GEOTHERMAL ENERGY UTILIZATION IN THE UNITED STATES - 2000

John W. Lund[1], Tonya L. Boyd[1], Alex Sifford[2], and R. Gordon Bloomquist[3]

[1]Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR
[2]Sifford Energy Services, Neskowin, OR
[3]Washington State University Energy Program, Olympia, WA
email: lundj@oit.edu

ABSTRACT

Geothermal energy is used for electric power generation and direct utilization in the United States. The present installed capacity for electric power generation is 2,776 MWe with only 2,020 MWe in operation due to reduction at The Geysers geothermal field in California; producing approximately16,000 GWh per year. Geothermal electric power plants are located in California, Nevada, Utah and Hawaii. The two largest concentrations of plants are at The Geysers in northern California and the Imperial Valley in southern California. The direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space heating and district heating, snow melting, agricultural drying, industrial applications and ground-source heat pumps. The installed capacity is 4,000 MWt and the annual energy use is 20,600 billion Btu (21,700 TJ - 6040 GWh). The largest applications is ground-source (geothermal) heat pumps (59% of the energy use), and the largest direct-use is in aquaculture. Direct utilization is increasing at about six percent per year; whereas, electric power plant development is almost static. Geothermal energy is a relatively benign energy source, displaying fossil fuels and thus, reducing greenhouse gas emissions. A recent initiative by the U.S. Department of Energy, "Geo-Powering the West," should stimulate future geothermal development. The proposal is especially oriented to small-scale power plants with cascaded uses of the geothermal fluid for direct applications

GEOTHERMAL ELECTRIC POWER GENERATION

Introduction

The United States continues to lead the world in installed geothermal power capacity as well as in electrical generation producing 16,000 GWh/yr from 2,020 MWe capacity for a load factor of 0.90%. These are approximately 32% and 26% of the world output and capacity, respectively. However, geothermal energy is a small contributor to the electric power capacity and generation in the United States. In 1998, geothermal plants constituted about 0.25 percent of the total operable power capacity. In 1998, those plants contributed 0.38 percent of the total generation and, for 2000, it stands at 0.45 percent.

On a state level, geothermal is a major player in California and Nevada. It is a minor source of power in Hawaii and Utah. Further, it has the potential to become significant on the Big Island of Hawaii and perhaps, in the future, the Pacific Northwest.

The most impressive geothermal growth in the United States occurred during the 1980s, with an average annual increase in capacity of about 11 percent. In contrast, from 1990-2000, it has averaged only one percent due to a leveling off of new plant construction. This recent period also saw a reduction at The Geysers in California to an operating capacity of about 965 MWe, down from a total installed capacity of 1,989 MWe in 1995 (DiPippo, 1995). Contributing to the capacity stagnation are the decline in steam production, and the retirement and shut down of nine units at The Geysers in California. These include the four original units (78 MWe), both the Central California Power Agency (CCPA) units (130 MWe), units 10 and 15 (110 MWe) and the 55 MWe Bottle Rock plant. However, the Bottle Rock plant has been purchased by ThermaSource, Inc. and should start operation by the summer of 2001. CalEnergy has completed Unit 5, a 49-MW facility and a 10-MW turbine at the Salton Sea in mid 2000.

Total Production of Electricity: All Sources

Table 1 presents operable geothermal electric production capacity and power generation in the United States for 2000. Geothermal power production fell from 1995 to 2000, but the steepness of the decline has been slowed by reinjection activities at The Geysers. This is discussed further below.

The Geysers

No new plants have been installed in The Geysers since 1989 after the 2x10 MW J.W. Aidlin plant came on-line. The four original PG&E units in The Geysers

Table 1. Geothermal Electric Power Generation in the United States

State	Location	#units	MW Rating	2000 MW actual
CA				
	The Geysers	23	1,614	965
	East Mesa	7	105.4	105.4
	Heber	13	80.0	80.0
	Salton Sea	14	326.3	326.3
	Honey Lake	5	4.3	4.3
	Coso	9	260	260
	Casa Diablo	8	27	27
NV				
	Beowawe	1	16	16
	Brady H.S.	3	21.1	21.1
	Desert Peak	2	8.7	8.7
	Dixie Valley	1	66	66
	Empire	4	3.6	3.6
	Soda Lake	9	16.6	16.6
	Steamboat	13	35.1	35.1
	Stillwater	14	13.0	13.0
	Wabuska	2	1.2	1.2
	Steamboat Hills	1	14.4	14.4
UT				
	Cove Fort	7	31	31
HI				
	Puna	1	25	25
	Total	137	2,668.7	2,019.7

were officially retired in 1992; all surface equipment for Units 1 through 4 has been dismantled. Supply wells have been redirected to other units. Unit 1 was designated a National Historic Mechanical Engineering Landmark in 1985 by the American Society of Mechanical Engineers. Other plants no longer in service include PG&E Unit 15 (59 MW, retired in 1989), DWR Bottle Rock plant (55 MW, closed in 1990), the CCPA Units 1&2 (130 MW, retired in 1996) and unit 10 (55 MW, retired in 1999). On the bright side, the Bottle Rock plant should be in operation again by summer 2001. Calpine Corporation now owns and operates 18 units for 800 MW and NCPA four units for 165 MW.

Owing to a shortfall of steam, the difference between rated and actual power capacity is significant (e.g., 649 MWe in 2000). However, this shortfall is being reversed in several units by the southeast Geysers effluent recycling system.

The latest development at The Geysers is injecting recycled wastewater into the reservoir. Two projects are underway, with the first system operational. The Southeast Geysers Effluent Recycling project is the world's first wastewater-to-electricity system (www.geysers-pipeline.org). It transports treated wastewater effluent from the California communities of Clearlake, Lower Lake, and Middletown to The Geysers geothermal steamfield for injection and recovery as steam for power generation. In Phase 1 of that system, a 30 mile (48 km) pipeline transports 5,400 gpm (20,500 L/min) of effluent to The Geysers. Power generation has increased 68 MW between January 1998 and January 2001. Plans are underway for Phase 2 of that system that would collect waste water from other community around Clear Lake. They recently received a $2million grant from USDOE towards the cost of the project.

Table 2. Operating Power Plant Types

Type	# Plants	# Units	MWe	Average Plant MWe	Average Unit MWe
Dry Steam	22	26	974	44	37
Single Flash	5	5	103	21	21
Double Flash	16	28	666	42	24
Binary	15	140	250	17	2
Hybrid	2	2	27	14	14

In addition, the city of Santa Rosa plans to send its treated wastewater 41 mi. (66km) to The Geysers (GRC, 1999). The $163 million project is slated to go on-line in 2002, providing the final routing issues can be settled. Together, these two projects are expected to make The Geysers production sustainable and provide local cities with wastewater disposal solutions.

In summary, the operating power plant types are in Table 2.

Single units range in size from 0.35 to 133 MWe. As can be seen from Table 2, the most common type of plants are dry steam and double flash. Binary units, because of their modular construction for ease of installing as wellhead units, have the smallest average unit size of about 2 MWe.

Figures 1 through 3 are maps of power plant locations within the three key states, with a detailed map of The Geysers showing inactive and dismantled plants in Figure 4.

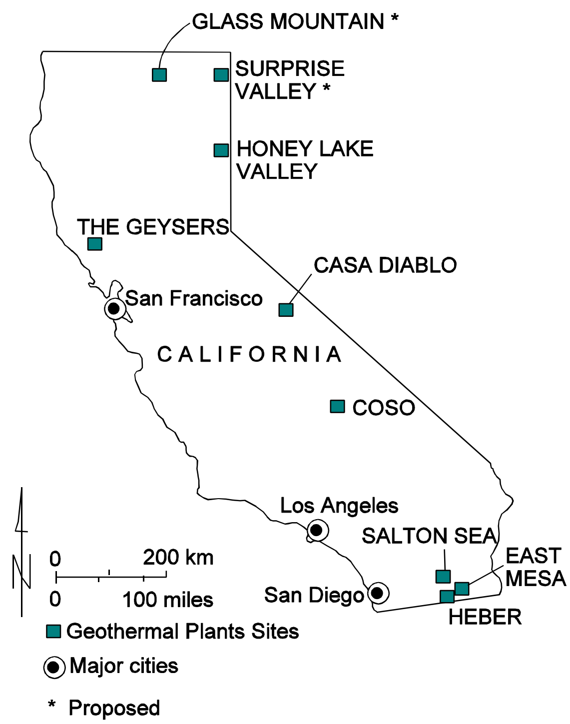

Figure 1. California power plants.

<u>Planned Additions</u>

New plants have been proposed at Glass Mountain (Medicine Lake area) in northern California, each with a capacity of 49.9 MWe. The EIS for the Fourmile Hill Project proposed by Calpine Corporation, has been approved, but is under appeal by a local Indian tribe The Telephone Flats project, proposed by CalEnergy Company, Inc., was denied by the Forest Service. The Bottle Rock plant (55 MWe) in The Geysers, original shut down in 1990, has been purchased by ThermaSource, Inc., and should be operational in the summer of 2001.

<u>Outlook and Conclusions</u>

If all the planned new capacity comes on-line during the next five years (Sifford and Bloomquist, 1999), the installed geothermal electric power capacity would increase by 578 MWe and reach a total of 3,374 MWe. This would represent a growth of about 20 percent of rated capacity. Most of the growth will be in the states of California and Nevada.

A more realistic assessment, based on the current <u>actual</u> capacity and assuming that only half of the planned additions appear over the next five years, would lead to the prediction of about 2,330 MWe of operable geothermal capacity in the year 2005, or about a 14 percent growth.

It will be interesting to see how the industry will fare when some of the power sales agreements that were negotiated in times of relatively high avoided costs go out of existence. Several of these apply to plants in the

Imperial Valley and are scheduled to change during the next three years. The price paid for the energy will become the then-current avoided cost, a much lower value than that paid during the early stage of the contract.

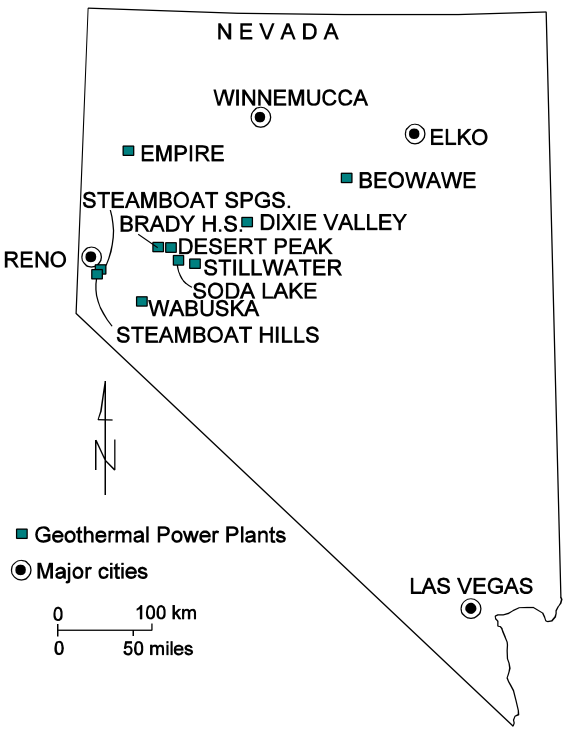

Figure 2. Nevada power plants.

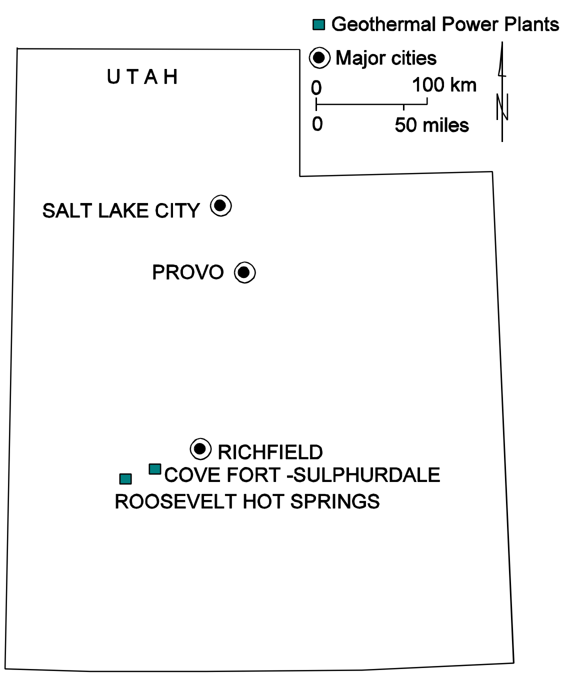

Figure 3. Utah power plants.

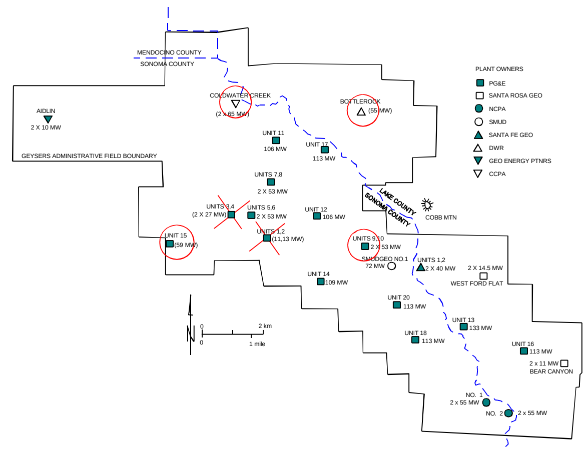

Figure 4. The Geysers power plants.

With the present excess capacity in the western states disappearing, and the increase in the price of fossil fuel, particularly natural gas, geothermal energy is expected to resume its once strong growth. The largest impediment to growth is the difficulty of getting permits to develop projects on public lands, as illustrated by the 10-year wait on the Glass Mountain projects in northern California.

GEOTHERMAL DIRECT UTILIZATION

Introduction

Geothermal energy is estimated to currently supply for direct heat uses and geothermal heat pumps approximately 20,600 billion Btu/yr (21,700 TJ/yr - 6,040 GWh) of heat energy through direct heat applications in the United States. The corresponding installed capacity is estimated at 4,000 MWt. Of these values, direct-use is 8,350 billion Btu/yr (8,800 TJ/yr - 2,450 GWh) and 600 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 exact number of units installed and most are sized for the cooling load, thus they are oversized in terms of capacity for the heating load (except possibly in the northern U.S.).

Most of the applications experienced some increase in use; however the largest annual energy growth has been in geothermal heat pumps. Aquaculture has the largest annual energy growth rate of the direct-use categories, increasing in annual use by 16.9% compound per year over the past five years. From 1990, the growth rate for direct- use was 6.0% annually and for geothermal heat pumps 8.4% annually for a total of 7.4% 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 sector, 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 (due to the low efficiency of the geothermal system); thus, there is no direct-heat cooling in the U.S. (except for geothermal heat pumps). Today, 35% of the annual energy use for direct-use is in the aquaculture industry, 28% is in bathing and swimming (resort and spa pool heating), 18% in space heating (including district heating), 14% in greenhouse heating 5% in industrial processing, including agriculture drying and snow melting. If geothermal heat pumps are included, then they contribute 59% to the annual energy use, and direct-use contributes 41%.

Figures 5 and 6 show in pie-chart form the relative portions of direct-use capacity and energy use (without heat pumps) for the U.S. at the end of 2000. Figures 7 and 8 show the growth of geothermal direct-use at five-year increments. The growth is summarized in Table 3–the direct-use growth column of figures do not include geothermal heat pumps.

Table 3. Growth of Direct-Heat Utilization

Period	Direct-Use	Heat Pumps	Total
1975-1985	3.0	19.7	5.9
1985-1995	4.1	17.6	10.0
1995-2000	7.9	8.1	8.0
(1975-2000)	*4.6*	*16.5*	*8.0*

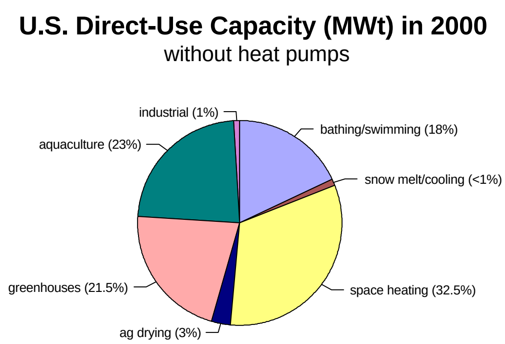

Figure 5.

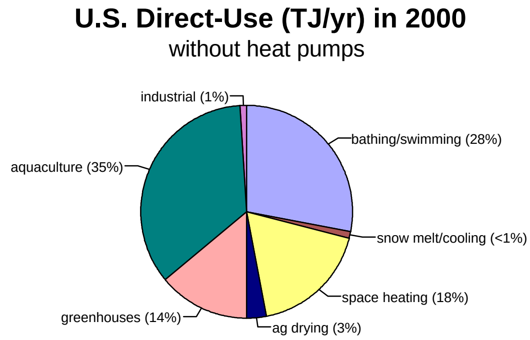

Figure 6.

<u>Direct Use Development Over the Past Five Years</u>

There were 27 new projects identified in seven states and 10 existing projects were expanded a significant amount over the past five years The new projects are mainly aquaculture pond and raceway heating in the Imperial Valley of California and along the Snake River Plain in Idaho, and greenhouses in Montana and Utah. The expanded projects include 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, due to the expense of royalty payments for geothermal energy from federal lands. The remainder of the increase was due to better reporting of space heating and resort/spa pool heating.

During this period, the thermal capacity of the direct heat projects increased by 170 MWt, representing an annual energy utilization of 2,649 billion Btu/yr (2,792 TJ/yr). Geothermal heat pumps increased in capacity by 1,956 MWt, representing an annual energy utilization of 3,950 billion Btu/yr (4,160 TJ/yr) (Lienau, et al., 1995). 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 1997 (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 size.

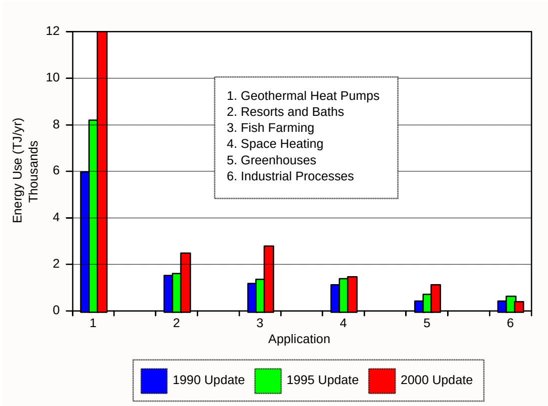

Figure 7. Direct-use comparison.

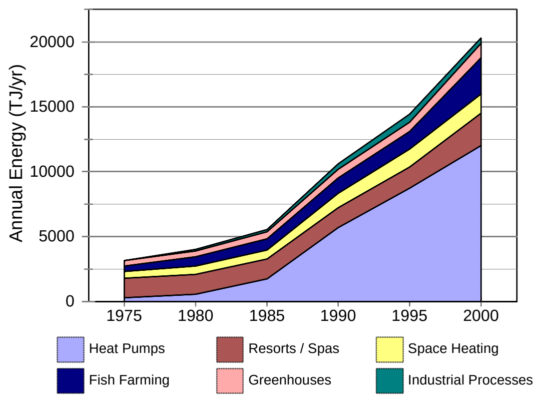

Figure 8. Direct-use growth.

Aquaculture Pond and Raceway Heating

The largest increase in geothermal direct-use in the United States in the past five years 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 8.06 million pounds (3.66 million kg) of Tilapia, catfish and hybrid striped bass are raised here 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. Seven new projects were identified in this area, adding an additional 2.20 million pound (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. In addition, aquaculture projects using 70 to 90°F (21 to 32°C) water are found in the southern states of Texas Arkansas, Louisiana, Mississippi, Alabama and Georgia. 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.

Geothermal Heat Pumps

Geothermal heat pumps has steadily increased over the past five years with an estimated 45,000 units installed in 1997 of 3.4 ton (12 kW) size capacity (Ragnarsson, 1998), increasing to 50,000 annually today. Of these, 46% are vertical closed loops, 38% horizontal closed loop and 15% open loop systems. Projections for the future are that the growth rate will increase about 10% annually, so that by 2010 an estimated 120,000 new units would be installed in that year. It is estimated that 450,000 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 450,000 equivalent 3.4 ton (12 kW) units remove approximately 12,250 billion Btu/yr (12,900 TJ/yr) from the ground. The cooling mode energy is not considered, since this rejects heat to the ground; however, the cooling mode does replace other forms of energy and is, thus, considered in the greenhouse gases emission savings.

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 have 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.

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 (2,700 ft^2 - 250 m^2) and sidewalk heating in downtown Klamath Falls (94,000 ft^2 - 8,700 m^2) (Boyd, 1999; 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 approximately 22,000 ft^2 (2,000 m^2) of concrete pavement (Lund, 1999).

Summary

The distribution of capacity and annual energy use for the various direct utilization categories is shown in Table 4. These figures are based on the best estimates made by the authors. We also feel that anywhere from 10 to 20% addition geothermal direct energy use is unreported throughout the country, due to their small size and often isolated location.

Conclusions

Direct heat use has had a steady growth of six percent compounded annually over the past ten years. This compares to the growth rate of four percent between 1980 and 1990. Growth during 1990 to 2000 could have been higher, but competition from natural gas was a major factor. There are some positive signs on the horizon, in additional to the aquaculture growth, 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 250 MWt with large commercial and industrial building heating [9]. The zinc project by CalEnergy Company, Inc., brought on-line in mid-2000, extracts 33,000 tons (30,000 tonnes) of zinc annually from geothermal water using power from a new geothermal electric plant. The waste water from eight power plants (totaling 300 MWe), having 600 ppm of zinc is utilized. In addition, the extraction of silica and manganese will also be considered (Clutter, 2000).

SUMMARY

The present installed capacity and energy use, at the end of the year 2000 in the U.S., are summarized in Table 5. Even though the electric installed capacity has declined since 1990, the energy produced has almost doubled from around 8,500 GWh/hr (DiPippo, 1995). This is due to increased time on-line as represented by the 0.90 capacity factor as compared to 0.54 in 1990. Direct-use and heat pumps have increased in installed capacity and energy use as shown in Table 3. The capacity factor for direct-use (excluding heat pumps) is about half of electric production indicating the seasonal use of heat, mainly in winter, for most projects. The geothermal heat pump capacity factor is extremely low, as typically only 1,000 full-load hours/year are estimated for the heating mode on the average in the U.S. Over 1,000 full-load hours/year are estimated for operation in the cooling mode for these units; since, cooling is the main function in most commercial and institutional buildings such as schools and offices.

Table 4. Summary of Geothermal Direct-Use

Use	# of Instllations	Installed Capacity (MWt)	Annual Energy Use 10^9Btu	Annual Energy Use TJ	Capacity Factor
Space Heating	1000	90	900	948	0.33
District Heating	18	105	628	662	0.20
Aquaculture	45	140	2,910	3,067	0.70
Greenhouses	37	129	1,164	1,227	0.30
Agriculture Drying	3	20	290	305	0.49
Industrial Processing	4	7	72	76	0.34
Resorts/Spas/Pools	219	107	2,370	2,498	0.74
Snow Melting	5	2	16	17	0.27
Subtotal	1,331	600	8,350	8,800	0.47
Geo. Heat Pumps	450,000	3,400	12,250	12,900	0.12
Total		4,000	20,600	21,700	0.17

Table 5. Summary of Geothermal Capacity & Use

Energy Source	Capacity MW	Energy Use GWh/yr	Capacity Factor
Electric	2,020	16,000	0.90
Direct-Use	600	2,450	0.47
Heat Pump	3,400	3,590	0.12

ENERGY SAVINGS

The total geothermal electricity produced in the United States is equivalent to saving 27.2 million barrels (4.07 million tonnes) of fuel oil per year (generating electricity at 0.35 efficiency factor). This produces a savings of between 0.84 million (natural gas), 3.58 million (oil) or 4.16 million (coal) tonnes of carbon pollution annually. The total direct-use and geothermal heat pumps energy use in the United States is equivalent to savings of 10.3 million barrels (1.54 million tonnes) of fuel oil per year (generating electricity at 0.35 efficiency factor). This produces a savings of between 0.32 million (natural gas), 1.35 million (oil) or 1.57 million (coal) tonnes of carbon pollution annually. If the replacement energy was provided by burning fuel directly, then about half this amount is used (35% vs 70% efficiency). If the savings in the cooling mode of geothermal heat pumps is considered, then this is equivalent to an additional savings of 6.1 million barrels (0.92 million tonnes) of fuel oil per year or from 0.19 million (natural gas), 0.81 million (oil), or 0.94 million (coal) tonnes of carbon pollution annually.

In total, the savings from present geothermal energy production, both electric and direct-use, would amount to 43.6 million barrels (6.53 million tonnes) of fuel oil per year, and reduces air pollution by 1.35 million (natural gas), 5.74 million (oil), or 6.67 million (coal) tonnes of carbon annually. Table 6 provides a summary of the savings.

Table 6. Annual Savings Through Geothermal Energy

(Oil Equivalent - Producing Electricity)
(Including Geothermal Heat Pumps)

43.6 million barrels of oil
6.53 million tonnes of oil (TOE)
5.74 million tonnes of carbon
20.9 million tonnes of CO_2

GEOPOWERING THE WEST

Early in 2000, in an effort to tap the vast geothermal resources of the western United States. Secretary of Energy Bill Richardson and U.S. Senator Harry Reid of Nevada announced a new Department of Energy (DOE) initiative to expand the production and use of energy generated from heat within the earth. The new initiative, known as *GeoPowering the West*, will help bring geothermal electricity and geothermal heat to millions of homes and businesses in the west (Geo-Heat Center, 2000).

Additional details on geothermal electric and direct-use capacity and production can be found in two papers included in the *Proceedings of the World Geothermal Congress 2000, Japan*

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