), bottling of water and carbonated drinks (Bulgaria, Serbia and the United States), milk pasteurization (Romania), leather industry (Serbia and Slovenia), chemical extraction (Bulgaria, Poland and Russia), CO_2 extraction (Iceland and Turkey), pulp and paper processing (New Zealand), iodine and salt extraction (Vietnam), and borate and boric acid production (Italy). The installed capacity is 533 MWt and the annual energy use 11,746 TJ/yr, a 10% and 8% increase over 2005 respectively. This application has the highest capacity factor of all direct uses (0.70), as is to be expected because of its almost year-around operation.

3.7 Snow Melting and Space Cooling

There are very limited applications in this area, with pavement snow melting project in Argentina, Iceland, Japan, Switzerland and the United States. A total of about two million square meters of pavement are heated worldwide, the majority of which is in Iceland. A project in Argentina uses geothermal steam for highway snow melting in the Andes to keep a resort community open during winters, and in the United States, with most of the pavement snow melting on the Oregon Institute of Technology campus and in the City of Klamath Falls, Oregon. The power required varies from 130 to 180 W/m^2 (United States and Iceland). The installed capacity is 311 MWt and the annual energy use is 1,845 TJ/yr, an increase over 2005. Space cooling is reported in five countries, amounting to 56 MWt and 281 TJ/yr. Heat pumps in the cooling mode are not included as they return heat to the subsurface, and thus do not use geothermal energy.

3.8 Bathing and Swimming

Figures for this use are the most difficult to collect and quantify. Almost every country has spas and resorts that have swimming pools heated with geothermal water (including balneology), but many allow the water to flow continuously, regardless of use. As a result, the actual usage and capacity figures may be high. In some cases where use was reported, no flows or temperature drops were known; in these cases 0.35 MWt and 7.0 TJ/yr were applied to estimate the capacity and energy use for typical installations. In other cases, 5 L/s and a 10^{o}C temperature change were used (0.21 MWt) for the installed capacity and 3 L/s and 10^{o}C temperature change (4.0 TJ/yr) were used for the annual use. Undeveloped natural hot springs are not included.

In addition to the 67 counties (up from 60 in 2005) that reported bathing and swimming pool use, we are also aware of developments in Malaysia, Mozambique, Singapore and Zambia, although no information was available. The installed capacity is 6,689 MWt and the annual energy use is 109,032 TJ/yr, up 24% and 31% respectively over 2005. We have also included the Japanese-style inns that utilize hot spring water for bathing, as we included these figures in 2000 and 2005 (Lund and Freeston, 2001; Lund et al., 2005). The largest reported uses are from China, Japan, Turkey, Brazil and Mexico.

3.9 Other Uses

Other uses, 41 MWt and 956 TJ/yr, are down compared to 2005. These were reported by seven countries, and include animal farming, spirulina cultivations, desalinations and sterilization of bottles.

4. CAPACITY FACTORS

Average capacity factors were determined for each country (Table 1) and for each category of use (Table 2). They vary from 0.09 to 0.99 for the countries and from 0.18 to 0.70 for the categories of use. The lower values refer to countries in which geothermal heat pumps usage predominates, as indicated by the 0.19 in Table 2, whereas the higher numbers are for countries with high industrial use (New Zealand) or continuous operation of pools for swimming and bathing (Iran).

The worldwide capacity factor has dropped from 0.40 in 2000 to 0.31 in 2005 to the current 0.27 over the past five years, again as a result in the increase in geothermal heat pump usage. Capacity factors for the various categories of use remained approximately constant, as compared to 2005.

The capacity factor is calculated as follows: (annual energy use in TJ/yr)/(installed capacity in MWt) x 0.1317. This number reflects the equivalent percentage of full load operating hours per year (i.e. CF = 0.70 is 70% full load hours or 6,132 equivalent hours/yr).

5. COUNTRY REVIEWS

5.1 Africa

5.1.1 Algeria

The most popular use of geothermal springs is for balneotherapy. These hot springs are mainly located in the northern part of the country, used by about ten public resorts. During the last few years, a significant interest has been shown for other uses of geothermal energy. Three sites have been selected for geothermal aquaculture projects. Currently, fish farms in Ghardaia and Ouargla are using the Albian geothermal water of the Sahara to produce about 1,500 tonnes/yr of Tilapia fish. A third, site, at Ain Skhouna, located near Saida produced 200 tonnes of Tilapia during 2008. A small geothermal heat pump project has been development in the region at Saida for heating and cooling of a school. These various applications of geothermal water are: 1.4 MWt and 45.1 TJ/yr for individual space heating; 9.8 MWt and 308 TJ/yr for fish farming; 44.27 MWt and 1,368.65 TJ/yr for bathing and swimming; and 0.17 MWT and 1.38 TJ/yr for geothermal heat pumps; for a total of 55.64 MWt and 1,723.13 TJ/yr (Fekraoui, 2010).

5.1.2 Djibouti

The country is in an early exploration stage for geothermal resources, thus, there is no geothermal use at present. The government's main interest is in developing geothermal for electric power generation in the Asal field. No direct-use projects are mentioned (Houssein, 2010).

5.1.3 Egypt

No data were submitted for WGC2005 or WGC2010. A paper by Idris (2000) and personal communications with the author in 2000 indicated that there are several spas with bathing facilities in Egypt. A spa at Hammam Faraun is also reference in Lashin and Al Arifi (2010). The estimates in Lund et al. (2005) of 1.0 MWt and 15 TJ/yr are assumed to still be valid.

5.1.4 Ethiopia

Teklemariam and Kebed (2010) provide details on geothermal fields and on development for power generation, but little data on direct-use. They list seven bathing swimming facility using geothermal energy, mainly in Addis Abba. These include the Sheraton, Filowh, Ghion, and Hilton hotels, the National Palace, Greek Community, and St. Joseph School. Base on this paper and on calculations made by one of the authors (Lund), the installed capacity is estimated at 2.2 MWt with an annual use of 41.6 TJ/yr.

5.1.5 Kenya

Oserian Development Company Ltd (ODLC) constructed a 2.0 MWe binary plant in Olkaria Central to utilize fluid from a well leased from KenGen. The plant which will provide electrical power for the farm's operation, was commissioned in July, 2004. ODLC, who grow cut flowers for export, is also utilizing steam from a 1.28 MWe well to heat fresh water through heat exchangers, enrich CO_2 levels and to fumigate the soils. The heated fresh water is then circulated through greenhouses. The advantage of using geothermal energy for heating is that it results in drastic reduction in operating costs. The capacity of the geothermal use is 16 MWt and the annual energy use is 126.624 TJ/yr (Simiyu, 2010).

5.1.6 Morocco

Geothermal direct use in the country is mainly limited to balneology, swimming pools and potable water bottling. Reconstruction of swimming pools has made some progress in the last years and the number of newly built outdoor pools has increase as well. The number of bottling companies has increased during the last five years from two to five private enterprises. The product is mainly for the local market. (Zarhloule et al., 2010). No data were provided for the geothermal use, thus, one of the authors (Lund) estimated the following for 12 pools: 5.02 MWt and 79.14 TJ/yr for bathing and swimming.

5.1.7 Rwanda

The country is currently evaluating its high and medium enthalpy geothermal resources that exist in the northwestern part of the country. Their main interest is in electric power generation, especially since 40% of their electricity comes from hydropower – which has been reduced due to low rainfall. No direct-use projects are reported (Rutagarama and Uhorakeye, 2010).

5.1.8 South Africa

Eighty-seven thermal springs with temperatures ranging from 25 to 67.5^{o}C have been documented in the country. Of these springs, 31 have been developed for direct-use mainly as family leisure and recreational resorts. Very few utilize the water for health or spa purposes. In the past these springs have been used for salt recovery, as health spas, for medicinal purposes and use of the mud for healing. Unfortunately, since coal is abundant and relatively cheap, little attention has been devoted to research on renewable energy sources. Also, in view of the low temperatures of thermal springs, no effort has been made to develop the geothermal resources. The authors (Tshibalo et al., 2010) list the various users of the springs along with the accommodation, resource temperature and mineral contact. However, no estimates of the geothermal energy use were made, thus one of the authors (Lund) made the following estimate: 6.01 MWt and 114.75 TJ/yr for bathing and swimming.

5.1.9 Tunisia

The use of geothermal energy in the country is limited to direct application because of the low enthalpy resources, which are located mainly in the southern part of the country. For thousands of years, geothermal water has been used in bathing and many of the geothermal manifestations in the country have the name of "Hammam" or bath, which reflects the main use of geothermal water over the centuries. Now, most of the resources are utilized for irrigation of oases and heating greenhouses. The government's policy in the beginning of the 1980s was oriented towards the development of the oasis section which is supplied with geothermal water for irrigation. About 31,500 ha of oases are irrigated after cooling the water in atmospheric cooling towers. In 1986, the government started using geothermal energy for greenhouse farming, which is considered a promising and economic development. The results are that now there are 194 ha of greenhouses (up from 111 ha in 2005), and by the end of 2016 this is planned to be increased to 315 ha. The geothermal use in the Kebili area is 70.8% for oasis, 27.0% for greenhouses, 1.0% for Hammams, 0.8% for tourism and pools, and 0.3% for animal husbandry and washing. The greenhouses raise tomatoes (52%), cucumbers and snake melons (21%), melons (18%), watermelons (3%), and others (6%) for a total production of 22,000 tonnes in 2009 for the Kebili region (Ben Mohamed, 2010). No data were provided on geothermal use, thus one of the authors (Lund), based on data from WGC2005 (Lund et al., 2005), estimated the following: an increase to 42.5 MWt and 335 TJ/yr for greenhouse heating; with the other uses remaining constant at: 0.9 MWt and 23 TJ/yr for bathing and swimming; 0.4 MWt and 6 TJ/yr for others (mainly animal husbandry); for a total of 43.8 MWt and 364 TJ/yr.

5.1.10 Uganda

Exploration for geothermal energy in the country has been in progress since 1993. Three areas, Katwe, Buranga and Kibiro are in advanced stages of surface exploration. The current focus is to develop the geothermal resource for power generation. No direct-use is reported; however, the preliminary investigations indicate that subsurface temperatures would be suitable for small scale electricity production and direct uses (Bahati et al., 2010).

5.2 The Americas

5.2.1 Central American and the Caribbean Islands

A number of countries in Central America and the Caribbean have geothermal power plants; however, as detailed below, only five countries and a few of the Caribbean islands report any geothermal direct use.

5.2.1.1 Caribbean Islands

Since 2004, geothermal exploration has accelerated in the region. In 2004 and 2005, the Organization of American States (OAS) funded a program that included geologic, geochemical, and geophysical studies on Nevis, reinterpretation of geophysical data on St. Lucia, and detailed geologic and geochemical work on the Wotton Wave, Dominica area. Additionally, OAS provided geothermally-relevant legal and institutional assistance to these three nations. Utilization of thermal fluids has not increased significantly in the islands since 2005. It is thus, limited to low temperature balneological facilities built on Nevis, St. Lucia and Grenada. There is geothermal power operating on Guadeloupe (under France) and plans to produce geothermal power on Nevis and Dominica. At present the installed capacity is 0.103 MWt and the annual energy use of 2.775 TJ/yr for bathing and swimming (Huttrer, 2010).

5.2.1.2 Costa Rica

Various studies have been completed in the country to look at moderate- and low-temperature geothermal resources and their potential use. Even though the study produced some favorable results, there has been no development of these resources. The main reason is the mild climate region which does not require the artificial heating of greenhouses and buildings. Currently, the use of these resources is limited to mountain hotel pools dedicated to ecological tourism. The Ministry of Agriculture has completed a technical study for the installation of a pilot plant for the drying of vegetables (onions) and grains (rice, beans, etc.) that will operate in the southern sector of the present power plant site at Miravalles. It will use some of the discharge water from the power plants (Mainieri Protti, 2010). . The estimated installed capacity is 1.0 MWt and the annual energy use is 21.0 TJ/yr based on Lund et al. (2005).

5.2.1.3 El Salvador

The country update report (Herrera et al., 2010), the authors make no mention of geothermal direct-use. However, a recent visit to the country by one of the authors (Lund) revealed that there were some limited development of greenhouse heating, fish farms and fruit drying. During a tour of the Berlin geothermal field, samples of dried pineapples, apples, bananas, coconuts, etc. were made available as " Procesco de deshidratado Natural Geotermico" and called "Geo Fruit or Funda-Geo" which are processed in Berlin for local consumption. A minimum value of 0.5 MWt and 10 TJ/yr is assumed for each of greenhouse heating and fish farming, and 1.0 MWt and 20

TJ/yr for agricultural drying, for a total of 2.0 MWt and 40 TJ/yr.

5.2.1.4 Guatemala

The direct-use of geothermal energy in the country in the past has been used for medicinal purposes, agriculture, and domestic use. The areas of Totonicapan, Quetzaltenango, and Amatitlan are popular tourist attraction known for their thermal bath houses and spas. These are estimated at a total of 0.21 MWt and 3.96 TJ/yr. The construction company, Bloteca, was the first to successfully apply a direct use application of geothermal steam in the curing process of concrete products (Merida, 1999). In 1999, a fruit dehydration plant, Agroindustrias La Laguan, was built to use hot water from a well in the Amatitlan geothermal field in the drying process. A downhole heat exchanger was installed in the well, along with an enhancer tube in order to increase the performance of the heat exchanger (a diagram is shown in the paper). The company produces dehydrated pineapple, mango, banana, apple, and chili peppers. No values for the energy used are provided in the paper, thus, the data from WGC2005 will be used (Lund et al., 2005). The concrete drying facility is reported at 1.6 MWt and 40.4 TJ/yr and the fruit drying facility is reported at 0.5 MWt and 12.1 TJ/yr (Merida, 1999, Manzo, 2005). The total for the country is then 2.31 MWt and 56.46 TJ/yr. The operations at Amatitlan are serving as direct-use examples than can be applied to other Central American countries (Asturias and Grajeda, 2010).

5.2.1.5 Honduras

A number of swimming pools are reported to be using geothermal energy; however, no estimates of energy use were made. Attempts are being made to visit these remote sites and determine the energy data (Lagos and Gomez, 2010). In the WGC2000 paper (Castillo and Salgado, 2000) and reported for WGC2005 (Lund et al., 2005) three pool sites (Tamara, Gracias 1 and Gracias 2) were being heated by geothermal water. A total of 0.7 MWt of installed capacity and 17.0 TJ/yr of utilization were reported. Recent communications from Lagos (2009) indicated that the two major pool sites are estimated at 1.933 MWt – thus, one of the authors (Lund) estimates the annual energy use at 45.0 TJ/yr.

5.2.1.6 Nicaragua

The geothermal resources in the country have been developed for electric power generation. No country update paper was submitted and no direct-use is reported in other papers (Ruiz Cordero, 2009).

5.2.2 North America

5.2.2.1 Canada

In recent years Canada has steadily embraced heat pump technology. It is estimated that up to 50,000 residential and 5,000 commercial systems are currently installed (Thompson, 2010). The cost of installing these units, especially in building retrofits, is often prohibited for the average consumer; however, federal and local subsidies have lightened the financial burden. The growth rate is estimated at 13% per year, with recent rates being as high as 50%. Heat pump technology has also been used in abandon mines, starting as early as 1989 in the Springhill Mine of Nova Scotia where the heating and cooling provides savings estimated C$45,000/yr in energy costs. The City of Yellowknife in the Northwest Territories commissioned a study in 2007 to use water from an abandoned gold mine with a heat pump to provide district heating to the community, saving an estimated C$13 million/yr. There are also 12 western hot springs used to heat swimming pools with individual flow rate of 6-32 l/s and total installed capacity of 10-15 MWt (Lund et al., 2005). Since, no specific data were available on the various Canadian geothermal uses, we estimate the following for heat pumps using a COP in the heating mode of 3.5, 3,000 full load heating hours per year, an average residential size of 12 kW, and commercial size of 100 kW, resulting in a total of 1,100 MWt and 8,487 TJ/yr. For the mine water the estimate is 11 MWt and 26 TJ/yr (Jessop, 1995), and for the 12 western swimming pool, 15 MWt and 360 TJ/yr. This gives a total of 1,126 MWt and 8,873 TJ/yr.

5.2.2.2 Greenland (Kalaallit Nunaat)

The island is under the jurisdiction of Denmark, but with home rule, and thus for this paper is considered part of North America. Warm springs were mentioned around 1300 A.D. near Ravensfjord, now known as the island of Unartoq. Ivar Bardarson describes their annual temperature fluctuations and their therapeutic properties. He writes: “In these islets there is a lot of warm water. In winter it is so hot that no one endures it, but in summer it is suitable for bathing. There many people have got holistic treatment and good healing and remedy of illnesses.” More recently, numerous warm springs have been located at Scoresbysund and Disko. The warm springs at Unartorssuaq (Engelskmandens havn) are the only ones located near an inhabited area. They are about 2 km outside of the capital Qeqertarsuaq (Godhavn), and thus, could be used for space heating in the community. However, little can be determined about the subsurface resources and the potential for utilization until exploratory drilling is undertaken. There is no current geothermal use on the island (Hjartarson and Armannsson, 2010).

5.2.2.3 Mexico

Geothermal energy in the country is almost entirely used to produce electricity, since its direct uses are still under development and currently remain restricted to bathing and swimming facilities with recreational purposes and some with therapeutic uses (reported at 20 locations). Almost all of the resorts have been developed and are operated by private investors, yet there are isolated facilities operated by federal, state or municipal government. These public facilities are usually operated through tourism offices, or in some cases, through federal institutions like the national social security institute (IMSS). Comision Federal de Electricidad (CFE) has developed some direct uses of geothermal resources at the Los Azufres geothermal field, including a wood-dryer, a fruit and vegetables dehydrator, a greenhouse and a system for heating of its offices and facilities in this field. A mushroom growing facility at Los Humeros geothermal field has been closed. The use of geothermal heat pumps is minimal, and underdeveloped with no information available. District and individual space heating is little used in Mexico due to the mild temperatures throughout the year in most of the country. The various direct use applications include: 0.460 MWt and 4.397 TJ/yr for individual space heating; 0.004 MWt and 0.059 TJ/yr for greenhouse heating; 0.007 MWt and 0.101 TJ/yr for agricultural drying; and 155.347 MWt and 4,018.229 TJ/yr for bathing and swimming; for a total of 155.818 MWt and 4,022.786 TJ/yr (Guitérrez-Negrin et al., 2010).

5.2.2.4 United States of America

Most of the direct use applications have remained fairly constant over the past five years; however, geothermal heat pumps have increased significantly. A total of 20 new projects have come on-line in the past five years and a number of projects have closed. Agricultural drying has decreased the most due to the closing of the onion/garlic dehydration plant at Empire, Nevada. Two district heating projects have also shut down; the Litchfield Correctional Facility in California and the New Mexico State University system. There has been a slight increase in snow melting, cooling and fish farming, with a major increase in industrial process heating due to two biodiesel plants (Oregon and Nevada), a brewery (Oregon), and a laundry (California) coming on line. The number of installed geothermal heat pumps has steadily increased over the past 15 years with an estimated 100,000 to 120,000 equivalent 12 kWt units installed this past year. Present estimates are that there are at least one million units installed, mainly in the mid-western and eastern states. Over 50% were installed in 10 states (Florida, Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, New York, Ohio and Pennsylvania) (EIA, 2008). Approximately 70% of the units are installed in residences and the remaining 30% in commercial and institutional buildings. Approximately 90% of the units are closed loop (ground-coupled) and the remaining open loop (water-source). It is presently a US$2 to US$3 billion annual industry in the country. The largest installation currently under construction is for Ball State University, Indiana where 4,100 vertical loops are being installed to heat and cool over 40 buildings using geothermal heat pumps. The distribution of the various applications are as follows: 139.89 MWt and 1,360.6 TJ/yr for individual space heating; 75.10 MWt and 7,73.2 TJ/yr for district heating; 2.31 MWt and 47.6 TJ/yr for air conditioning (cooling); 96.91 MWt and 799.8 TJ/yr for greenhouse heating; 141.95 MWt and 3,074.0 TJ/yr for fish farming; 22.41 MWt and 292.0 TJ/yr for agricultural drying; 17.43 MWt and 227.1 TJ/yr for industrial processing; 2.53 MWt and 20.0 TJ/yr for snow melting; 112.93 MWt and 2,557.5 TJ/yr for bathing and swimming; and 12,000 MWt and 47,400 TJ/yr for geothermal heat pumps. The total is 12,611.46 MWt and 56,551.8 TJ/yr (Lund et al., 2010).

5.2.3 South America

5.2.3.1 Argentina

Development of geothermal resources increased in the last few years with the discovered of new thermal areas linked to sedimentary basins that belong to the hydrothermal conductive system, along with advanced research of high enthalpy thermal fields. This allowed the development of new therapeutic-recreational complexes that generated income for different regions of the country. During the last five years 11 new projects were started and are now in the exploration field for direct-use. These projects are being considered for recreational therapeutic facilities and to supply drinking water to nearby towns. At present there are 64 bathing and swimming development, two greenhouse sites, two fish farms, one snow melting site, and three space heating sites (Pesce, 2010). A summary of the installed capacity and annual energy uses for the various sites were provided, however, several uses had to be estimated from combined uses by one of the authors (Boyd). The various applications of geothermal direct use are: 22.25 MWt and 295.82 TJ/yr for individual space heating; 20.44 MWt and 269.95 TJ/yr for greenhouse heating; 19.9 MWt and 252.92 TJ/yr for fish farming; 2.00 MWt and 15.14 TJ/yr for snow melting (at Copahue in the Andes); 91.36 MWt and 2,169.74 TJ/yr for bathing and swimming; 1.62 MWt and 44.62 TJ/yr for other uses (water consumption); and 149.90 MWt and 858.55 TJ/yr for geothermal heat pumps. The total for the country is 307.47 MWt and 3,906.74 TJ/yr.

5.2.3.2 Brazil

A significant number of low temperature resources (<90°C) have been identified in the continental area, but the potential for high temperature geothermal systems appears to be restricted to the Atlantic islands of Fernando de Noronha and Trindade. Most of the springs that account for the potential are located in the west central Brazil (in the states of Goiás and Mato Grosso) and in the south (in the state of Santa Catarina). The potential for large scale exploitation of low temperature geothermal water for industrial use and space heating is considered to be significant in the central part of the Paraná basin (situated at southern and southeastern Brazil), where cold winter seasons prevail under subtropical climate conditions. The various applications of direct use are: 0.9 MWt and 15.4 TJ/yr for fish farming, 4.20 MWt and 77.0 TJ/yr for an industrial wool processing plant ; 355 MWt and 6530 TJ/yr for bathing and swimming, for a total of 360.1 MWt and 6622.4 TJ/yr (Hamza et al, 2010).

5.2.3.3 Chile

Geothermal energy in the country has been only utilized for recreational purposes. Current use in spa and swimming pools, accounts for all the capacity. However, there are many private thermal spas and resorts in the geothermal area, for which quantitative information regarding their use of geothermal resources is not available. In some spas, shallow wells have been drilled to obtain hot water, while in others hot water is collected rudimentary and piped to the buildings pools, through shallow drains and plastic hoses. A total of 20 bathing and swimming sites have been identified amounting to 9.11 MWt and 131.82 TJ/yr (Lahsen et al., 2010).

5.2.3.4 Columbia

No country update report was filed for this country as nothing has changed since the last report according to Alfaro (personal communication September, 2009). Thus, the figures from WGC2005 are (see Lund et al., 2005): 14.4 MWt and 287 TJ/yr for bathing and swimming at 41 sites.

5.2.3.5 Ecuador

The utilization of geothermal resources in the country is restricted to direct uses only, that is, bathing resorts, balneology and swimming pools. Recently, the first use of space heating at the private Termas Papallacta Spa Resort Hotel has been commissioned, but no data are available. In addition, several projects for fish hatcheries are waiting funding for development. Thus, the data from WGC2005 (Lund et al., 2005) has not changed and the installed capacity is 5.157 MWt and annual energy use of 102.401 TJ/yr, all for bathing and swimming (Beate and Salgado, 2010).

5.2.3.6 Peru

No report on use of geothermal resources was made available for WGC2010. Based on personal communication with G. W. Huttrer in 2000, we assume that the figures given by Lund et al. (2005) of 2.4 MWt and 49 TJ/yr for seven spas have not changed during the last five years.

5.2.3.7 Venezuela

No report on the use of geothermal resources was made available for WGC2010. Personal communication with Urbani (2009) indicated that there has been no change since 2005. Thus, the figures of 0.7 MWt and 14 TJ/yr estimated for several small spas is used (Lund et al., 2005).

5.3 Asia

5.3.1 Bangladesh

This is a new country to appear on the list of geothermal countries. However the current paper, Guha et al. 2010, gives no detailed numbers that we can use to add to the Data base. The need for geothermal programs is explained in the text, with the current energy needs being supplied mainly by natural gas. With current population of about 150 million and increasing at the rate of about 2% per year, the demand for electricity and energy resources is rising at about 10% per year. The rise in demand is related to irrigation needs in the rural areas and air conditioning in the urban areas. A number of abandon wells and a recent survey have given an insight into the geothermal potential related to the major tectonic structural regions. Bangladesh is looking for development partners, donors, private investors, etc. to assist in the development of these resources.

5.3.2 China

The Chinese government, since 2006 has encouraged the development of geothermal energy, along with other renewable energies (Zheng et al. 2010). Geothermal district heating capacity has continued to increase at about 10% annually (52% since reported in 2005) to 1,291 MWt and 14,798.5 TJ/yr, and there has been a large increase in heat pump capacity from 383 MWt (2004/5) to 5,210MWt and 29,035 TJ/yr in 2009. Geothermal district heating in Tianjin utilizing GHP water is now servicing some 1 million people using 26.4 million m^3 annually saving 1.17 million tons of standard coal equivalent and reducing 2.78 million tons of CO_2 emissions. Using geothermal fluids for bathing, agriculture, and fish farming have continued to be major users. There has been a rapid development in the use of GHP's across the country. Renewable energy accounts for about 26% of the total heating and cooling requirements of the Olympic venues in Beijing and served as a good demonstration of the use of these forms of energy. In 2007 Chinese and Australian experts signed an agreement to undertake a survey of likely sites for the development of Enhance Geothermal Systems. A program of work has been established in 2009 and it is hoped to have an in depth study in 2010 of suitable sites. Other uses in the country include: 147 MWt and 1,687.9 TJ/yr for greenhouse heating; 197 MWt and 2,170.8 TJ/yr for fish farming; 82 MWt and 1,037.5 TJ/yr for agricultural drying; 145 MWt and 2,732.6 TJ/yr for industrial process heat; and 1,826 MWt and 23,886.0 TJ/yr for bathing and swimming. The total is 8,898 MWt and 75,348.3 TJ/yr.

5.3.3 India

Chandrasekharem et al. (2010) discusses again the geothermal potential of the country and the current use of its resources. As of December 2009, 265 MWt are installed all for bathing and swimming with an annual use of 2,545 TJ/yr. No other uses of geothermal direct heat are recorded, including a zero entry for GHP. Currently the building sector utilizes 33% of thermal power and the food processing industry 13%, generated by coal fired plant these activities could easily be serviced by geothermal if the environment was right for the conversion. However there appears to be little incentive for the conversion to geothermal heat. One of the major difficulties is having trained manpower to undertake these developments.

5.3.4 Indonesia

The paper by Darma et al. (2010) focuses, as in the past on the development of electricity generation by geothermal energy, however five years ago a group of researchers in government sponsored research and technology agency (BPPT) began to investigate methods to apply geothermal energy to the agriculture sector, particularly to sterilize the growing medium used in mushroom cultivation. The process is still at the research stage not having yet become commercial. Other uses of geothermal fluids include palm sugar processing, copra drying, tea drying and pasteurization and some fish farming. These activities are spread over about six areas totaling about 200 – 300 tonnes /hr of fluid. No heat pump installations are used to date as they appear to be uneconomical at this time due to the availability and abundance of high enthalpy fluids. Lund and Freeston (2001) cited 2.3MWt and 42.6TJ/yr as the usage for bathing and swimming and are assumed to remain unchanged. A paper by Surana et al. (2010) indicates additional direct use installations in the country, including bathing and swimming, Mushroom growing, palm sugar production, copra and cocoa drying, aquaculture, and space heating. Unfortunately, no data on capacity and annual energy us were provided, and thus cannot be estimated for this report.

5.3.5 Iran

Saffarzadeh et al. (2010) cite a small improvement in the utilization of geothermal fluids for bathing, capacity 41.583 MWt and 1,063.72 TJ/yr annual utilization, 2005 figures were 30.1 MWt and 752 .3 TJ/yr. New resorts have been constructed and older ones updated resulting in increased flows and capacity driven by joint ventures from the private and public sectors. Ground source heat pumps have been installed as demonstration projects in five different regions of the country in order to evaluate the efficiency under different climatic conditions. The installed capacity is 0.025 MWt and the annual energy use is 0.46 TJ/yr. The total is 41.608 MWt and 1,064.18 TJ/yr.

5.3.6 Israel

No country update paper was received from Israel. Thus, assuming the direct-use in the country has not changed, we will use reports and estimates from WGC2005 (Lund et al., 2005). Geothermal energy is used for spas, greenhouses and aquaculture as follows (Leviite and Greitzer, 2005): 27.6 MWt and 512.0 TJ/yr for greenhouse heating; 31.4 MWt and 989.0 MWt for fish farming; and 23.4 MWt and 692 TJ/yr for bathing and swimming; for a total of 82.4 MWT and 2,193 TJ/yr.

5.3.7 Japan

The direct use of medium- and low-enthalpy geothermal water is mainly located in the areas around the high-enthalpy geothermal area, where hot spring resources are abundant. Otherwise, the use of shallow geothermal heat pump systems in available nationwide. These latter installation account for only 0.3% of the direct-use, and thus have limited use in the country. Although many hotels and Japanese-style inns utilize hot spring water, this bathing utilization has been excluded in past reports and was only estimated by the authors (Freeston and Lund) for WGC2005, mainly as it is difficult to evaluate the actual use. However, to be consistent with reports from other countries and the world-wide summary, the numbers for bathing and swimming are included in this report. The total capacity without bathing has not changed much from WGC2005. Bathing now accounts for about 90% of the utilization in the country for direct-use. Since 2002, 141 new direct-use facilities has been added to the database, while 136 facilities were removed of which 58 facilities were dismantled or stopped operating due to economic problems, switching to oil or corrosion/scaling problems. The various applications are as follows: 77.37 MWt and 969.49 TJ/yr for space heating; 36.92 MWt and 451.73 TJ/yr for greenhouse heating; 7.91 MWt and 141.86 TJ/yr for fish farming, 1.24 MWt and 30.92 TJ/yr for industrial applications; 152.54 MWt and 516.27 TJ/yr for air conditioning and snow melting (assuming a 30% - 70% split as for WGC2005); 1,810.19 MWt and 23,519.81 TJ/yr for bathing and swimming; and 13.36 MWt and 67.86 TJ/yr for geothermal heat pumps. The total is 2,099.53 MWt and 25,697.94 TJ/yr (Sugino and Akeno, 2010).

5.3.8 Jordan

No paper was received from this country. Saudi and Swarich (2005) reported no new development in the country using geothermal energy for direct-use for WGC2005. Thus, our data is based on the situation described in Lund and Freeston (2001). It appears that at least six sites have installation for direct-use, mainly for bathing and swimming. The estimated capacity and use is 153.3 MWt and annual energy use of 1,540 TJ/yr.

5.3.9 Korea (South)

Direct-use statistics on 13 major hot springs showing discharge temperatures higher than 42^{o}C, some of which have been used for more than a thousand years. Many of these hot springs are used for space heating of small hotel buildings and for greenhouses. There has been a large increase in greenhouse heating use in rural areas due to financial support for a special rural subsidy program. Recently, some private universities installed large heating systems without government subsidy in order to reduce operating costs of heating and cooling on campus. Geothermal or ground-source heat pump installation is rapidly increasing over the past four years, with a large increase in 2009, due again to an active rural subsidy program. Most installations in the country are mainly for office and public buildings and relatively large buildings such as dormitory, university campus and hospitals. Geothermal heat pumps are found in over 700 locations throughout the country and are typically in the 300 to 100 kW size for a total of over 3,000 units. The various applications are: 8.66 MWt and 53.43 TJ/yr for individual space heating; 2.21 MWt and 31.28 TJ/yr for district heating; 0.17 MWt and 1.33 TJ/yr for greenhouse heating; 32.56 MWt and 507.61 TJ/yr for bathing and swimming; and 185.7 MWt and 1,361 TJ/yr for geothermal heat pumps. The total for the country is 229.3 MWt and 1,954.65 TJ/yr (Song et al., 2010).

5.3.10 Mongolia

No country update report was received for WGC2010. Based on data from Bignall et al. (2005) and estimates by Lund et al. (2005), we assume that the use has not changed over the past five years. Hot springs in the country are utilized for heating, bathing and medical treatment, with three hot springs currently popular tourist attractions. Data were only available from one area, Shargaljuut. Based on the previous data and estimates mentioned above, the various applications are: 1.4 MWt and 44.0 TJ/yr for individual space heating; 2.4 MWt and 74.0 TJ/yr for greenhouse heating; and 3.0 MWt and 95.2 TJ/yr for bathing and swimming; for a total of 6.8 MWt and 213.2 TJ/yr.

5.3.11 Nepal

Geothermal development has been taking place on a very small scale with the increased participation of local government and the limited financial resources. Increased popularization of geothermal springs has led to more attraction of visitors. The local people have been able to boost their business and as a result, taken the initiative to building road infrastructure with the assistance of local government bodies. The main use has been for bathing and swimming at 25 locations. There is also some small use for boiling eggs in restaurants and for direct drinking of the water to cure gastroenteritis disease; however, these two uses are not quantified and are included in the bathing and swimming numbers: 2.717 MWt and 73.743 TJ/yr (Ranjit, 2010).

5.3.12 Philippines

Direct-use of geothermal energy in the country is very limited. Two agricultural drying plants using geothermal heat are located at Palinpinon and Manito. The Palinpinon project uses steam from the Southern Negros Geothermal Projects (Palinpinon I geothermal power plant) where coconut meat and copra are dried (Chua and Abito, 1994). The main resorts using geothermal heat are at Laguna and Agco. The various applications are: 1.63 MWt and 26.93 TJ/yr for agricultural draying (the majority at the Palinpinon plant); and 1.67 MWt and 12.65 TJ/yr for bathing and swimming; for a total of 3.3 MWt and 39.58 TJ/yr (Ogena et al., 2010).

5.3.13 Saudi Arabia

There are ten thermal springs in the country. Of these, six are in Gizan (southwest near the Yemen border) and four in Al-Lith area (west-central on the Red Sea). None are being exploited at present (Rehman, 2010).

5.3.14 Thailand

No country update papers were submitted for either WGC2005 or WGC2010. Based on communications from Praserdvigai (2005), an estimate of 2.54 MWt and 79.1 TJ/yr are currently installed and being utilized at a 0.3 MWe binary plant at Fang in Chiang-Mai province. A small crop-drying facility and air-conditioning unit are utilizing the exhaust from the power plant. The distribution of use is 0.04 MWt and 0.3 TJ/yr for crop drying and 2.5 MWt and 78.8 TJ/yr for bathing and swimming, for a total of 2.54 MWt and 79.1 TJ/yr.

5.3.15 Tajikistan

A number of uses of geothermal water are described in the paper by Normatov (2010); however, no estimates of the installed capacity or annual energy use were made. Fourteen sites are listed using geothermal fluids for balneology and health resorts, two for drinking and bottling the water, and two for other uses. Seven locations are listed that have potential to be developed for balneology and for health resorts. The six main health resorts using geothermal water are listed at Garm-Chashma in the Pamir Mountains, and Hodzha-Obigarm, Tamdikul, Hovatag, Obi-Garm and Yavroz in central Tajikistan. Based on these uses an estimate was made (assuming 5 l/s and 10^{o}C "ΔT" for peak use and 3 l/s and 10^{o}C "ΔT" for annual use) of 2.93 MWt and 55.40 TJ/yr for bathing and swimming (which includes balneology).

5.3.16 Turkey

Turkey has extensive geothermal resources, that have been utilized for heating of residences, district heating, greenhouse heating and for spas. There are a total of 260 spas in the country using geothermal water for balneological purposes. There is also a liguid carbon dioxide and dry ice production factory integrated with a power plant at Kizildere. Greenhouse heating has increased substantially in the last three year, with installations in six major area covering 230 ha. Tourism is also an important industry with over 12 million local and 10,000 foreign visitors benefiting from the balneological aspects of hot springs and spas. Geothermal heat pump applications include the Metro Meydan M1 Shopping Center in Istanbul and the Terme Maris Facility in Dalaman. The geothermal heating is equivalent to supplying energy to 201,000 residences. The various applications are: 219 MWt and 2,417 TJ/yr for individual space heating; 792 MWt and 7,386.4 TJ/yr for district heating; 483 MWt and 9,138 TJ/yr for greenhouse heating; 552 MWt and 17,408 TJ/yr for bathing and swimming; and 38 MWt and 536.5 TJ/yr for geothermal heat pumps. The total for the country is 2,084 MWt and 36,885.9 TJ/yr (Mertoglu et al, 2010).

5.3.17 Vietnam

No country update paper was received; however, a related paper described the current development in the country (Ngoc et al., 2010). They described an experimental drying facility for bananas, coconuts, and medicinal herbs being carried out at the Hoi Van geothermal source in Binh Dinh province, estimated at 0.5 MWt and 11.83 TJ/yr; a salt factor that produces 7,000 tonnes/yr of iodized salt from evaporation using geothermal energy at the Hoi Van resource, estimated at 1.4 MWt and 21.6 TJ/yr; and a geothermal resources providing hot water for balneological and medical treatment which attracts tourism, estimated at 29.3 MWt and 58.9 TJ/yr. These estimates are based in part on data from WGC2005 (Cuong et al., 2005; Lund et al., 2005) and add to a total of 31.2 MWt and 92.33 TJ/yr.

5.3.18 Yemen

No country updates were submitted for WGC2005 and WGC2010, thus, the figures from 2000 (Lund and Freeston, 2001) will be assumed to still be valid. These are 1.0 MWt and 15 TJ/yr for bathing and swimming.

5.4 Europe

5.4.1 Albania

The basis for most of the work in the country is from the "Atlas of Geothermal Resources in Albania published in 2004. More recently, two publications in 2008 have described the potential for direct-use: "Space Heating/Cooling Borehole Vertical Heat Exchanger – Heat Pump System", and "Geothermal Center for Integrated and Cascade Direct Use of Geothermal Energy of Kozani-8 Well, near Elbasani City". The later publications describes spa-hotels with hot pools, greenhouse and aquaculture installations. The geothermal energy resources for direct-use include natural springs and deep wells with thermal water of temperature up to 65.5^{o}C, and ground heat of temperature of 16.4^{o}C (using geothermal heat pumps). At present the only direct geothermal use is for bathing and swimming with an installed capacity of 9.57 MWt and an annual energy use of 8.53 TJ. Geothermal heat pumps use is 1.914 MWt and 31.93 TJ/yr with 105 installed units. This gives a total of 11.48 MWt and 40.46 TJ/yr (Frasheri, 2010).

5.4.2 Austria

Only seven deep boreholes were drilled in the country over the past year, all of which were used to supply heat for balneological purposes. No other geothermal projects were undertaken in Austria since 2005 due to lack of public support and low feed-in terriffs for electric power (7.3 cents/kWh). However, the number of ground source heat pumps has shown a steady increase with the estimated number of units at 50,000 having a capacity of 600 MWt and producing 800 GWh/yr. As in most countries the data on geothermal heat pumps are hard to obtain as only groundwater wells are documented with the authorities. Future projects are expected in the Vienna basin near the capital and in the Austrian Molasse Basin. Geothermal heat pumps are expected to increase with more than 50% of the new family houses to have units installed. The various direct-uses include: district heating (50.03 MWt and 602.4 TJ/yr); greenhouse heating (1.80 MWt and 29.0 TJ/yr); industrial process heat (2.15 MWt and 31.3 TJ/yr); bathing and swimming (8.87 MWt and 185.0 TJ/yr); and geothermal heat pumps (600.0 MWt and 2,880 TJ/yr) for a total of 662.85 MWt and 3,727.70 TJ/yr (Goldbrunner, 2010).

5.4.3 Belgium

No country update report was received for Belgium, thus data from WGC 2000 and WGC2005 will be utilized along with some updated material on geothermal heat pumps (Lund et al., 2005; EurObserv'ER, 2009). Since, only an abstract was submitted in 2005 and data from WGC2000 was used at that time (Berckmans and Vandenberghe, 1998). Geothermal energy used in the country is focused on shallow applications with the geothermal heat pump market growing significantly over the past few years, with the open-loop type being the most common. Most applications are in the eastern provinces. Aquifer thermal energy storage is also being utilized in a number of locations. The total estimated installed capacity and use is: space heating 2.1 MWt and 53.8 TJ/yr; greenhouse heating 0.9 MWt and 22.1 TJ/yr; aquaculture 0.3 MWt and10.1 TJ/yr; agricultural drying 0.5 MWt and 13.1 TJ/yr; and swimming pool 0.1 MWt and 8.1 TJ/yr. The estimated geothermal heat pumps based on 2008 data is 9,500 units (up from 5,000 in 2005), with an installed capacity of 114.0 MWt. Using 1,500 full load heating hours per year and a 3.5 COP in the heating mode, the energy use is estimated at 439.77 TJ/yr. Thus, the total capacity and use in the country is 117.90 MWt and 546.97 TJ/yr.

5.4.4 Bosnia and Herzegovina

Geothermal research and development in the country has increased over the past five years, however, only five new wells were drilled. Direct-use of geothermal energy has been implemented at 23 locations, with individual space heating being the largest use of the energy (44.9%), followed by spas and recreation centers (39.2%); greenhouses at 15.5% and fish farming at one location using 0.4%. Geothermal heat pumps are installed at three locations. There are 20 spas including nine recreational centers. Individual space heating is used in five locations. Greenhouses using geothermal waters for heating grow flowers and vegetables for the domestic market and for export to Croatia. A planned project is for drilling five wells for district heating in Bijeljina in the Pannonian

Basin. The use for individual space heating: 6.73 MWt and 114.08 TJ/yr; for greenhouse heating; 1.51 MWt and 39.41 TJ/yr; for fish farming; 0.09 MWt and 1.1 TJ/yr; for bathing and swimming; 13.21 MWt and 99.62 TJ/yr; and for geothermal heat pumps; 0.1555 MWt and 1.15 TJ/yr; for a total of 21.696 MWt and 255.36 TJ/yr (Miošić et al., 2010).

5.4.5 Bulgaria

The country is rich in geothermal water within the temperature range of 20 to 100°C with the main geothermal activity concentrated in the southern part of the country due to the higher water temperature and low water salinity. The information in the paper is based mainly on state-owned and only partially municipality-owned geothermal fields and is based on existing permits and concessions. The main geothermal direct-use in the country is for balneology (prevention, treatment and rehabilitation, bathing and swimming pools), space heating and air-conditioning, greenhouse heating, geothermal heat pumps, direct thermal water supply, bottling of potable water and soft drinks and for unspecified industrial use. The cultivation of microalgae and production of iodine paste and methane extraction have been terminated. The installed capacity for direct use, excluding geothermal heat pumps, is about 30% less as compared to five years ago. The geothermal direct use is: 9.28 MWt and 128.56 TJ/yr for individual space heating, 6.7 MWt and 65.5 TJ/yr for air conditioning, 5.99 MWt and 88.68 TJ/yr for greenhouse heating, 48.78 MWt and 768.32 TJ/yr for bathing and swimming, 6.92 MWt and 32.83 TJ/yr for other uses (preparing steam for heat stations and public laundry), and 20.63 MWt and 286.23 TJ/yr for geothermal heat pumps, for a total of 98.30 MWt and 1,370.12 TJ/yr (Bojadgieva et al., 2010).

5.4.6 Croatia

Direct utilization in the country is mainly for heating swimming pools and spas along with recreational centers, as well as space heating. There are 20 spas and five geothermal fields above 100°C that are using geothermal energy. The five high temperature geothermal fields are being considered for combine heat and electrical energy production and may be started in 2010. The estimated total direct-use is 34.78 MWt and 253.05 TJ/yr for individual space heating and 32.70 MWt and 215.84 TJ/yr for bathing and swimming, for a total of 67.48 MWt and 468.89 TJ/yr (Jelić et al., 2010).

5.4.7 Czech Republic

No country update paper was received for this country, thus the data from WGC2005 will have to be utilized, assuming no changes (Myslil et al., 2005). The direct use of thermal water in spas and swimming pools dates back several hundred years. There are 11 major spas and thermal springs in the Czech Republic, the most famous being Karlovy Vary (Karlsbad) and Marianske Lazně (Marienbad). More than 10,000 geothermal heat pumps have been installed, at an average capacity of 20 kW (a report from 2009 (EurObserv'ER, 2009), reports in 2008, 9,168 units installed with a capacity of 147.0 MWt), thus the geothermal heat pump numbers will be reduced to the 2008 figure. Using a COP of 3.5 and 2,200 full load operating hours per year, the annual energy use is then estimated at 832 TJ/yr. The estimated capacity for the spas is 4.5 MWt, with an energy use of 90 TJ/yr (Lund, 1990). The total for the country is 151.5 MWt and 922 TJ/yr.

5.4.8 Denmark

Temperatures in the country are of low-enthalpy with no pronounced temperature anomalies, with normal gradients of 25 to 30°C/km. Two large district heating plants using heat pumps have been built in the country. The first was established in 1984 at Thisted producing 44°C saline water at 200 m^3/h from 1,250 m depth resulting in 7 MWt of installed capacity. The second in Copenhagen started in 2005, uses 73°C saline water at 235 m^3/h from 2,560 m depth resulting in an installed capacity of 14 MWt. These two plants along with other heat pump district heating projects have an installed capacity of 44 MWt and annual energy use of 800 TJ. Additional projects are being investigated for district heating at Sønderborg, Hjørring, and other communities. The plants at Thisted and Copenhagen are being considered for expansion. A number of small heat pump projects have been installed, estimated at 20,000 units in a vertical configuration with a capacity and annual energy use of 160 MWt and 1,700 TJ/yr. Ground water is also being used for cooling and industrial locations. The total geothermal capacity is 200 MWt and the annual use is 2,500 TJ (Mahler and Magtengaard, 2010).

5.4.9 Estonia

No country update paper was received from this country; however, an estimate of geothermal heat pump capacity is presented in EurObserv'ER 2009. For 2008, the number of installed units was 4,874 with an installed capacity of 63.0 MWt. Using a COP of 3.5 and 2,200 full load operating hours annually, the estimated use is 356 TJ/yr. No other geothermal use has been recorded.

5.4.10 Finland

No country update paper was received from this country; however, a few estimates were made for 2008 (Jarmo, 2009) for geothermal heat pumps – the only geothermal use in the country. Based on his estimate, approximately 7,500 geothermal heat pumps units were sold in 2008, or about 40% more than 2007 with a total energy supply of 1 to 2 TWh/yr. Based on the EurObserv'ER 2009 report, the estimate is that 46,412 total units were installed by 2008 for a capacity of 857.9 MWt and the total units installed between 2007 and 2008 was 7,500 units (which is only a 19% increase). Based on data from the WGC2005 world report (Lund, et al., 2005) the number of full load hours annually is 4,000 with an average COP of 3.1. Thus, based on the EurObserve'ER numbers, the annual energy use would be 8,370 TJ (2,325 GWh/yr) which is slightly higher than Jarmo's estimate, but is the one that will be utilized.

5.4.11 France

The development of geothermal resources in the country has seen several phases: after a major development phase based on low enthalpy resources from sedimentary basins at the beginning of the 1980s; followed by a period of withdrawal during the 1990s with very little new activity; then more recently by a revival of activity of all kinds, based on a policy by the government for energy management and development, especially of renewable energy (French Energy Law in 2005 and the large consulting process "Grenelle de l'environnement" in 2007). The goal of the latter act is to have 535 ktoe/year of geothermal heating by 2012, and 1,300 by 2020 composed of district heating (about 40%), large heat pumps (about 20%), and individual geothermal heat pumps (about 40%), based on 220 ktoe/yr in 2006. A "renewable heating and cooling fund" was set up by the finance law 2009-2011, which supports renewable heating and cooling projects. The use of geothermal heat pumps started in the 80s, and now provides 20,000 units for heating individual houses. Most geothermal heat pump units are either direct expansion or water-source type with 74% new and 26% retrofit installations. Geothermal district heating supplies heat to 150,000 dwellings mainly in the Paris and Aquitaine basins. At present the direct-uses include: district heating (300 MWt and 4,900 TJ/yr), greenhouse heating (9 MWt and 155 TJ/yr), fish farming (19 MWT and 212 TJ/yr), bathing and swimming (17 MWt and 162 TJ/yr), and geothermal heat pumps (mainly individual homes) (1,000 MWt and 7,500 TJ/yr), for a total of 1,345 MWt and 12,929 TJ/yr. Fish farming, greenhouses and bathing uses are mainly located in the Aquitance Basin or other regions outside of Paris (Boissier et al., 2010).

5.4.12 Germany

Presently, there are 162 geothermal direct-use installations in the country. The installations comprise district heating, space heating in some cases combined with greenhouses and thermal spas. Most of the district heating plants are located in the Northern German Basin, the Molasse Basin in Southern Germany, or along the Upper Rhine Graben. Two geothermal power plants at Neustadt-Glewe and Unterhaching also provide water for district heating. In addition to these large installations, there are numerous small- and medium-size geothermal heat pump units located throughout the country. Under the prevailing economic and political conditions, multiple or cascaded uses are employed to help improve the economic efficiency of the direct use. For this reason many installations combine district or space heating with greenhouses and thermal spas. No numbers are given for greenhouse heating. Geothermal heat pump installations are difficult to determine, however, estimates from sales statistics indicated that there are 148,000 units operating in 2008 and a 20% increase estimated for 2009 for a total of 178,000 units (13% water-source and 87% ground-coupled). The capacity and energy use for the various applications are: 1.2 MWt and 2.9 TJ/yr for individual space heating, 209.3 MWt and 1054.4 TJ/yr for district heating; 44.9 MWt and 1,339.2 TJ/yr for bathing and swimming; and 2,230 MWt and 10,368 TJ/yr for geothermal heat pumps, for a country total of 2,485.4 MWt and 12,764.5 TJ/yr (Schellschmidt et al., 2010).

5.4.13 Greece

The first half of the present decade was characterized by a diversification of direct applications with new uses such as aquaculture, spirulina production, outdoor pool heating, water desalination and fruit and vegetable dehydration. However, in the past few years there has been a rapid expansion of geothermal heat pumps, with the increase in installed capacity since WGC2005 has been almost solely attributed to geothermal heat pumps. There have been some reduction in use, mainly with the greenhouses and desalination plant on Kimolos Island being taken out of operation, and the 2.0 MWt project for heating and cooling several public buildings in Langadas (Thessaloniki) has been abandoned. The fate of a novel desalination project on Milos Island is still unclear, despite the completion of eight production and injection wells. Space heating is practiced only in two spa buildings, in a hotel in Milos, in several individual houses, and in a high school. Approximately 21 ha of greenhouses are heated, mainly for vegetable and cut flower growing, with 27 greenhouse units in the country run by 21 operators. Some soil heating, especially for asparagus, has increased significantly and is now 17 ha. There are more than 60 thermal spas and bathing centers in operation. A tomato dehydration unit has been operating since 2001 producing more than 1,000 kg of dehydrated tomatoes per day. Geothermal water is used for frost protection for a number of aquaculture ponds during the winter. Approximately 350 geothermal heat pump applications are located in the country with about 65% being of the open loop configuration. The figures for the various direct uses are: 1.5 MWt and 16.5 TJ/yr for individual space heating; 34.8 MWt and 340 TJ/yr for greenhouse heating; 9.0 MWt and 71.5 TJ/yr for fish farming; 0.3 MWt and 1.8 TJ/yr for agricultural drying,; 39.0 MWt and 238 TJ/yr for bathing and swimming; and 50.0 MWt and 270 TJ/yr for geothermal heat pumps. The total for the country is 134.6 MWt and 937.8 TJ/yr (Andritsos et al., 2010).

5.4.14 Hungary

Surface manifestations have been known in the country since ancient times, and thermal springs in Budapest have been used during the Roman Empire and also later in the Medieval Hungarian Kingdom. Exploration for thermal waters began in 1877 and during the 1950s and 1960s hundreds of geothermal wells were drilled, mainly for agricultural utilization. More recently, the use of geothermal energy has decreased substantially due to the global recession; however, promising projects are being investigated for both power production and direct-uses. Balneology was the earliest use of thermal waters, with 289 thermal wells and 120 natural springs presently used for sport and therapeutically purposes. Agricultural use is one of the important applications of geothermal waters in the country with 193 operating wells supplying heat for 67 ha of greenhouses. Animal farms use thermal water in more than 52 cases to raise chickens, turkeys, calves, pigs and snails. At present more than 40 townships with more than 9,000 flats are heated in district heating projects. Thermal waters are also used in secondary oil production with 5,400 m^3/s of hot water being injected into oil reservoirs for enhanced oil recovery. In addition, gathering pipes in a heavy oil producing oilfield are heated with geothermal waters. Geothermal heat pumps have had the largest growth in the country since 2005, with more than 4,000 units installed. The various uses are: 23.7 MWt and 232 TJ/yr for individual space heating; 94.9 MWt and 930 TJ/yr for district heating; 196 MWt and 2,388 TJ/yr for greenhouse heating; 4 MWt and 44 TJ/yr for fish farming; 2 MWt and 17 TJ/yr for animal farming; 10 MWt and 123 TJ/yr for agricultural drying; 12 MWt and 159 TJ/yr for industrial process heating; 272 MWt and 5,356 TJ/yr for bathing and swimming; and 40 MWt and 518 TJ/yr for geothermal heat pumps. The total for the country is 654.6 MWt and 9,767 TJ/yr (Toth, 2010).

5.4.15 Iceland

Due to its location the country has very favorable conditions for geothermal development. The geothermal resources are utilized for both electricity generation and direct heat applications. It provides 62% of the nation's primary energy supply, with space heating the most important direct-use, providing 89% of all space heating in the country. The largest geothermal district heating system is in Reykjavik where 197,404 people are served with an installed capacity of 1,264 MWt and peak load of 924 MWt. Two other large district heating systems are located on the Reykjanes peninsula which serves about 20,000 people and the Akureyri system in northern Iceland serving about 23,000 people. There are 135 swimming pools in the country that use geothermal heat, generally open throughout the year. Snow melting has been recently increased to where 820,000 m^2 are heated throughout the country, with most in Reykjavik. Most of the heat energy comes from the return water from space heating systems. Industrial uses include the seaweed drying plant at Thorverk; carbon dioxide production at Haedarendi; and fish drying by 18 small companies, producing about 15,000 tonnes of dried cod heads for export. The diatomaceous earth drying plant at Kisilidjan has been closed. Other industrial applications using geothermal heat are salt production, drying of imported hardwood, retreading of car tires, wood washing, curing of cement blocks, and steam baking of bread at several locations. After space heating, heating of greenhouses is the oldest and most important uses of geothermal energy. Crops produce include vegetables (55%) and flowers (45%), with an estimated 17.5 ha in operation at present. Fish farming has increased to around 10,000 tonnes in 40 plants by 2006, with salmon the main specie; however, arctic char and cod production are increasing rapidly. Geothermal energy installed capacity and annual use are: 1,380 MWt and 17,483 TJ/yr for district heating; 40 MWt and 677 TJ/yr for greenhouse heating; 67 MWt and 1,835 TJ/yr for fish farming; 65 MWt and 1,642 TJ/yr for industrial process heat; 200 MWt and 1,448 TJ/yr for snow melting; 70 MWt and 1,256 TJ/yr for bathing and swimming; and 4 MWt and 20 TJ/yr for geothermal heat pumps (2 large units in Akureyri); for a total of 1,826 MWt and 24,361 TJ/yr (Ragnarsson, 2010).

5.4.16 Irish Republic

Geothermal energy exploitation in the country has expanded rapidly over the last few years, despite low general gradients (<25°C/km) and limited geothermal resources. There are 42 warm springs in the country between 13 and 24.7°C. The emphasis is on exploitation of low temperature resources for space heating, using heat pump technology. However, a major new development is the first deep drilling project to reach warmer water at depth for district heating projects, with a trial well drilled to over 1.3 km in the western suburbs of Dublin. Approximately 9,500 geothermal heat pump units have been installed, with most in the 15 kW size, but a number of larger units in the 100 to 450 kW range are serving public and institutional/commercial buildings. The largest installation is a 3 MW open loop system at the Athlone City Center Retail Complex. The domestic market primarily uses closed loop systems, whereas the commercial market prefers the open loop using ground water. At present 1.45 MWt and 7.91 TJ/yr are used for bathing and swimming, and 151.43 MWt and 756.11 TJ/yr are used for geothermal heat pumps, for a total of 152.88 MWt and 764.02 TJ/yr (Allen and Burgess, 2010).

5.4.17 Italy

Geothermal direct-use has increased by a factor of 1.2 in the past five years to 867 MWt and 9,941 TJ/yr. This larger contribution, in terms of installed power, is mainly due to the wide development, mainly in the northern areas of Italy, of geothermal district heating and in the number of single household installation. Both heating and cooling have been developed using geothermal energy, mainly by a large increase in geothermal heat pumps, both open and closed systems. Much of the growth has been due to interest from the designer's community, as well as the decrease in the cost of systems. For centuries Italian people have largely used thermal waters for bathing, medical cures and relaxation, and the industry is still an important part of geothermal use, accounting for 32% of the annual energy use. A number of district heating systems using geothermal energy are operating in the country, with Ferrara being the most important. A number of geothermal district heating systems are also operating in the Tuscany region. Greenhouse heating and fish farming are also important parts of direct use applications, amounting to 13% and 16 % respectively of the annual energy use. The largest greenhouse operation uses "waste" water from the Mt. Amiata power plant in Tuscany. Large geothermal heat pump installations (2-5 MWt) have played an important role in Italy. Installations of geothermal heat pumps has increased 15% in the past year with an about 12,000 units installed. The installed capacity and annual energy use for the various applications are: 92 MWt and 1,769 TJ/yr for individual space heating; 118 MWt and 963 TJ/yr for district heating; 111 MWt and 1,329 TJ/yr for greenhouse heating; 100 MWt and 1,632 TJ/yr for fish farming; 28 MWt and 130 TJ/yr for industrial applications; 187 MWt and 3,157 TJ/yr for swimming and bathing; and 231 MTW; and 961 TJ/yr for geothermal heat pumps. The total is 867 MWt and 9,941 TJ/yr (Buonasorte et al., 2010).

5.4.18 Latvia

No country update paper was received from Latvia, thus the data will be based on communications from Skapare (2005), the Geothermics report (Lund, et al., 2005), and EurObserv'ER (2009). In 2005 the following use of geothermal energy were reported: two balneology facilities at Jurmala and Lieapaja for a total of 0.53 MWt and 9.50 TJ/yr; a fish farm at Dobele for 0.23 MWt and 6.44 TJ/yr; individual space heating for 0.38 MWt and 8.90 TJ/yr; and district heating of 0.17 MWt and 4.75 TJ/yr. In 2005, geothermal heat pumps were reported at four locations for a total of 20 units, which is more than reported in EurObserv'ER (10 units). Thus, we will use the 2005 report which states an installed capacity of 0.321 MWt and 2.22 TJ/yr. The total for Latvia is then 1.63 MWt and 31.81 TJ/yr.

5.4.19 Lithuania

In June of 2004 the State Commission confirmed that the plant capacity for the Klaipeda geothermal demonstration plant on the west coast of the country was 35 MWt, of which 18.0 MWt was from geothermal energy. Four absorption heat pumps (at 4.5 MWt each) extract energy from 39°C geothermal water which is boosted to 175°C by three natural gas hot water boilers (16.2 MWt each). The heat energy is then supplied to the local district heating system. The installed geothermal capacity for the Klaipeda plant is 18.0 MWt (now operating at 13.6 MWt) producing 105.80 TJ/yr. In addition there are a number of smaller geothermal heat pumps units in single family houses throughout the country adding 34.5 MWt and 305.72 TJ/yr. The total for the country is 48.1 MWt and 411.52 TJ/yr (Zinevicius and Sliaupa, 2010).

5.4.20 Macedonia

The use of geothermal waters in the country is from seven projects and six spas; however, there has been little change since WGC2005. All were completed before and during the 1980s. The majority of the geothermal energy use is for district heating followed by greenhouse heating. No figures were given for spa heating, thus these numbers are estimated. Greenhouses are located in Istibanja (6 ha), Kocani (18 ha), and Smokvica (22.5 ha). In addition, space and district heating is carried out in Bansko and Kocani and spas in Katlanovo, Kezovica and Bansko. There is renewed interest in revitalizing the Strumica project at Bansko, mainly consisting of greenhouses. The energy use for the various applications are: 0.84 MWt and 6.60 TJ/yr for individual space heating; 42.55 MWt and 518.37 TJ/yr for district heating; 2.79 MWt and 61.14 TJ/yr for greenhouse heating; balneology and hot water heating is recorded from WGC2005 by the same authors at 1.0 MWt and 15.3 TJ/yr. The total for the country is 47.18 MWt and 601.41 TJ/yr (Popovska-Vasilevska et al., 2010).

5.4.21 Netherlands

Originally the object of drilling energy wells in the country was to store solar energy for space heating in winter. Later, this application broadened to the storage of thermal energy (both heat and cold) from other sources and to include geothermal heat pumps. The R&D of the early applications in the 1980s was focused on large scale applications such as commercial buildings rather than residential houses. Almost all of these early projects used ground water wells to store and extract thermal energy. In the late 1990s, borehole heat exchangers began to pay a more important role with geothermal heat pumps. At present, most of the geothermal heat pumps projects are using vertical borehole heat exchangers, with over 10,000 of these in operation. Most are small scale applications such as for single family houses or small office and commercial buildings. Systems in family homes are designed for the heating load, whereas in commercial/office building the design is for both heating and cooling. Most projects use aquifer storage for both heating and cooling, with heat pump capacities in the 50 to 100 kWt range, and using ground water flow rates at less than 10 m^3/hr (as no permits are need up to this rate). In Amsterdam about 1,200 large systems are installed with heat pump capacities around 1,000 kWt in some cases extracting over 250 m^3/hr from a single well. Direct groundwater cooling is also practiced with the larger projects. The estimated capacity and use of geothermal heat pumps in the country is 175 MWt and 1,012.6 TJ/yr for the smaller units (average 7 kWt) and 1,219.3 MWt and 9,407.2 TJ/yr for the larger units (average 1,006 kWt) for a total of 1,394.30 MWt and 10,419.80 TJ/yr. In addition there is 5.83 MWt and 89.7 TJ/yr for district heating and 10.13 MWt and 189.9 TJ/yr for greenhouse heating. The total for the country is 1,410.26 MWt and 10,699.40 TJ/yr (van Heekeren and Koenders, 2010).

5.4.22 Norway

Recent policy in Norway is to reduce the dependence on hydropower by restricting demand and increasing diversity. To plan, coordinate and promote research and development within geothermal energy in Norway, the “Norwegian Centre for Geothermal Energy Research” (CGER) was established in 2009 with 19 partners from universities, colleges, research institutes and industry. The center aims to facilitate the exploitation of geothermal energy as a national energy source and international business object. At present the geothermal energy use in the country is with geothermal heat pumps (GSHP). The total number of installations is estimated at 26,000 with an installed capacity of 3,300 MWt. More than 90% of these installations are vertical boreholes with single U-shaped pipes in open groundwater-filled boreholes. Today, about 350 large GSHP systems for public, commercial buildings or multi-family dwellings are installed, including some of the European largest GSHP with borehole heat exchangers (BHE). These installations are borehole thermal energy storage (BTES) systems providing a balanced combination of both heating and cooling. One of the largest system comprising 228 boreholes of 200 m depth provides heating and cooling to the new Akershus University Hospital (137,000 m^2). It is planned to expand the system to 350 boreholes. The total installed capacity of GSHP is 3,300 MWt producing 25,200 TJ/yr of heat energy (Midttømme et al., 2010); however, the accuracy of the data is uncertain.

5.4.23 Poland

Poland is characterized by low-enthalpy geothermal resources found mostly in the Mesozoic sedimentary formations. For many centuries warm springs have been used for balneotherapy in several spas. At present five geothermal heating plants are in operation, the largest in the Podhale region in southern Poland with an installed capcity of 41 MW and producing 267 TJ/yr (peak). Seven new bathing centers opened in the past five years. Other types of geothermal use include greenhouse heating, wood drying, fish farming (these three are at the Podhale Geothermal Laboratory as R&D projects), and salt extraction from geothermal water. Geothermal heat pumps installations have increased by at least 50% over the past five years with three large units in two major heating plants (water-source units), and over 11,000 units in individual buildings (ground-coupled units, both vertical and horizontal). The various uses include: district heating of 68.0 MWt and 393 TJ/yr; greenhouse heating 0.5 MWt and 2.0 TJ/yr; fish farming 0.5 MWt and 2.0 TJ/yr; bathing and swimming 8.67 MWt and 55.2 TJ/yr; and geothermal heat pumps at 203.10 MWt and 1,044.5 TJ/yr; others (salt extraction and playground heating) 0.28 MWt and 4.4 TJ/yr; for a total of 281.05 MWt and 1,501.1 TJ/yr (Kepinska, 2010).

5.4.24 Portugal

High temperature geothermal resources in Portugal are limited to the volcanic islands of the Azores, where electric power has been produced since 1980. Low-temperature geothermal resources are exploited for direct uses in balneotherapy, small space heating systems and geothermal heat pumps. In 2008, private investors obtained concession rights for exploration of geothermal resources for a total area of 2,655 km^2, aiming for future development of small scale EGS generation projects. District heating projects are operating at Chaves in northern Portugal and S. Pedro do Sul, in central Portugal. There is a single greenhouse project in S. Pedro do Sul covering 2 ha, for raising tropic fruit (mainly pineapple). About 30 spas are operating in the country, but most are only open in the summer. Several dozen small geothermal heat pump installations are operating throughout the country, but unfortunately, this application is not recognized as a geothermal resource by the Portuguese administration. The data on the various geothermal utilizations are: 1.5 MWt and 12.9 TJ/yr for district heating; 1.0 MWt and 13.8 TJ/yr for greenhouse heating; and 25.3 MWt and 358.6 TJ/yr for bathing and swimming. No estimates were made for geothermal heat pumps, thus we estimate 24 installations at 12 kW, a COP of 3.5 and 1,500 full load operating hours per year, gives 0.3 MWt and 1.1 TJ/yr. This gives a total for the country of 28.1 MWt and 386.4 TJ/yr (Cabeças et al., 2010).

5.4.25 Romania

The main geothermal resources in the country are found in porous and permeable sandstones and siltstones (such as in the western plains), or in the fractured carbonate formations (such as at Oradea and Bors in the western part of the country). The total capacity of the existing wells is about 480 MWt; however, only about 148 MWt from 80 wells are currently used. 35 of these wells are used for balneology and producing water at temperatures from 40 to 115^{o}C. During the last five years seven geothermal wells have been drilled in the country with National financing, with some to depths of 1,500 to 3,000 m producing up to 90°C water. There are two main companies in Romania currently exploiting geothermal resources: Transgex S.A. and Foradex S.A., have been given long term concession for practically all known geothermal reservoirs. Transgex, the most active company, is looking at developing district heating projects in a number of communities. The University of Oradea has established a Geothermal Research Center which provides geothermal training and research. The current direct utilization in the country includes: 13.28 MWt and 164.83 TJ/yr for individual space heating; 58.95 MWt and 531.72 TJ/yr for district heating; 4.18 MWt and 20.78 TJ/yr for greenhouses (8 locations); 4.50 MWt and 9.70 TJ/yr for fish farming (one location); 1.40 MWt and 12.70 TJ/yr for agricultural drying; 0.75 MWt and 6.84 TJ/yr for industrial process heat (4 locations); 64.68 MWt and 489.16 TJ/yr for bathing and swimming; and an estimated 5.5 MWt and 29.70 TJ/yr for geothermal heat pumps, giving a total of 153.24 MWt and 1,265.43 TJ/yr (Rosca et al., 2010).

5.4.26 Serbia

The most common use of geothermal energy in the country is for balneology and recreation. Archeological evidence indicates similar uses by the Romans in the locations of the present spas such as Vranjuska, Niska, Vrnjacka and Gamzigradska. Today there are 59 thermal water spas in the country used for balneology, sports and recreation and as tourist centers. Thermal waters are also bottled by nine mineral water bottling companies. Space heating and electric power generation from geothermal energy is in the exploration stages. There are presently 25 wells in use within the Pannonian Basin, and with uses for heating greenhouses (4 wells), heating pig farms (3 wells), industrial process such as in leather and textile factories (2 wells), space heating (3 wells) and 13 wells for various uses in spas and for sport and recreation facilities. Outside the basin, geothermal water is used for space heating, greenhouse heating (raising flowers), a poultry farm, a textile workshop, a spa rehabilitation center and a hotel. Three other spas and rehabilitation centers also use geothermal heat, including heat pumps of 6 MWt, which uses water at 25°C, and in the carpet industry. The various applications include: 20.9 MWt and 356 TJ/yr for space heating; 18.5 MWt and 128 TJ/yr for greenhouse heating; 6.4 MWt and 128 TJ/yr for fish and animal farming; 0.7 MWt and 10 TJ/yr for agricultural drying; 4.6 MWt and 58 TJ/yr for industrial process heating; 39.8 MWt and 647 TJ/yr for bathing and swimming; and 9.9 MWt and 83 TJ/yr for geothermal heat pumps. The total for the country is 100.8 MWt and 1,410 TJ/yr (Martinovic and Milivojevic, 2010).

5.4.27 Slovak Republic

Geothermal direct-use is distributed in eight counties in the country with Nitra County (southwest of the center of the country) having the highest number of locations (19), and Trnava Country (western Slovakia) having the highest amount of thermal energy used. The smallest number of uses is in Kosice Country (eastern Slovakia) with five locations reported; however, this area has the highest potential for geothermal use in the country, including the generation of electricity. Greenhouse heating is reported in 11 locations, two of which receive heat at the end of a cascaded system. Vegetables and cut flowers are the main products grown in these greenhouses. There are 19 installation using geothermal energy for individual space heating and two locations for district heating. The main district heating system is for heating of blocks of flats and a hospital in Galanta. There are 59 locations using geothermal water for swimming pools, both outside and inside. For some, the combined utilization (cascaded use) of the energy is for greenhouse heating, district heating and finally for bathing – in Topolniky and Podhajska. Two locations use geothermal energy for fish farming. There are also nine locations using geothermal heat pumps with a total of 16 units installed. The various direct-uses include: 16.7 MWt and 381.1 TJ/yr for individual space heating; 10.8 MWt and 232.0 TJ/yr for district heating; 17.6 MWt and 461.1 TJ/yr for greenhouse heating; 11.9 MWt and 271.0 TJ/yr for fish farming; 73.6 MWt and 1,708.5 TJ/yr for bathing and swimming; and 1.6 MWt and 13.5 TJ/yr for geothermal heat pumps. The total for the country is 132.2 MWt and 3,067.2 TJ/yr (Fendek and Fendekova, 2010).

5.4.28 Slovenia

Geothermal direct-use is implemented at 28 locations in the country and discontinued at three locations due to economics. This includes four new sites that have come on line and which are located in the northeaster part of the country. There are 20 thermal spas and health resorts, and five recreation centers (four of which are part of a hotel complex). Space heating is implemented at 13 locations, mainly at thermal spas, with air conditioning (cooling) at one location. There are two district heating projects, at Murska Sobota for about 300 dwellings and in Lendava where several building are heated in the downtown area. In Lendava there is also snow melting. There are a number of greenhouse locations, one growing flowers for the domestic market of 4.5 ha, one of 1 ha growing tomatoes and one of 1.4 ha growing orchids. The leather factor at Vrhnika is closed. A total of about 3,440 heat pump units are installed in the country, about half open loop systems (47%) extracting 190 TJ/yr from shallow ground water, and the others are closed loop, mostly horizontal (49%)(159 TJ/yr), with 4% being vertical closed loop installations (30 TJ/yr). About 13 TJ/yr of heat is rejected to the ground in the cooling mode, presumably by vertical systems. Geothermal heat pumps are the largest direct-use in the country; however one of the obstacles to their use is the higher tariff imposed for electricity for these units. The various uses include: 22.4 MWt and 306.23 TJ/yr for individual space heating; 3.29 MWt and 44 TJ/yr for district heating; 0.13 MWt and 2 TJ/yr for air conditioning (cooling); 13.6 MWt and 94.6 TJ/yr for greenhouse heating; 25.04 MWt; 310.56 TJ/yr for bathing and swimming; and 49.71 MWt and 379 TJ/yr for geothermal heat pumps. The total for the country is 104.17 MWt and 1,136.39 TJ/yr (Rajver et al., 2010).

5.4.29 Spain

In the 1970s to early 1990s more than seventy geothermal projects were undertaken; however, in the past 10 years only four or five projects were instituted. Recently, new activity is focusing on very low-temperature resources and the development of geothermal heat pump facilities Geothermal heat pumps are being installed in all areas of the country. In addition, with the possibility of finding locations with favorable geological characteristics, the potential for enhance geothermal systems (EGS) is being investigated, especially in Cataluña and Galicia. Also using low-temperature geothermal resources are being considered for district heating and cooling, especially north of Madrid. The Andalusian Energy Agency has started a study for the evaluation of the geothermal resources and reserves in their territory, and a group of organizations are looking at the potential in Catalonia. The installed capacity and annual energy use for the various applications are: individual space heating of 3.51 MWt and 76.21 TJ/yr; greenhouse heating of 14.93 MWt and 92.42 TJ/yr (estimated at 10 ha – Lund, et al., 2005); and 120 MWt estimated for geothermal heat pump, though the actual data is very poor and not specific. We then estimate, using a COP in the heating mode of 3.5 and 1,500 full load heating hours per year, that the annual energy use is approximately 462.92 TJ/yr. In addition, in 2005, the reported value for swimming and bathing was 2.6 MWt and 52.5 TJ/yr, which we assume these facilities are still in use (Lund et al., 2005). The total for the country is 141.04 MWt and 684.05 TJ/yr (Sanchez-Guzman and Garcia-de-la-Noceda, 2010).

5.4.30 Sweden

Heat pumps are the main geothermal use in the country, with the Lund district heating project being the largest geothermal plant producing about 250 GWh/yr, and has been doing so for 25 years. The majority of the heat pumps are small and typically used in single houses. There are currently around 230,000 installations with about 25,000 units installed annually. Bedrock-soil-water is the most common source for heat pumps using geothermal energy with about 12 TWh of energy extracts or about 15% of the national heat demand covered. A number of systems used underground thermal energy storage UTES), either as *aquifer thermal energy storage* (ATES) or *borehole thermal energy storage* (BTES). The former was implemented in the mid 1980s and current there are approximately 100 plants using this system, mainly large scale with average capacity of 2.5 MWt. Water wells are used and serve a dual function, both as production and injections wells, with the flow direction being reversed from summer to winter. The BTES systems consist of a number of closed spaced boreholes, normally 50 to 200 m deep. These are equipped with borehole heat exchanger, with the holes filled with ground water and not grouted. It has been shown that water filled boreholes are more efficient than grouted ones. These are typically used for combined heat and cooling of commercial and institutional buildings. The reported total for UTES is 90 MWt and 504 TJ/yr for heatings and 90 MWt and 612 TJ/yr for cooling. For geothermal use in the country the following is listed: 140 MWt and 828 TJ/yr for individual space heating; 90 MWt and 504 TJ/yr for UTES; and 4,230 MWt and 43,969 TJ/yr for other geothermal heat pump systems; for a total of 4,460 MWt and 45,301 TJ/yr, all as geothermal heat pumps (Bjelm et al., 2010).

5.4.31 Switzerland

The use of geothermal energy for direct-use has increased substantially, mainly with the installations of geothermal heat pumps (GHP). GHP have increased at rates up to 17% per year, with borehole heat exchangers-coupled systems dominating. Novel applications such as using warm tunnel waters and energy piles have been developed. In just 2009 along, over 2,000 km of borehole heat exchangers (BHE) have been drilled. The majority of the BHEs have been installed in new buildings, but the number of retrofits is increasing. The second largest use of geothermal energy is with thermal spas and wellness facilities. The proportion of the various uses in terms of energy use (GWh) is 73.9% for BHE and horizontal loops, 13.6% for balneology, 10.4% using shallow groundwater, 1.0% using geostructures (energy piles), 0.6% using deep aquifers which includes using tunnel water. With about one GHP installed on the average every square km, this is the highest concentration in the world. One geothermal district heating system is located on Riehen, Canton Basel city. A recent change in governmental policy was the introduction of a feed-in tariff and a risk coverage system in 2008. The geothermal use by the various categories is: 2 MWt and 14.7 TJ/yr for individual space heating; 3 MWt and 33.5 TJ/yr for district heating; 1.4 MWt and 11 TJ/yr for air conditioning; 0.1 MWt and 0.3 TJ/yr for snow melting; 34.9 MWt and 1,045.4 TJ/yr for bathing and swimming; 2.4 MWt and 7.7 TJ/yr for using tunnel water; and 1,017.1 MWt and 6,602 TJ/yr for GHP. The total for the country is 1,060.6 MWt and 7,714.6 TJ/yr (Rybach and Signorelli, 2010).

5.4.31 United Kingdom

The exploitation of geothermal resources in the country continues to be minimal. There are no proven high temperature resources and limited development of low and medium enthalpy resources. The main area of UK activity in the last five years has been in the rapid growth of ground source heat pump installations. The City of Southampton Energy Scheme remains the only exploitation of low enthalpy geothermal energy in the UK for district heating starting operation in 1987. It has been expanded to become a combine heat and power scheme for 3,000 homes, 10 schools and numerous commercial buildings. The famous hot springs at Bath have long been a tourist attraction among the Roman architecture of the ancient city. Now the baths, together with four adjacent buildings, have undergone a major refurbishment, and have been reopened in 2008 and are now fully operational. The level of activity with geothermal heat pumps is estimated to be in the range of 3,000 to 5,000 installations per year. A few of these installations are large scale open loop systems (~500 kW to 2 MWt), the majority are closed loop systems in the range of 3.5 kW heating only, with approximately 750 units at commercial/institutional sites and 4,500 units at residential sites with full load operating hours per years of 1,500 and 1,800 respectively. The main driver for the geothermal heat pumps activity has been the realization that these connected to the UK grid can offer significant reductions in overall carbon emissions compared to traditional methods of heat delivery. The distribution of the various applications are: 2.761 MWt and 72.545 TJ/yr for district heating; 0.251 MWt and 7.914 TJ/yr for greenhouse heating; 2.11 MWt and 15.88 TJ/yr for bathing (Bath); and 181.50 MWt and 753.40 TJ/yr for geothermal heat pumps. The total is: 186.62 MWt and 849.74 TJ/yr (Batchelor et al., 2010).

5.5 Commonwealth of Independent States

5.5.1 Armenia

No country update report was received, nor was one received for WGC2005. The data reported here is based on a report by Henneberger et al., (2000) and personal communication with Henneberger (2009). Geothermal water from an operating well is bottled and sold as mineral water, and also used to heat a nearby guesthouse. Two wells produce CO_2 one for a bottling plant and the other for a dry-ice factory. These wells also supply hot water to the Ankavan Sanatorium, a facility dedicated to the treatment of stomach ailments. Using numbers from *Geothermics* (Lund et al., 2005), it is estimated that the capacity is 1.0 MWt and the use (mainly for bathing and swimming) is 15 TJ/yr.

5.5.2 Belarus

Starting in 1997 the first small heat pump systems were installed in the country for heating of waterworks and sewage treatment building, mostly in the Minsk District. Today, around 15 large geothermal heat pump installations are in operation in the country supplying space heating for industrial buildings. In addition 40 small heat pump systems have been installed in private cottages in and around the main towns and cities. All of these installations use water taken from shallow boreholes with typical temperatures of 8 to 10°C. One source uses river water. Another 12 to 15 heat pump installations are under construction. Heating of several new apartment buildings and a greenhouse complex are planned. Only the total installed capacity of 3.422 MWt is reported with an average COP of 3.5. Using 3840 full load operating hours per year in the country (email communication from Zui, 2009), the corresponding annual energy use would calculate to be 33.79 TJ/yr (Zui, 2010).

5.5.3 Georgia

Currently, the water low in minerals (45 to 50°C) is used in the central area of the capital by the Tbilisi Balneological Health Resort and the hygienic bath houses. The high temperature water (57 to 74°C) in the Lisi and Sburtalo area of Tbilisi is used for hot-water supply and for the heating of residences and offices. In addition, there is farming and other complexes under construction at Lisi Lake. Future plans are to install a central distribution system in Tbilisi so as to eventually supply all of the city with geothermal heated water for heating. The various applications are: 12.57 MWt and 345.09 TJ/yr for individual space heating; 7.74 MWt and 224.79 TJ/yr for district heating; 2.20 MWt and 59.36 TJ/yr for greenhouse heating; and 2.00 MWt and 30.00 TJ/yr for bathing and swimming. The total is 24.51 MWt and 659.24 TJ/yr (Melikadze et al., 2010).

5.5.4 Russia

Direct use of geothermal resources is mostly developed in the Kuril-Kamchatka region, Dagestan and Drasnodar Krai, mainly for district and greenhouse heating. To date, 66 thermal water and steam-and hydrothermal fields have been exploited in Russia. Half of them are in operation providing approximately 1.5 million Gkal of heat annually (Povarov and Svalova, 2010). Approximately half of the extracted resource is used for space heating, a third for heating greenhouses, and about 13% for industrial processes. There are also approximately 150 health resorts and 40 factories bottling mineral water. Heat pumps are at an early stage of development in Russia. An experimental facility was set up in early 1999 in the Philippovo settlement of the Yaroslavl district. Eight heat pumps are used for a 160-pupil school building. There are also some buildings using heat pumps in Moscow (Svalova, 2010). A district heating project is being proposed for Vilyuchinsk City on Kamchatka (Nikolskiy et al., 2010). Unfortunately, no specific data were provided on direct-use geothermal, thus it was suggested that we use the data from WGC2005 (Svalova, personal communication, 2009). Based on data from Kononov and Povarov (2005) and modified by Lund et al. (2005), the breakdown of the various applications are: 16.5 MWt and 328 TJ/yr for individual space heating; 93.5 MWt and 1,857 TJ/yr for district heating; 160 MWt and 3,279 TJ/yr for greenhouse heating (estimated at 46.5 ha); 4 MWt and 63 TJ/yr of fish and cattle raising; 4 MWt and 69 TJ/yr for agricultural drying (wool washing, paper production and wood drying); 4 MWt and 63 TJ/yr for swimming and bathing; 25 MWt and 473 TJ/yr for industrial processes; and 1.2 MWt and 11.5 TJ/yr for geothermal heat pumps – mainly in Kamchatka, consisting of 100 units. The total for the country is then 308.2 MWt and 6,143.5 TJ/yr. The installed capacity figures are confirmed in a paper by Butuzov et al. (2010).

5.5.5 Ukraine

No country update paper was received from this country, thus, the data from WGC2005 will be utilized, assuming no changes (Lund et al., 2005). According to the report in 2005, the direct-uses in the country are for individual space heating (3.5 MWT and 36.3 TJ/year); and district heating (10.9 MWt and 118.8 TJ/yr). Two of these applications are associated with power plants in co-generating schemes (1.8 MWt). Most of the uses were installed between 1978 and 1998 with only one project coming on line in 2002 (Khvorov et al., 2005).

5.6 Oceania

5.6.1 Australia

Australia’s only geothermal district heating system, at Portland in Victoria, was decommissioned in 2006 for environmental reasons (spent water was being discharged into a surface stream). However, geothermal energy is increasingly being recognized as a cheap source of energy around the country. A number of public swimming pools are using geothermal water in the Perth Basin in Western Australia, and at Christchurch and Craigie, and at the sporting arena “Challenge Stadium”, along with it being used for domestic hot water in the arena. At Robe in South Australia barramundi are grown in tanks using 29°C water. Here 22 local people are employed with annual revenue of AU$2 million. A similar facility is located in Victoria at Werribee. At Warrnambool geothermal water is used for washing down and sterilizing an industrial meat processing facility. Spas using geothermal water are located at Warrnambool and at Rye on the Mornington Peninsula south of Melbourne. This latter facility has undergone a major expansion for accommodations, agriculture, greenhouses, space heating, and balneology in a cascaded process using 45°C water. Throughout the rest of the county a number of recreational swimming and bathing centers are located from Hastings, Tasmania in the south to Innot Hot Springs in Queensland. A total of 12 sites are listed. However, the use by all these facilities are difficult to determine, and thus, are estimated in some cases. The Geoscience Australia building in Canberra is the country’s largest ground source heat pump installation with 2,500 kW of installed power. Other geothermal heat pump units are installed in New South Wales, Canberra, Tasmania, Victoria, South Australia, Queensland and Northern Territory. The various applications are: 2.3 MWt and 43.5 TJ/yr for fish farming; 7.03 MWt and 61.6 TJ/yr for bathing and swimming; and 24 MWt and 130 TJ/yr for geothermal heat pumps. The total for the country is 33.33 MWt and 235.1 TJ/yr (Beardsmore and Hill, 2010).

5.6.2 New Zealand

Direst use applications are found in both the North and South Islands. The most common application for the lower temperature resources is for bathing (9 sites identified), with space and water heating to a lesser extend, and occasional direct use for frost protection and irrigation. Higher temperature resources found in the Taupo Volcanic Zone are used for greenhouse heating, prawn farming, glasshouse heating, kiln drying of timber (at Kawerau), and for special tourism development (Rotorua and Wairakei). The Kawerau facility, pulp and paper manufacturing, now accounts for 56% of the national geothermal direct-use. It is also the largest industrial use in the world and is set to expand further to adjacent industrial users. Geothermal heat pumps are only just taking off in the country. There are now multiple companies in the country that can supply the necessary services for both residences and commercial users. The majority of the applications appear to be water source installations. Most installations are in the colder part of South Island at Queenstown, though there are installations in Auckland with the luxury housing market. Commercial buildings owners are recognizing that geothermal heat pumps should be considered, and an initial project has been installed at the Dunedin airport (South Island). The various applications are; 19 MWt and 181 TJ/yr for space heating; 24 MWt and 379 TJ/yr for greenhouse heating; 17 MWt and 273 TJ/yr for fish farming; 224 MWt and 6104 TJ/yr for industrial process heat; 74 MWt and 1,733 TJ/yr for bathing and swimming; 28 MWt and 843 TJ/yr for other uses (irrigation, frost protection, geothermal tourist park); and 7.22 MWt and 39 TJ/yr for geothermal heat pumps. The total for the country is 393.22 MWt and 9,552 TJ/yr (Harvey et al., 2010).

5.6.3 Papua New Guinea

Geothermal resources on the Island of Lihir are exploited to generate electricity for the gold mines, now at 56 MWe (Melaku and Mendive, 2010). On New Britain Island, however, low-enthalpy heat is used to boil megpod eggs and the megapod (local fowl) use the hot ground to incubate their eggs, which are harvested by the locals – creating something of a tourist attraction. During World War II, at Rabaul on the north end of the island, the Japanese used the hot springs for bath houses, and used oil drums split lengthwise, evaporated sea water for the salt using a combination of hot springs and solar heat. The current direct-use geothermal heat is estimated for bathing and swimming at 0.1 MWt and 1.0 TJ/yr.

6. ENERGY SAVINGS

Geothermal, a domestic source of sustainable and renewable energy, replaces other forms of energy use, especially fossil fuels. For many countries, geothermal energy leads to a reduction in their dependence on imported fuel, and for all countries, it means the elimination of pollutants such as particulates and greenhouse gases. An attempt is made here to quantify the fossil fuel savings, using a 0.35 efficiency factor if the competing energy is used to generate electricity and 0.70 if it is used directly to produce heat, such as in a furnace.

Using the 438,071 TJ/year of energy consumed in direct geothermal applications in 2009 (see Table 1), 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 savings would be 206.5 million barrels of oil or 31.0 million tonnes of oil annually. If the oil were used directly to produce energy by burning for heating, then these savings would be 103.2 million barrels and 15.5 million tonnes respectively. The actual savings are most likely somewhere in between these two values. Note that 206.5 million barrels is almost three days of worldwide oil consumption.

Using figures developed by Lawrence Livermore Laboratories for the U.S. Department of energy (Kasameyer, 1997) and by private consultants Goddard and Goddard (1990) the following savings would be realized for carbon, CO_2, SO_x and NO_x. If electricity were produced then the carbon savings would be 14.65 tonnes/TJ from natural gas, 62.6 tonnes/TJ for oil or 72.7 tonnes/TJ from coal, which then produces a savings in carbon production of 6.42, 27.42 or 31.85 million tonnes, respectively. Similarly, using 193 kg/MWh (53.6 tonnes/TJ), 817 kg/MWh (227.0 tonnes/TJ), and 953 kg/MWh (264.7 tonnes/TJ) for carbon dioxide emissions when producing electricity from natural gas, oil and coal, respectively, the savings in CO_2 emissions would be 23.48, 99.44, and 115.96 million tonnes, respectivey7. The savings in SO_x and NO_x producing electricity from natural gas, oil and coal would be 0.0, 0.66 and 0.61 million tonnes, and 0.05, 0.19, and 0.19 million tonnes, respectively. If heat were produced by burning these fuels, the carbon, CO_2 and SO_x and NO_x savings would be half of these values. Again, the actual savings would be somewhere in between these values since a mix of fossil fuels would be used for heating and electricity generation.

If savings in the cooling mode of geothermal heat pumps is considered, which is not geothermal, then this is equivalent to an additional annual savings of approximately 101.3 million barrels (15.2 million tonnes) of fuel oil, or 19.2 million tonnes of carbon pollution from burning fuel oil. The above figures are summaried in Table 3.

Table 3. Worldwide savings in energy, carbon and greenhouse gases using geothermal energy in terms of fuel oil (million of tonnes - TOE) including geothermal heat pump cooling.

	Fuel Oil		Carbon	CO2	SOx	NOx
	bbl	TOE	TOE	TOE	TOE	TOE
As Electricity	307.8	46.2	46.62	148.19	0.98	0.28
As Direct Heat	153.9	23.1	23.21	74.1	0.49	0.14

7. CONCLUDING REMARKS

As in 1995, 2000 and 2005, several countries stand out as major consumers of geothermal fluids for direct uses; however, in most countries development has been slow. This is not surprising as fossil fuels are a major competitor, and development has been curtained due to the recent downturn in the world economy, and the initial high investment costs. Many countries have; however, been doing the necessary groundwork, conducting inventories and quantifying their resources in preparation for development with the economic situation is better and governments and private investors see the benefits of developing a domestic renewable energy source.

With the increased interest in geothermal heat pumps, geothermal energy can now be developed anywhere, for both heating and cooling. Low-to-moderate temperature geothermal resources are also being used in combined heat and power plants (CHP), where hot waters with temperatures below 100^oC are first run through a binary (Organic Rankine Cycle) power plant and then cascaded for space, swimming pool, greenhouse and aquaculture pond heating, before being injected back into the aquifer. CHP projects certainly maximize the use of the resources and improve the economics, as has been shown in Iceland, Austria and Germany.

Key data and explanations were frequently missing from the WGC2010 country update reports used in this worldwide summary. Some data also appeared to be in error or misreported. We have attempted to correct for these errors by contacting WGC2010 authors and by making estimates for the missing data, and have pointed this out in the relevant country summaries.

Despite these discrepancies and the effort required to correct them, work on this review has proved useful, as it has allowed us to demonstrate that using low-to-moderate temperature geothermal resources in the direct heat applications, given the right conditions, is an economically feasible business, and can make a significant contribution to a country's or region's energy mix. As oil and gas supplies dwindle and increase in price, geothermal energy will become an even more economically viable alternative source of energy.

At the moment of writing this report (December, 2009), the cost of crude oil is at US$78/barrel and has been in the recent past over US$100/barrel, and natural gas prices are also on the rise. Thus, with geothermal energy becoming increasingly more competitive with fossil fuels and the environmental benefits associated with renewable energy resources better understood, development of this natural "heat from the earth" should accelerate in the future. An important task for all of us in the geothermal community is to spread the word on geothermal energy, its various applications, and the many environmental benefits that can accrue from its use.

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