GEOTHERMAL DIRECT-USE IN THE UNITED STATES UPDATE: 1995-1999

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ABSTRACT

Information is provided on the status of geothermal direct heat utilization in the United States, with emphasis on the developments from 1995-1999. Since the 1995 report, there were 27 new and 10 expanded direct-use projects representing an increase in thermal capacity of 136 MWt and annual energy utilization of 2,600 TJ. Geothermal heat pumps represent the largest growth sector during the period, adding an estimated 2,956 MWt and 3,812 TJ/yr to these figures. The total capacity of the U.S. is now at 5,366 MWt with an annual utilization of 20,302 TJ (5,643 GWh). This is equivalent to saving 0.84 million tonnes of fuel oil per year.

1. INTRODUCTION

Geothermal energy is estimated to currently supply for direct heat uses and geothermal heat pumps approximately 20,302 TJ/yr (5,643 GWh) of heat energy through direct heat applications in the United States. The corresponding installed capacity is estimated at 5,366 MWt. Of these values, direct-use is 8,302 TJ/yr (2,308 GWh) and 566 MWt and geothermal heat pumps the remainder. It should be noted that values for the capacity and the energy supplied by geothermal heat pumps are only approximate since it is difficult to determine the number of units installed and most are sized for the cooling load, thus they are oversized for the heating load (except possibly in the northern U.S.).

Figure 1 shows the distribution of the current direct heat use for the various applications for 1990, 1995 and 2000. Figure 2 shows the growth of the various applications since 1975. Most of the applications experienced some increase in use; however the largest annual energy growth, as in the previous reporting period (Lienau, et al., 1995), has been in geothermal heat pumps. Aquaculture has the largest annual energy growth rate of the direct-use categories, increasing in annual use by 15.5% compound per year over the past five years. From 1990 the growth rate for direct-use was 7.8% annually and for geothermal heat pumps 7.9% annually for a total of 7.9% annually.

Resorts and spa use and development has actually remained fairly constant with only slight growth - most of the increase is due to better reporting of the data. There has been a major decrease in the industrial section, as the gold and silver heap leaching projects in Nevada are no longer using geothermal energy. In addition, the lithium-bromide chiller used on the Oregon Institute of Technology campus has been replaced with an electric chiller, thus there is no direct-heat cooling in the U.S. (except for geothermal heat pumps). Today, 33.7% of the annual energy use for direct-use is in the aquaculture industry, 30.1% is in bathing and swimming (resort and spa pool heating), 17.8% in space heating (including district heating), 13.6% in greenhouse heating 4.8% in industrial processing, including agriculture drying and snow melting as shown in Figure 3a. If geothermal heat pumps are included, then they contribute 59% to the annual energy use, and direct-use contributes 41% as shown in Figure 3b.

The total direct-use and geothermal heat pumps energy use in the United States is equivalent to savings of 5.6 million barrels (0.84 million tonnes) of fuel oil per year (at 60% efficiency).

Figure 1. Direct Heat Utilization in the United States from 1990 to 2000.

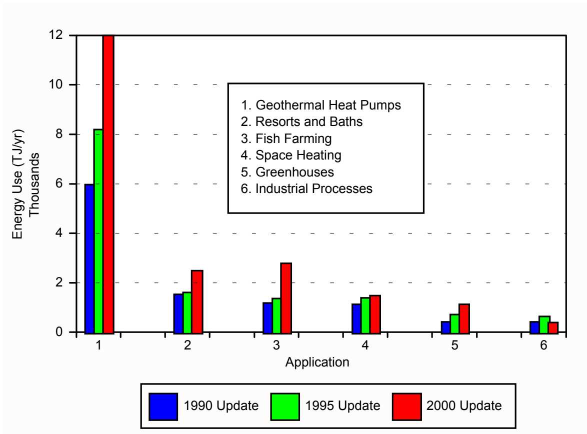
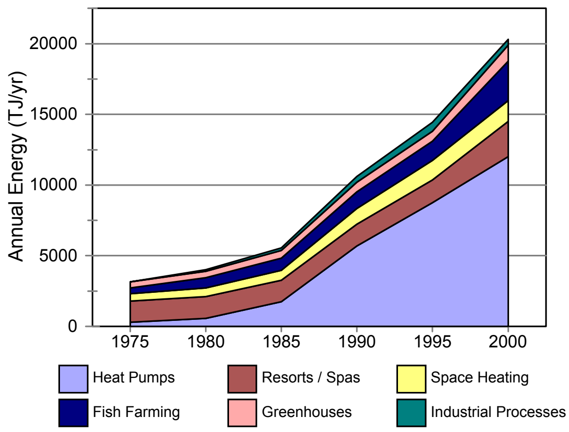
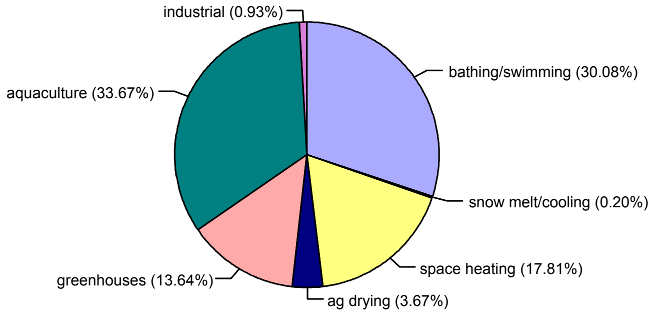


Figure 2. Growth of the U.S. direct utilization by category.





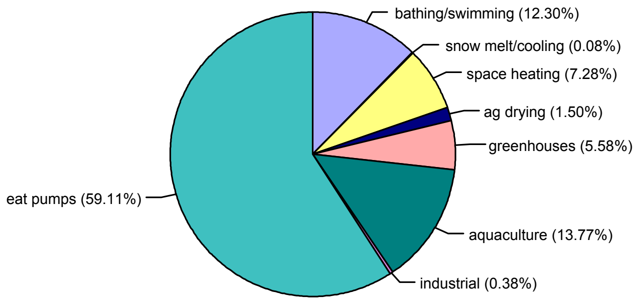


Figure 3a. 2000 direct-use percentages by category based on annual energy use.

Figure 3b. 2000 direct-use and geothermal heat pump annual energy use.

2. DIRECT-USE DEVELOPMENT

Direct heat projects that were expanded or became operational from 1995 to 1999 are listed in Tables 3 and 3A. Note: Tables 1 and 2 appear in the U.S. country update for electric power generation by Sifford and Bloomquist in this volume. There were 27 new projects identified in 7 states as shown in Table 3, and 10 existing projects were expanded a significant amount as shown in Table 3A. The expanded projects included the Klamath Falls and Oregon Institute of Technology district heating projects, six greenhouse projects in California, Idaho and New Mexico, and two aquaculture projects in the Imperial Valley of California. Two major industrial projects, both silver and gold heap leaching in Nevada no longer use geothermal energy in their process. The remainder of the increase was due to better reporting of space heating and spa pool heating.

During this period (1994 - 1999), the thermal capacity of the direct heat projects increased by 136 MWt , representing an annual energy utilization of 2,600 TJ/yr (Lienau, et al, 1995). Geothermal heat pumps increased in capacity by2,956 MWt, representing an annual energy utilization of 3,812 TJ/yr (Lienau, et al., 1995) (Table 4). A mini-heating district in Midland, South Dakota has been added as a new project, even though it was started in 1969. This project was unknown to the geothermal community until recently (Lund, 1997).

The majority of the increase in direct utilization since 1995 is in aquaculture (Imperial Valley of California and Snake River Plain of Idaho), greenhouse heating, and snow melting (Klamath Falls, Oregon). The increase in space heating and resorts/spa is mainly do to refinement of the data, since most of these projects already existed and have minor increases in use.

A summary of the direct utilization in the United States is presented in Table 5.

2.1 Aquaculture Pond and Raceway Heating

The largest increase in geothermal direct-use in the United States was in aquaculture pond and raceway heating. Ten new pond heating projects were recently identified in the Imperial Valley of California along with the expansion of two existing projects (Rafferty, 1999). Approximately 3.65 million kg of Tilapia, catfish and hybrid striped bass are raised annually. Most are shipped live to markets in Los Angeles and San Francisco. A second area identified as having a significant increase in aquaculture projects is along the Snake River Plain of southern Idaho (Ray, 2000). Seven new projects were identified in this area, adding an additional one million kg of Tilapia and catfish in annual production. These installations use cascaded water in raceways for raising their fish, whereas in the Imperial Valley, ponds and tanks are the most common. Fish from these sites are also shipped live to cities in Canada and the northwestern US states. It is difficult to calculate the exact energy used by the various installations, thus based on data from a limited number of operations, the remaining are proportioned according to the amount of fish raised annually.

2.2 Geothermal Heat Pumps

Geothermal heat pumps has steadily increased over the past five years with an estimated 45,000 units installed annually of 3.4 ton (12 kW) size capacity (Ragnarsson, 1998). Of these, 46% are vertical closed loops, 38% horizontal closed loop and 15% open loop systems. Projections for the future are that the rate will increase about 10% annually, so that by 2010 and estimated 120,000 new units would be installed in that year. It is estimated that 400,000 units are presently installed in the U.S., thus, this rate would add an addition 1.1 million units for a total of about 1.5 million units by 2010. Using a COP of 3.0, and a 1,000 full load hours per year in the heating mode, the 400,000 units remove approximately 12,000 TJ/yr from the ground. The cooling mode energy is not considered, since this rejects heat to the ground; however, this does replace other forms of energy. A summary of geothermal heat pump projects are shown in Table 4. (Ragnarsson, 1998).

The majority of the geothermal heat pump installations in the U.S. are in the mid-west and southern states (from North Dakota
to Florida). There has been few installation in the west, due to some environmental concerns and lack of general knowledge on the subject by HVAC companies and

installers. Hopefully recent geothermal heat pump seminars, offered by the Geo-Heat

Center, will improve the understanding and use of this technology in the west.

2.3 Space and Pool Heating

Data from space heating (other than district heating) and for pool heating at resorts and spa were updated. We lacked information for approximately 20% of these sites, and thus estimates were made for the missing data based on the knowledge and experience of the authors. This increase, in most cases, is not due to new installations, but reflects the gathering of better data. The other space heating category that increased by a significant percentage was snow melting. These systems were recently added in Klamath Falls and include new sidewalk and handicap ramp heating on the Oregon Institute of Technology campus (250 m^2) and sidewalk heating in downtown Klamath Falls (6,000 m^2) (Boyd, 1999 and Brown, 1999). In addition, a major highway geothermal snow melting systems in Klamath Falls, that had been used for 50 years, was replaced in the Fall of 1998 and is used to heat 2,000 m^2 of concrete pavement (Lund, 1999).

3. WELLS DRILLED

A major injection well was drilled for the City of Boise district heating system (Johnson, 1998). The well was completed to a depth of 975 m for $870,000. The temperature of the water in the well is 76ºC. It can accept up to 114 L/s of injected water. A number of smaller downhole heat exchanger and injection wells were drilled in the Klamath Falls area. The U.S. Department of Energy has provided cost share funds ($700,000) for the drilling of three direct-use wells for : (1) greenhouse expansion in New Mexico, (2) injection well for the Alturas, California school district, and (3) mini-heating district in Canby, California. These three wells should be drilled in 2000. A number of wells were also drilled in the Imperial Valley and Snake River plain for aquaculture projects. No data are available for slim holes (closed loop) and wells (open loop) drilled for geothermal heat pump installations. Table 6 is a summary of the geothermal wells drilled in the past five years.

For geothermal heat pumps, it is estimated that approximately 60,000 50-m holes were drilled for vertical loop (closed loop) installation or about 3,000 km annually. In addition it is estimated that 6,000 100-m deep wells were drilled for water well (open loop) installations or about 600 km. These numbers are not included in Table 6 due to the uncertainly of the data.

4. INVESTMENTS IN DIRECT USE

The number of professional person-years of work contributed to direct-use projects has decreased slightly since the 1990-1994 report, due in part to a decline in the United States geothermal industry and the associated federal research funds available. The decrease has been primarily in the university and public utility sector (Table 7).

Investments in geothermal direct-use projects are down in R & D from 1990-1994 for the same reason. Field investment and utilization are up with the main funding coming from the private sector - primarily individual homeowners. Recent investments are from the Geothermal Resources Development Account (GRDA) funding in California. This account of $7.5 million, contains funds from the U.S. Bureau of Land Management leases of federal lands and mineral rights in California where 30 percent of the revenue received is used by the Energy Commission for geothermal-related planning, development and mitigation activities. Recent awards in 1999 attracted matching funds of about $160.6 million from the project developers. Two major direct use projects funded were a mineral extraction project in the Imperial Valley and the drilling of a well for district heating in Canby. Table 8 is a summary of investment in direct-use projects during the past five years.

In addition, it is estimated that the annual 3,000 km of geothermal heat pump holes (closed loop) at 10-cm diameter, cost $60 million (at $20/m) and the 600 km of wells (open loop) of 20 to 30 cm diameter cost $30 million (at $50/m) to drill. Again these figures are not included in Table 6 due to the uncertainty of the data.

5. CONCLUSIONS

The growth in direct heat use has been almost eight percent compounded annually over the past five years. This compares to the growth rate between 1985 and 1990. The period from 1990 to 1995 was lower at approximately six percent annually. Growth during 1995 to 2000 could have been higher, but competition from natural gas was a major limiting factor. There are some positive signs on the horizon with proposed new district heating projects in Mammoth, CA; Reno, NV and Sun Valley, ID, and a zinc extraction plant in the Imperial Valley. The Reno project could expand district heating by as much as 250 MWt with large commercial and industrial building heating (Lienau, 1997). The zinc project by CalEnergy Company, Inc., to be on line in mid-2000, will extract 30,000 tonnes of zinc annually from geothermal water using power from a new geothermal electric power plant. The waste water, from eight power plants (totaling 300 MWe) having 600 mg/liter of zinc, will be utilized. In addition, the extraction of silica and manganese will also be considered.

6. ACKNOWLEDGMENTS

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TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

[1)] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish and animal farming
S = Snow melting
H = Space heating & district heating
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other

Locality		Type[1)]	Maximum Utilization			Capacity	Annual Utilization	
			Flow Rate	Temperature (°C)			Energy	Capacity
			(kg/s)	Inlet	Outlet	(MWt)	(TJ/yr)	Factor
New Projects:								
CA	S.S. Vong - Imperial Valley	A	32.2	46	39	1.0	24.7	0.81
	H & T - Imperial Valley	A	21.5	46	39	0.6	16.4	0.81
	Oceanridge - Imperial Valley	A	42.9	46	39	1.3	32.9	0.81
	Coachella Valley Fish Farm	A	64.4	46	39	2.0	49.3	0.80
	Dashun Fisheries - Imperial V.	A	45.8	46	39	1.4	35.1	0.81
	Blue Aquarius - Imperial Valley	A	17.7	46	39	0.5	13.7	0.82
	Kent Sea Farms - Imperial V.	A	429.5	46	39	13.0	328.8	0.80
	Valley Fish Farm - Imperial V.	A	85.9	40	33	2.6	65.8	0.81
	Hsiang Niching - Imperial V.	A	28.4	46	39	0.9	21.9	0.79
	California Desert Fish Farm - IV	A	55.8	60	53	1.7	42.8	0.80
ID	First Assent Fish Farms - Buhl	A	97.9	32	28	1.8	45.8	0.80
	Epicenter Aquaculture - Challis	A	97.9	32	28	1.8	45.8	0.80
	Opline Farms - Given H.S.	A	130.6	38	34	2.4	61.1	0.80
	Sunnybrook Farms - Twin Falls	A	261.1	38	34	4.8	122.3	0.80
	Unknown - Bruneau	A	130.6	32	28	2.4	61.1	0.80
	Ace Development - Bruneau	A	163.2	32	28	3.0	76.4	0.80
	Silver Creek Farms - Twin Falls	A	130.6	32	28	2.4	61.1	0.80
MT	Hunter H.S. Greenhouses	G	15.2	60	41	1.2	11.5	0.30
	Bigfork Greenhouses	G	18.3	53	36	1.3	17.8	0.45
	Chico H.S. - Pray	G, S, P	12.6	43	41	0.1	0.3	0.11
NM	Americulture - Animas	A	12.6	85	63	1.2	29.5	0.80
OR	City of Klamath Falls sidewalks	S	18.9	52	37	1.2	3.7	0.10
	Oregon Inst. of Tech. sidewalks	S	3.2	66	64	0.1	0.2	0.10
SD	Min-Kota Fisheries - Philip	A	12.6	69	36	1.8	44.3	0.80
	Midland District Heating	H	5.4	67	63	0.1	0.8	0.30
UT	Milgro No. 2 - Newcastle	G	25.3	95	73	2.3	21.6	0.30
	Christianson Bros. - Newcastle	G	30.3	95	67	3.5	31.6	0.29
	TOTAL		1990.4			56.4	1266.3	

TABLE 3A. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

[1)] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish and animal farming
S = Snow melting
H = Space heating & district heating
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other

Locality		Type[1)]	Capacity (MWt)	Annual Utilization Increase	
				Energy (TJ/yr)	Capacity Factor
Existing Projects Increases					
CA	Fish Producers	A	4.7	120.2	0.81
	Pacific Aqua Farms	A	1.1	27.4	0.79
	Big Bend Preventorium	G	0.06	0.2	0.11
	Lake County Ag Park	G	0.10	0.5	0.16
ID	Bliss Greenhouse	G	0.1	1.3	0.35
	Green Canyon Hot Springs	G	0.06	0.1	0.05
	Jack Ward Greenhouses	G	2.40	18.9	0.25
NM	Burgett Wholesale	G	14.9	184.0	0.39
OR	City of Klamath Falls	H	0.3	7.0	0.74
	Oregon Inst. of Tech.	H	1.1	8.7	0.25
TOTAL			24.8	368.3	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF DECEMBER 1999

V = vertical ground coupled
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

Locality		Ground or water temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type	COP	Equivalent Full Load Hr/Year	Thermal Energy Used (TJ/yr = 10^{12}J/yr)
States:								
Northeast	28%							
Midwest	48%				V=47%		ave.	
South	17%	6^o - 25^o	12.0	400,000	H=38%	3.0	1000	12,000
West	7%				W=15%			
(North Dakota to Florida)								
TOTAL				400,000				12,000

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 1999

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Space Heating	83	855	0.33
Air Conditioning (Cooling)	0	0	0.00
Greenhouse Heating	119	1132	0.30
Fish and Animal Farming	129	2,795	0.69
Agricultural Drying	20	305	0.49
Industrial Process Heat	7	77	0.35
Snow Melting	2	17	0.27
Bathing and Swimming	107	2,497	0.74
District Heating	99	624	0.20
Subtotal	566	8,302	0.47
Geothermal Heat Pumps	4800	12,000	0.08
TOTAL	5366	20,302	0.12

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)					
Production	>150° C					
	150-100° C					
	<100° C		40			5.21
Injection	(all)		4			1.25
Total			44			6.46

Note: does not include heat pump slim holes (closed loop) and water wells (open loop)

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	2.5	1.5	5.8	0	0	2.2
1996	2.5	1.5	5.8	0	0	2.2
1997	2.5	0.5	5.8	0	0	2.2
1998	2.5	0.5	4.8	0	0	2.2
1999	2.5	0.5	4.8	0	0	2.2

Note: does not include approximately 7 person years work in geothermal heat pumps

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1985-1989	10.00	0.40	20.00		58	42
1990-1994	6.35	0.24	27.37		75	25
1995-1999	0.00	2.00	40.00		95	5

Note: heat pump slim holes (closed loop) and water wells (open loop) not included