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The United States of America Direct Utilization Update 2019

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ABSTRACT

Geothermal energy is used for a variety of direct-use applications in the United States. These direct- uses includes the heating of pools and spas, greenhouse and aquaculture facilities, space and district heating, snow melting, agricultural drying, industrial applications and ground-source (geothermal) heat pumps. Most applications use geothermal fluids below the boiling point in the range of 40 to 100oC. The installed capacity is 20,712 MWt and the annual energy use is 152,810 TJ or 42,447 GWh. The largest application is ground-source (geothermal) heat pumps (97.7% of the energy use), followed by fish farming and swimming pool heating. Direct utilization (without heat pumps) has dropped about 20% over the past five years; however, ground-source heat pumps are being installed at 3.8% annual rate with 1.685 million units (12 kW size) in operation. The Geothermal Technologies Office (GTO) of the U.S. Department of Energy funds high risk R&D for geothermal direct-use, including projects in Advanced Energy Storage, Deep Direct Use, and Efficient Drilling for Geothermal Energy. GTO has recently released a major GeoVision study which provides ambitious but achievable targets for the direct-use sector. The energy saving from all direct-uses is about 25.4 million tonnes of equivalent oil per year (168 million barrels) and reduces air pollution by about 22.6 million tonnes of carbon and 63.2 million tonnes of CO_2 annually (compared to fuel oil).

1. INTRODUCTION

Geothermal resources capable of supporting direct-use projects are found primarily in the Western United States, where most the recent volcanic and mountain building activity have occurred (Figure 1.) The San Andreas Fault, running through California from the Imperial Valley to the San Francisco area, the subduction zone off the coast of northern California, Oregon and Washington, and the Cascade volcanism are the source of much of the geothermal activity. However, some of the activity extends eastward to the Dakotas, Colorado and Texas. Ground-source (geothermal) heat pumps extend the utilization to all 50 states with the majority found in the central and eastern states.

Direct-use, other than geothermal heat pumps, has decreased slightly with the closing of some facilities. Losses have been reducing the number of aquaculture projects in the Imperial Valley of California, closing of greenhouses in Susanville, California, a greenhouse in Ennis, Montana, fish farm at Jemez Springs, New Mexico, and the pool at Harbin Hot Springs in California.

Geothermal heat pumps have seen the largest growth, increasing from an estimated 1.4 million to 1.686 million equivalent 12 kW installed units. The estimated installation rate is about 57.2 units per year, or about a 3.8 percent annual growth rate, with most of the growth taking place in the mid-western and eastern states, from North Dakota to Florida. A few states have tax rebates program for geothermal heat pumps, but currently there is little federal or state support for implementing any direct-use projects as they are considered “proven technology”.

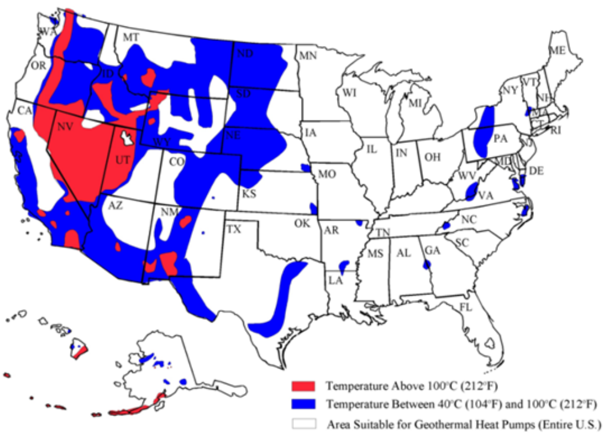

Figure 1. Geothermal resource map of the United States.

2. GEOTHERMAL DIRECT UTILIZATION DETAILS

Geothermal energy is estimated to currently supply for direct heat uses and geothermal (ground-source) heat pumps 152,810 TJ/yr (42,447 GWh/yr) of heat energy in the United States. The corresponding installed capacity is 20,712 MWt. Of these values, direct-use is 7,350 TJ/yr (2,042 GWh/yr) and 483 MWt, and geothermal heat pumps the remainder. It should be noted that values for the energy supplied and capacity by geothermal heat pumps are only approximate (and probably conservative) as it is difficult to determine the exact number of units installed, and since most are sized for the cooling load, they are generally oversized in terms of capacity for the heating load.

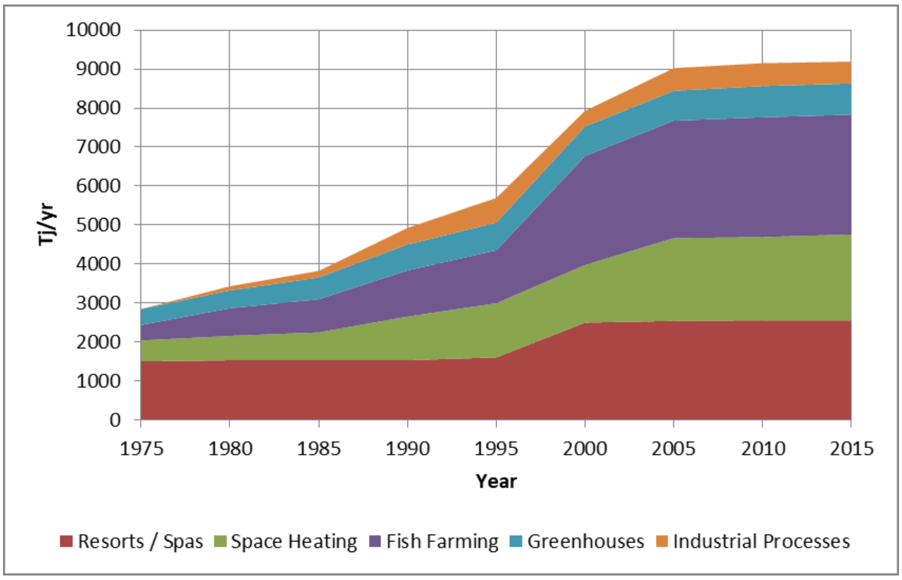

Figure 2. Geothermal direct-use growth in the United States without geothermal heat pumps

Note: space heating includes district heating; industrial includes: industrial process heat, agricultural drying, space cooling, and snow melting (see Table 1). There are no significant changes from 2010 to 2015 and only a slight decrease from 2015 to 2020.

3. STATE DETAILS OF GEOTHERMAL DIRECT-USE PROJECTS AS OF 2019

ALASKA

A total of 15 geothermal direct-use sites have been reported for Alaska, of which 5 were closed between 1913-2002, with remaining 10 in operation at this date (NREL, GHC). Of these 10 sites, 6 are listed as resorts/spas/pools of which 4 are located in southeastern (the "panhandle") Alaska and the other near the Fairbanks area in the center of the state. Of those listed as space heating, 2 are in the southeast and 2 are near Fairbanks, the two largest being Chena Hot Springs at 0.97 MWt and 16.3 TJ/yr and Manley Hot Springs at 0.76 MWt and 13.3 TJ/yr. The one greenhouse is located at Manley Hot Springs north of Fairbanks, raising vegetables for the local market in a single greenhouse. Resource temperatures range between 41° and 72°C. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	6	0.96	24.3	0.80
Space Heat.	4	1.79	30.5	0.54
Greenhouses	1	0.29	7.4	0.81
TOTAL	10*	3.04	62.2	0.65

*Baranof Warm Springs in SE Alaska lists both swimming pool and space heating.

ARIZONA

A total of 25 geothermal direct-use sites have been reported for Arizona, of which 7 were closed between 1934 and 2010 with the remaining 18 in operation at this date (NREL, GHC). Of these 10 sites are listed as resorts, pools and spas, 4 sites for aquaculture, 1 site for greenhouses and 3 sites use water for irrigation. No sites were listed for district heating and space heating. No details were given on the resorts, pools and spa sites so they are all each estimated at 0.29 MWt and 7.4 TJ/yr. The largest aquaculture site is at Desert Springs Tilapia at Gila Bend with an installed capacity of 11.72 MWt and annual energy use of 147.8 TJ. The greenhouse site is Best Fresh Farms at Wilcox at 3.0 ha in size raising vegetables along with an aquaculture facility. Three sites report using geothermal water for irrigation, but no thermal energy use is reported. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	10	2.90	74.0	0.80
Aquaculture	4	19.63	247.4	0.40
District Heat.	0			
Space Heat.	0			
Greenhouses	1	7.60	86.0	0.36

Irrigation	3	0	0	0
TOTAL	25	30.13	407.4	0.43

ARKANSAS

There is only one major geothermal usage in the state, at Hot Springs National Park located 80 km to the west of the capitol Little Rock. This resort community has used geothermal hot water for both pools and space heating. The site used by the Quapaw Indians for centuries, was ceded to the state in 1818 and was set aside as a federal reservation in 1820. It became national park in 1921. However, the warm waters were also used by early explorers and settles for their healing properties. Babe Ruth had his start here in 1918 with two home runs. On average, as much as 2.65 million liters/day has issued from the various springs in the area at 62°C. There are other minor geothermal uses in the states, but records are lacking. The estimated summary for the national park:

Facilities	No.	MWt	TJ/yr	L.F.
Pools/Spas	10	0.36	6.9	0.61
Space Heat.	10	0.11	1.0	0.29
TOTAL	20	0.47	7.9	0.53

CALIFORNIA

A total of 111 geothermal direct-use sites have been reported for California, of which 24 were closed between 1983 and 2015 with the remaining 87 in operation at this date (NREL, GHC). Of these, 55 sites are listed as resorts, pools and spas, 14 sites for aquaculture, 3 sites for district heating, 14 sites for individual space heating, 0 sites are listed for greenhouse operation, and one industrial site. The largest resort/spa site is at Murrieta Hot Springs/Conference Center located in Riverside Country, Southern California (2.40 MWt, 46.1 x TJ/yr). The largest aquaculture facility is Kent Sea Technology near Meca (13.01 MWt, 328.8 TJ/yr). The largest district heating installation is in San Bernardino (12.83 MWt, 79.1 TJ/yr), the largest individual space heating is at Warner Springs Ranch in Southern California (1.76 MWt, 390 TJ/yr), and the industrial facility is a private operation in Calistoga bottling “Geyser Water”. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	55	12.55	292.9	0.74
Aquaculture	14	39.79	989.6	0.79
District Heat.	3	18.78	96.8	0.16
Space Heat.	14	6.99	86.6	0.39
Greenhouses	0			
Industrial	1	0.67	15.8	0.74
TOTAL	87	78.78	1,481.7	0.60

COLORADO

A total of 48 geothermal direct-use sites have been reported for Colorado, of which 3 were closed between 1981 and 2014 with the remaining 45 in operation at this date (NREL, GHC). Of these, 26 sites are listed as resorts, pools and spas, 3 sites for aquaculture, 1 for district heating, 12 sites for individual space heating, 3 sites for greenhouse operations, and one for the raising of alligators for tourists at Mosca near San Dunes National Monument. The largest resort/spa is at Glenwood Hot Springs Lodge, Glenwood west of Denver in the mountains (2.64 MWt, 66.8 TJ/yr). The largest aquaculture site is a fish hatchery northeast of Gunnison (2.08 MWt. 52.8 TJ/yr). The only district heating is for the City of Pagosa Spring along with the nearby largest individual space heating project (private resort at 1.46 MWt, 13.7 TJ/yr). The largest greenhouses are in the foothills of Mt. Princeton at 0.47 MWt and 7.6 TJ/yr. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	26	10.67	266.2	0.79
Aquaculture	2	4.28	107.8	0.80
District Heat.	1	5.13	17.3	0.11
Space Heat.	12	4.40	64.5	0.46
Greenhouses	3	1.41	22.8	0.51
Alligators	1	2.34	59.0	0.50
TOTAL	45	28.23	537.6	0.60

FLORIDA

Warm Mineral Springs swimming pool is located in and old sink hole where submerged Pre-Indian and Indian burial remain have been found. Artifacts and remains of these native who lived in the area as long a 14,000 year ago have been found from archeological dives and exploration. Evidence of saber tooth tiger, giant sloths, tortoises and camels has been extracted from the spring. It is listed in the National Register of Historical Places. The pool is 70 m deep and 72 m in diameter, remaining at a constant 31°C year around. The primary water supply is from a spring 63 m below the pool water surface. The water contains 51 minerals, one of the highest of any natural spring in the U.S; mainly chloride and hydrogen sulfide with no oxygen. The pool is charged with 34,000 cubic meters of fresh water every two hours. It is located on the west coast of Florida, south of Sarasota and north Ft. Myers at North Point. It is the only warm water mineral spring in the state and is reputed to be the fountain of youth sought by Ponce de Leon with heating powers. In summary:

Swimming pool: 31°C 0.07 MWt 2.1 TJ/yr L.F.1.00 (est.)

GEORGIA

Warm Springs is located about 120 km south of Atlanta. The springs were used by Indians from as far away as New York, as they were on a major trail system. The trails later became military and post road, with a tavern built in the early 1800s. The springs is known chiefly for the treatment of polio from the early 1920s to the 1960s. It was promoted by President Franklin Delano Roosevelt, who had polio and established the "Little White House" on its premises in 1932. The Georgia Warm springs Foundation, who managed the springs, dedicated itself to the conquest of polio. It provided treatment in various pools supplied by warm spring flowing around 58 L/s at 31°C. With the advent of polio vaccines in the 1950s and 60s, use of the facilities declined. Today, the Roosevelt Warm Springs Institute for Rehabilitation of the state of Georgia provides medical rehabilitation and therapy for a broad range of disabilities. The Institute also uses the water for bathing, heating and cooling, assisted by water-to-air heat pumps. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	1	0.29	7.4	0.80
Space Heat.	1	0.32	3.6	0.36
TOTAL	2	0.6 1	11.0	0.57

HAWAII

No direct-use operations exist in Hawaii today (Thomas, 2019). All of the geothermal direct-use in the state took place on the "Big Island" of Hawaii. In the 1980s through 2000 several experimental geothermal projects were developed in the Puna area using waste water from well HPGA located in the SE area of the island. These projects included growing ornamental palms, fixing the colors on hand dyed silk with geothermal steam, experimental lumber drying, aquaculture, pasteurizing of growing media, silica bronze projects, and green papaya powder drying (Boyd, et al., 2002). Today all that remains is the Hawaii Glass Project using waste silica to employ local artists. Geothermal water is also used to heat 32 ponds (0.80 ha) owned by Tropical Ponds Hawaii growing tropical ornamental fish. The 43°C well water is cooled to 21 to 27°C before entering the ponds. Normally in Hawaii the water temperature would vary as much as 5.5°C during the year, but the geothermally heated pond water is kept within 1°C of the optimum growth temperature. A major lava eruption covered most of the area in 2018.

IDAHO

The state has the largest number of geothermal direct-use application in the U.S. for a total of 88 of which 8 were closed between 1980 and 2011, leaving 80 active sites (2 of which have multiple uses). Of the active ones 33 are resorts/spas/pools for 9.32 MWt and 209.9 TJ/yr with Lava Hot Springs being the largest at 1.11 MWt and 21.3 TJ/yr, 18 are aquaculture facilities for an estimated 45.32 MWt and 608.9 TJ/yr (data on 11 of these sites had to be estimated) with Fish Breeders of Idaho in Buhl being the largest at 7.27 MWt and 183.4 TJ/yr. There are 7 district heating sites for 37.59 MWt and 595.8 TJ/yr, of which the largest are the Boise City District Heating at 20.6 MWt and an estimated 418.2 TJ/yr heating 92 buildings of 600,000 square meters, along with the Capitol Mall in Boise at 3.31 MWt and 67.2 TJ/yr. The city system has also been extended across the Boise River supplying heat to Boise State University. The Warm Springs Avenue is the oldest district heating system in the country starting in 1890 with 200 homes and 40 businesses. It is still in operation, with 275 customers at 3.60 MWt and 31.6 TJ/yr. Individual space heating includes 11 projects for 10.26 MWt and 93.6 TJ/yr with the largest being College of Southern Idaho in Twin Falls at 6.34 MWt and 50.4 TJ/yr. Greenhouse heating includes 13 sites for and estimate 17.05 MWt and 151.8 TJ/yr (3 sites had to be estimated), with largest being Jack Ward's Greenhouses in Garden Valley at 4.42 MWt and 34.8 TJ/yr raising nursery stock, along with Canyon Bloomers in Buhl at 3.84 MWt and 30.1 TJ/yr raising flowers. In summary:

Facilities	No.	MWt	TJ/yr	L.F.	
Resorts/Spas	33	9.32	209.9	0.71	
Aquaculture	18	45.32	609.9	0.43	(estimate)
District Heat.	7	37.59	595.8	0.50	
Space Heat.	11	10.26	93.6	0.29	
Greenhouses	13	17.05	151.8	0.28	
TOTAL	82	119.54	1,661.0	0.44	

MONTANA

A total of 40 geothermal direct-use sites have been identified in the state with 9 being closed leaving 31 active sites, one of which has two applications for a total of 32 applications. Most of the geothermal applications are located in the southwestern part of the stare in the Rocky Mountain region. Resorts/spas/pools have the largest number of application, 16 for 5.95 MWt and 146.2 TJ/yr of which the largest are Fairmont Hot spring Resort in Anaconda at 1.11 MWT and 29.4 TJ/yr and Barkells Hot Springs in Silver Star at 1.03 MWt and 25.6 TJ/yr where there is also reported geothermal use for space heating. One of the hot spring sites, now closed is Sleeping Child using 54oC spring water, where Chief Joseph of the Nez Perce with his followers were trying to escape to Canada in 1870. They were being pursued by General Howard, and since the women also had to fight, they left their children at the hot spring where they slept peacefully during the battle. The only aquaculture site is at Brooks Warm Springs in Fergus Country at 0.29 MWT and 7.4 TJ/yr. There are 10 space heating sites in the state amounting to 4.21 MWt and 71.2 TJ/yr, the largest are spa buildings being heated at Fairmont Hot Springs (0.88 MWt, 15.3 TJ/yr), Bozeman Hot Springs (0.59 MWt, 6.1 TJ/yr) and Lolo Hot Springs (0.53 MWt, 13.3 TJ/yr). Three greenhouse operation are found in the state, the largest being Bigfork Greenhouses raising tomatoes at 1.26 MWt and 178 TJ/yr. Two industrial sites are found in the state, at the Ennis RV Village Laundry and at the Spa Hot Spring Motel in White Sulfur Spring for snow melting. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	16	5.95	146.2	0.78

Aquaculture	1	0.29	7.4	0.80
Space Heat.	10	4.21	71.2	0.54
Greenhouses	3	1.45	18.4	0.40
Industrial	2	0.48	3.8	0.25
TOTAL	32	12.38	247.0	0.63

NEVADA

The state's geothermal district-use is dominated by two large district heating projects in Reno and Elko, by a large casino in Reno, and an onion dehydration plant at Brady Hot Springs east of Reno. All of the geothermal uses are found in the northern part of the state. A total of 27 direct-use sites have been reported for Nevada, of which 11 were closed between 1983 and 2013 with the remaining 16 in operation at this date (NREL, GHC). Of these, 6 sites are listed as resorts, pools and spas, 0 sites for aquaculture (4 sites have been recently closed), 4 district heating sites, 5 individual space heating sites, no greenhouse sites, and one large industrial site, the onion dehydration plant. The largest swimming pool site is at Bowers Mansion east of Reno (0.41 MWt, 5.0 TJ/yr). The two large district heating sites are located in Reno's Manzanita Estates, heating 100 homes (3.6 MWt, 76.3 TJ/yr), and in Elko heating buildings in the commercial district (3.81 MWt, 23.4 TJ/yr). Individual space heating is dominated by the heating of the Peppermill Inn and Casino in Reno (7.03 MWt, 66.4 TJ/yr) and in the Moana district of southwest Reno heating 300 homes from individual wells (5.27 MWt, 41.5 TJ/yr). In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	6	1.63	35.7	0.69
Aquaculture	0			
District Heat.	4	12.71	124.5	0.31
Space Heat.	5	14.56	128.0	0.28
Greenhouses	0			
Industrial	1	5.57	90.6	0.52
TOTAL	16	34.47	378.8	0.35

NEW MEXICO

Geothermal uses in the state are centered on 20 resorts/spas/pools, a fish farm, Americulture at Animas, and a large greenhouse complex at Radium Springs run by Masson Farms. A total of 32 geothermal direct-use sites have been reported for New Mexico, of which 7 are closed, with the remaining 25 sites in operation at this date (NREL, GHC). Of these 20 sites are listed as resorts, pools and spas, 1 site raising tilapia at Americulture farms in Animas, 1 district heating site at Gila Hot Springs Ranch serving a ranch building with apartments and RV park, 2 space heating sites, one at Geronimo Springs Museum at Truth of Consequences, and one at Jemez Springs, and one large greenhouse site as described above. In summary :

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	20	4.32	97.4	0.71
Aquaculture	1	1.17	29.5	0.80
District Heat.	1	0.30	0.9	0.10
Space Heat.	2	0.19	1.5	0.26
Greenhouses	1	13.27	125.4	0.13
TOTAL	25	19.25	254.7	0.42

NEW YORK

The state has two reported geothermal resorts/spas/pools, Lebanon Hot Springs and Saratoga Springs located in upstate New York north of Albany. Saratoga Springs is the more famous of the two with more details available on the geothermal use (Lund, 2000). Lebanon Hot Springs was used by the Indians and was first visited by Europeans in 1771. A bath house was built in 1771. The pool today uses 24°C water, but little is known about its facilities and energy use. Saratoga Springs is much better known as the largest hot spring in the state located 250 km north of New York City. It has approximately 18 springs and hot wells discharging 13oC carbonated water along a fault. The Mohawk and Iroquois Indian tribes frequented the springs during hunting trips in the area. The first written report of the springs by European settlers was in the early 1600's. Since this time, the springs have been used for drinking and bathing to cure everything from skin disorders to digestive problems. The water and carbon dioxide has also been bottled and sold as a commercial produce. Because of the use and decline in flow of the springs in the early 1900s, the state of New York formed Saratoga Spa State Park, and now manages the geothermal activity including the only spouting geyser east of the Mississippi River. Several of the older bathhouses, Lincoln and Roosevelt (originally separate men's and women's bathhouses), have been restored providing mineral baths, hot packs and massages. In summary:

Saratoga Springs: 13°C 74 L/s 0.29 MWt 7.4 TJ/yr L.F. 0.8

NORTH CAROLINA

Hot Springs Resort and Spa is located in the mountains of western North Carolina just north of Ashville. It has 17 outdoor jetted hot tubs using geothermal water at 98° to 100°C. The springs in the area were used by Native Americans starting 5000 years ago. It is the locations of numerous elaborate resorts built before WWI, but the last burned down in 1920. In summary:

Hot Springs Resort and Spa: 100° – 104°C 0.25 MWt 6.3 TJ/yr L.F. 0.80

OREGON

The state has 66 reported geothermal direct-use sites of which 8 have been closed (between 1950 and 2013) leaving 58 active sites. Of those, 21 are listed as resorts/spas/pools of which the pool at “Ka-Nee-Ta” Native American resort at the Warm Springs Reservations is the largest (1.32 MWt, 29.1 TJ/yr). There are 3 aquaculture site all at about the same capacity: 1.17 MWt and 29.5 TJ/yr. These are Gone Fishing and Liskey Farms south of Klamath Falls where they raises tropical fish and tilapia, and Summer Lake Aquaculture north of Lakeview raising trout for the commercial market. District heating is found in three places, two in Klamath Falls: the City of Klamath Falls (4.69 MWt, 36.9 TJ/yr) heating 23 buildings in the downtown area, and Oregon Institute of Technology (6.21 MWt, 49.1 TJ/yr) heating 7 campus building. There are 23 individual space heating sites, most in Klamath Falls. The largest is approximately 600 homes heated using individual wells from 50 to 100oF using a downhole heat exchanger. Seven Klamath Falls schools are also heated with geothermal waters from wells located on their grounds amounting to 2.55MWt and 20.9 TJ/yr. Others, include the Klamath County Jail at 3.08 MWt and 24.2 TJ/y and several apartment buildings at 1.90 MWt and 15.0 TJ/yr. There are 4 greenhouse complexes being heated, the two main ones are Liskey Greenhouses south of Klamath Falls at 1.73 MWt and 16.3 TJ/y raising potted plants, and IFA Nursery in Klamath Falls at an estimate 2.0 MWt and 20.0 TJ/yr raising tree seedlings for commercial firms in four houses covering 1.6 ha. These houses are provided geothermal water from the city district heating system. Finally, there are 4 industrial sites, one a potato dryer in Vale at 0.88 MWt and 6.9 TJ/yr, one is for snow melting projects for sidewalks in downtown Klamath Falls and on a bridge deck leading up to the high school at 1.17 MWt and 3.7 TJ/yr, and the other for stairs on the Oregon Institute of Technology camps at 0.06 MWt and 0.2 TJ/yr. A deicing project for a state highway is located on a steep hill just before a traffic signal at 0.26 MWt and 6.3 TJ/yr, to prevent trucks from sliding while stopped at the signal. Almost half of the sites are located in the Klamath Falls/Southern Oregon area. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	21	6.68	147.8	0.70
Aquaculture	3	3.54	88.5	0.79
District Heat.	3	12.54	102.4	0.26
Space Heat.	23	39.21	536.8	0.43
Greenhouses	4	4.03	38.3	0.30
Industrial	4	2.37	17.1	0.23
TOTAL	58	68.37	930.9	0.43

SOUTH DAKOTA

There are 8 geothermal direct-use projects listed for the state, of which 2 are closed leaving 6 projects active. Two projects provide heat for resorts/spas/pools, with the largest at Evan’s Plunge in Hot Springs on the southern edge of the Black Hills (1.52 MWt, 38.2 TJ/yr). One aquaculture project raising juvenile tilapia in a series of greenhouses is at Philip (1.76 MWt, 44.3 TJ/yr) along with the district the city district heating project. The district heating was provided from well for the local high school and then cascaded down to 8 businesses, then serving the water treatment facility after being treated and disposed into the Mad River (2.46 MWt, 18.8 TJ/yr). The school district saves over $75,000/year and the city $100,000/yr (Lund, 1997). A smaller district heating project is found in Midland. Space heating is provided at Scotchman Industries manufacturing metal fabrication equipment, accessories and custom tool, is also in Philip. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	2	1.54	38.6	0.79
Aquaculture	1	1.76	44.3	0.80
District Heat.	2	2.55	19.6	0.24
Space Heat.	1	0.40	3.8	0.30
TOTAL	6	6.25	106.3	0.54

TEXAS

The state has only a few geothermal direct-use projects, 3 pools and 2 space heating sites. Most are located in south central Texas near Austin, except for Chinatti hot spring pool located in west Texas. The Langford pool in Big Bend National Park is a primitive pool adjacent to the ruins of an old bath house. Stacy Park pool is located in downtown Austin. The Cotulla High School is the largest user for space heating (2.90 MWt, 13.7 TJ/yr), but has a lower load factor (0.15) compared to the second largest user of heat, Falls Community Hospital and Clinic in Marlin (0.88 MWt, 7.9 TJ/yr) with a load factor of 0.29, being open more of the time. In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	3	0.84	20.6	0.78
Space Heat.	2	3.78	21.6	0.18
TOTAL	5	4.62	42.2	0.29

UTAH

A total of 28 geothermal direct-use sites have been reported for Utah, of which 9 were closed between 1984 and 2014, with the remaining19 in operation at this date (NREL, GHC). Some data were missing for the resorts/spas/pools list and for the aquaculture list. These missing data have been estimated based on the literature and our experience visiting these sites. Of these 19 sites 9 are listed as resorts/spas/pools, 2 sites raising aquaculture, 2 sites for individual space heating (none for district heating), and 6 for greenhouses. The largest resort/spa/pool site is at Crystal Hot Springs near Honeyville (1.03 MWt, 22.6 TJ/yr) , along with an interesting site of the Bonneville Seabase Scuba Dive Pool in the Bonneville salt flats west of Salt Lake City (estimated at 0.29

MWt and 7.4 TJ/yr). The largest space heating facility is at the Utah State Prison at Draper (1.98 MWt, 15.5 TJ/yr). The largest aquaculture site is Crystal Springs Fishery also at Draper raising tropic fish (11.72 MWt, 86.4 TJ/yr). Unfortunately, competition for the geothermal water used by the adjacent Utah State Prison, Bluffdale Flowers, Hi-Tech Fisheries have caused water levels to drop in the hot springs that feeds their 1 ha lake and has temporality left the Fishery without water. So far the lake has kept the 0.5 to 1 million tropic fish alive that have been supplied to pet stores for over 30 year. The prison well is a resent use of the water and is causing most of the drop in water levels. The largest greenhouse operation is Migro Nusery, Inc. at Newcastle in southern Utah growing 6 million potted flowers per year in 10 ha of greenhouses (22.06 MWt, 173.8 TJ/yr). In summary :

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	9	3.40	79.5	0.74
Aquaculture	2	1.87	37.5	0.64
District Heat.	0			
Space Heat.	2	2.57	24.7	0.30
Greenhouses	6	34.45	277.9	0.26
TOTAL	19	42.29	419.6	0.31

VIRGINIA

Virginia has a listed 20 geothermal springs varying from 16° to 41°C. The most famous geothermal resort is the Omni Homestead Resort at Hot Springs located on the eastern border of the state in the Allegheny Mountains. The original lodge was built in 1766, later revised and burnt down and rebuilt in 1902. The spring is the largest hot spring in the state and has been visited by 23 presidents. At the beginning of WWII it was an internment camp for Japanese diplomates and their family before they could be returned to Japan through a neutral country. The resort is known for its octagon pools filled with geothermal water (36 m in diameter, originally one for men and one for women. The "Gentlemen's" pool house built in 1761, is the oldest spa structure in the U.S. and the "Ladies" pools was building in 1836. The area is also known for its golf and downhill skiing. A total of 74 L/s flows from springs in the area. The details are:

2 pools 40°C 0.75 MWt 23.8 TJ/yr L.F. 1.00

WASHINGTON

A total of 7 resorts/spas/pools using geothermal heat are found in the state. Several are found along the Columbia Rivers (Bonneville and Carson), two at Soap Lake in central Washington, and one is even located in the north edge of the Olympic Peninsula (Sol Duc). The largest is Bonneville Hot Springs Resort and Spa with both geothermally heated pool and rooms, some with hot tubs, for an estimate total of 0.29 MWt and 7.4 TJ/yr for the pool and 0.35 MWt and 4.2 TJ/yr for the space heating (Bloomquist, 2006). In summary:

Facilities	No.	MWt	TJ/yr	L.F.
Resorts/Spas	7	1.89	45.7	0.77
Space Heat.	1	0.35	4.2	0.38
TOTAL	8	2.24	49.9	0.71

WEST VIRGINIA

Two resorts using geothermal water in their spas are at Berkeley Springs State Park and the Greenbrier at White Sulphur Springs, located on opposite ends of the state, the former in the north and the latter in the south. Berkeley Springs is considered Americas first spa, used by the Indians and since 1730 by immigrate citizens, mainly for the Washington D. C. area. George Washington visited there many time, as a boy and as President. The geothermal waters are 24°C and are used in the Country Inn, the outdoor Roman Bath House pool and the Atasia Spa. The estimated geothermal use is 0.4 MWt and 7.2 TJ/yr with a load factor of 0.8. The Greenbrier uses low temperature geothermal wat at 17oC which are then heated with steam for use in pools. It has been used by immigrates since 1778 for "to take the waters". The resorts was built by the Chesapeake and Ohio Railroad in 1913, and since 26 presidents have stayed there, the last being Franklin Roosevelt. During the "cold war" it was used as an emergency shelter for Congress. The geothermal use is 0.2 MWt and 3.6 TJ/yr also with a load factor of 0.8 (Lund, 2000).

Resorts/Spas 2 0.6 MWt 10.8 TJ/yr L.F. 0.80

WYOMING

The state has 26 geothermal direct-use listings, of which 4 have been closed, leaving 22 active sites. The majority of these listing are for resorts/spas/pools (10) and aquaculture (8). The main listings for resorts/spas/pools are for Hot Spring State Park (16.00 MWt, 403.3 TJ/yr) and Paynes Fountain of Youth RV park (4.45 MWt, 112.3 TJ/yr) both located in Thermopolis. Unfortunately, only one of the 8 listings for Aquaculture had data, thus a conservative estimate was made for the remainders. Otherwise there is only one listing for space heating of a residence in Thermopolis, one greenhouse listing at Countryman Wells near Landers growing vegetables, and two unusual listing for bridge deck snow melting in Laramie at 0.06 MWt and 1.1 TJ/yr and in Cheyenne at 0.26 MWt and 5.3 TJ/yr. These two snow melting systems use heat pipes circulating ammonia heated from a ground temperature of 8oC, which is adequate to keep the bridge deck snow/ice free in the winter (Lund), 2000). In summary:

Facilities	No.	MWt	TJ/yr	L.F.	
Resorts/Spas	10	24.59	609.7	0.79	
Aquaculture	8	4.48	80.0	0.57	(estimated)
District Heat.	0				
Space Heat.	21	0.29	2.6	0.28	

Greenhouses	1	0.23	2.2	0.30
Bridge snow melt	2	0.32	6.4	0.63
TOTAL	22	29.91	700.9	0.74

4. SUMMARY OF DIRECT-USES WITHOUT GEOTHERMAL HEAT PUMPS

STATE (MWt)	Resort/spas	Aquaculture	District Heat.	Space Heat	Greenhouse	Industrial	TOTAL (MWt)
Arizona	2.90	19.63			7.60		**30.13**
Alaska	0.96			1.79	0.29		**3.04**
Arkansas	0.36			0.11			**0.47**
California	12.55	39.79	18.78	6.99		0.67	**78.78**
Colorado	10.67	4.28	5.13	4.40	1.41	2.34	**28.23**
Florida	0.07						**0.07**
Georgia	0.29			0.32			**0.61**
Hawaii							**0**
Idaho	9.32	45.32	37.59	10.26	17.05		**119.54**
Montana	5.95	0.29		4.21	1.45	0.48	**12.38**
Nevada	1.63		12.71	14.56		5.57	**34.47**
New Mexico	4.32	1.17	0.30	0.19	13.27		**19.25**
New York	0.29						**0.29**
North Carolina	0.25						**0.25**
Oregon	6.68	3.54	12.54	39.21	4.03	2.37	**68.37**
South Dakota	1.54	1.76	2.55	0.40			**6.25**
Texas	0.84			3.78			**4.62**
Utah	3.40	1.87		2.57	34.45		**42.29**
Virginia	0.75						**0.75**
Washington	1.89			0.35			**2.24**
West Virginia	0.60						**0.60**
Wyoming	24.59	4.48		0.29	0.23	0.32	**29.91**
TOTAL	**89.85**	**122.13**	**89.60**	**89.43**	**79.78**	**11.75**	**482.54**
WGC2015	112.93	141.95	81.55	139.89	96.91	37.84*	615.91

*includes industrial, agricultural drying and snow melt

STATE (TJ/yr))	Resort/spas	Aquaculture	District Heat.	Space Heat	Greenhouse	Industrial	**TOTAL (TJ/yr)**
Arizona	74.0	247.4			86.0		**407.4**
Alaska	24.3			30.5	7.4		**62.2**
Arkansas	6.9		1.0				**7.9**
California	292.9	989.6	96.8	86.6		15.8	**1,481.7**
Colorado	266.2	107.8	17.3	64.5	22.8	59.0	**537.6**
Florida	2.1						**2.1**
Georgia	7.4			3.6			**11.0**
Hawaii							**0**
Idaho	209.9	609.9	595.8	93.6	151.8		**1,661.0**
Montana	146.2	7.4		71.2	18.4	3.8	**247.0**
Nevada	35.7		124.5	128.0		90.6	**378.8**

New Mexico	97.4	29.5	0.9	1.5	125.4		**254.7**
New York	7.4						**7.4**
North Carolina	6.3						**6.3**
Oregon	147.8	88.5	102.4	536.8	38.3	17.1	**930.9**
South Dakota	38.6	44.3	19.6	3.8			**106.3**
Texas	20.6			21.6			**42.2**
Utah	79.5	37.5		24.7	277.9		**419.6**
Virginia	23.8						**23.8**
Washington	45.7			4.2			**49.9**
West Virginia	10.8						**10.8**
Wyoming	609.7	80.0		2.6	2.2	6.4	**700.9**
TOTAL	**2,153.2**	**2,241.9**	**958.3**	**1,073.2**	**730.2**	**192.7**	**7,349.5**
2015	2,257.50	3,074.00	839.6	1,360.60	799.80	493.1*	9,192.20

* includes industrial, agricultural drying and snow melt

STATE	No.	MWt	TJ/yr	L.F.
Arizona	25	30.13	407.4	0.43
Alaska	10	3.04	62.2	0.65
Arkansas	20	0.47	7.9	0.43
California	87	78.78	1,481.7	0.68
Colorado	45	28.23	537.6	0.60
Florida	1	0.07	2.1	1.00
Georgia	2	0.61	11.0	0.57
Hawaii	0	0	0	0
Idaho	82	119.54	1,661.0	0.44
Montana	32	12.38	247.0	0.63
Nevada	16	34.47	278.8	0.35
New Mexico	25	19.25	354.7	0.42
New York	1	0.29	7.4	0.80
North Carolina	1	0.25	6.3	0.80
Oregon	58	68.37	930.9	0.43
South Dakota	6	6.25	106.3	0.54
Texas	5	4.62	42.2	0.29
Utah	19	42.29	419.6	0.31
Virginia	2	0.75	23.8	1.00
Washington	8	2.24	49.9	0.71
West Virginia	2	0.60	10.8	0.80
Wyoming	22	29.89	700.9	0.74
Total	**469**	**482.54**	**7,349.5**	**0.48**

5. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS

The number of installed geothermal heat pump units (sometime referred to as ground-source heat pumps) has steadily increase over the past 20 years with an estimated 57,160 equivalent 12 kWt united installed each of the past five year – a decreased of 80,000 units per year during the previous five years. Even though the actual number of installed units is difficult to determine, the present estimate is that there are at least 1.686 million units installed, mainly in the mid-western and eastern states (BRG, 2018; IGSHPA, 2018). Of these approximately 60% of the units are installed in residences and the remaining 40% in commercial and institutional buildings. Approximately 90% of the units are closed loop (ground-coupled) and the remaining open loop (water-source). Within the residential sector, of the closed loops systems, approximately 30% are vertical and 70% horizontal, as the latter are cheaper to installed, especially where there is yard available. In the institutional and commercial section, 90% are vertical and only 10% horizontal, constrained by ground space in urban areas. Presently, the ratio of new installations to retrofit installations is 3:1. The estimated full load hours in the heating mode is 2,000/yr, and in the cooling mode is 2,200/yr, however this varies between regions of the country (see Table 4 in the Appendix). The units are found in all 50 states and are growing about 3.8% a years (down from 8%/yr during 2010-2014). The current installed capacity is 20,230 MWt and the annual energy used in the heating mode is 145,460 TJ (40,406 GWh). The largest installation is at Ball State University in Indiana where 3,600 vertical loops were installed in 2012 (J. Lowe, USDOE, 2016). The system heats and cools 47 buildings, replacing four aging coal-fired builders. The system supplies 6°C cold water for cooling and 66°C hot water for heating at an annual savings of $2 million.

6. USDOE PROGRAMS

FEDERAL GEOTHERMAL RESEARCH & DEVELOPMENT INITIATIVES

Introduction

The primary federal agency responsible for geothermal R&D initiatives is the U.S. Department of Energy's Geothermal Technologies Office (DOE GTO), whose mission is to drive research and development (R&D) and manufacturing solutions to address technical challenges and support widespread development and deployment of innovative, clean, geothermal energy technologies. Technological innovation will help reduce the costs and risks in converting geothermal resources into useful energy services.

The program's technology portfolio includes R&D in low-temperature resources for direct use. This research addresses the high risk in R&D that the geothermal industry does not have the technical capabilities or institutional knowledge to conduct, especially in the early stages of research. Federal involvement in early-stage research and development enables the geothermal sector to develop innovative technologies that will help harness American heat energy resources safely and efficiently.

GTO spends the bulk of its budget on extramural research at national laboratories, universities, and industry. Appropriated funding for GTO is shown in Figure 3. Funding for related work from other Federal agencies is not considered in this report. GTO has seen an increase of 52% since FY 2015. The FY 2019 budget of $84 million supports projects in 4 subprogram areas: Enhanced Geothermal Systems, Hydrothermal, Low-Temperature and Coproduced Resources, and Systems Analysis. The programs that support R&D for the direct use sector are described in the next section. The programs that support R&D for the electric sector are described in a companion piece (Ann Robinson-Tate, et al., 2019).

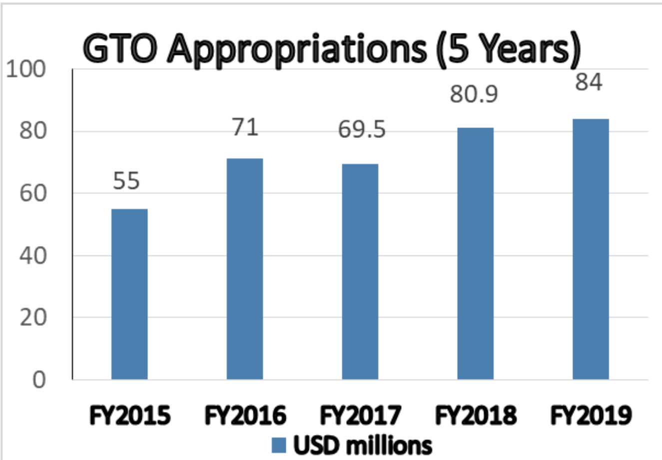

Figure 3. Geothermal Technologies Office Appropriations 2015-2019.

DOE GTO Programs, 2017 – 2019

GTO supports projects and programs in several areas related to the direct use sector. GTO's major programs over the last few years include:

6.1 GeoVision Analysis and Report

GTO recently completed a rigorous, multi-year research effort to examine the potential role for geothermal in the Nation's affordable energy future. The result is GeoVision: Harnessing the Heat Beneath Our Feet. The GeoVision analysis (which was initiated in FY 2015 and completed in FY 2019) included collaboration among national laboratories, industry experts, and academia to evaluate the geothermal potential and impacts in the U.S. from the present until 2050. The effort assessed opportunities to expand nationwide geothermal energy deployment by improving technologies, reducing costs, and mitigating project development barriers such as permitting. The GeoVision analysis also: examined economic benefits to the U.S. geothermal industry; investigated opportunities for desalination, mineral recovery, and hybridization with other energy technologies for greater efficiencies and lower costs; and quantified potential environmental impacts of increased geothermal deployment.

The GeoVision report along with 8 supporting National Laboratory Task Force Reports, including two specifically aimed at the direct use (non-electric) sector, were published in May, 2019 and can be found here: www.energy.gov/GeoVision. Key findings for the direct use sector from the GeoVision study include:

- The GeoVision analysis determined that the market potential for GHP technologies in the residential sector is equivalent to supplying heating and cooling solutions to 28 million households, or 14 times greater than the existing installed capacity. This potential represents about 23% of the total residential heating and cooling market share by 2050.

- Similarly, the economic potential for district-heating systems using existing direct-use geothermal resources combined with EGS technology advances is more than 17,500 installations nationwide, compared to the 21 total district-heating installations installed in the United States as of 2017. These district-heating installations could satisfy the demand of about 45 million households.

- Increased geothermal deployment could improve U.S. air quality and reduce CO2 emissions. The GeoVision analysis indicates opportunities for reductions in sulfur dioxide (SO2), nitrogen oxides (NOx), and fine particulate matter (PM2.5) emissions. For the heating and cooling sector, impacts through 2050 could cumulatively include up to 1,281 MMT of CO2e emissions avoided. By 2050, the combined CO2e reductions for the two sectors are equivalent to removing about 26 million cars from the road annually.

6.2. Advanced Energy Storage Initiative

In support of the U.S. DOE Grid Modernization Initiative, GTO is investing close to $10 million in reservoir thermal energy storage (RTES), cements, and geothermal heat pump (GHP) RD&D at DOE's national laboratories. As a result, national laboratory researchers are partnering with industry and geothermal stakeholders to develop energy storage (as an alternative to battery storage) and "behind-the meter" generation, storage and electric load shaping technologies. An example of a behind-the-meter system approach is the Reservoir Thermal Energy Storage (RTES) research underway at Lawrence Berkley National Lab aimed at providing communities a source of reliable power and utilities the ability to control peak load. Subsurface optimization through modeling is key to minimizing the risk of using RTES for district heating and cooling. Another behind-the-meter example is Oak Ridge National Laboratory efforts aimed at developing two novel underground thermal energy storage technologies integrated with electric-driven heat pumps to enable flexible behind-the-meter demand of buildings while meeting their thermal demands energy efficiently.

Alternative storage technologies developed to increase flexibility on the generation side also has the potential for direct use application. For example, Idaho National Laboratory is studying the potential for using excess heat from large, inflexible thermal power stations in a synthetic geothermal reservoir to allow these power stations to reduce electrical power output while remaining connected to the grid during periods of high variable renewable availability. While a pre-existing hydrothermal resource is not necessary to obtain the benefits of the reservoir thermal energy storage system, co-locating one with a low-temperature geothermal resource would improve the efficiency of the power cycle and the economic viability of such resources, and increase low temperature geothermal resource development in the U.S. In addition, the geothermal gradient in most large sedimentary basins is sufficient that the target reservoirs would be at or near low-grade direct use geothermal temperature.

By developing thermal insulating lightweight and shock-resistant cements, Brookhaven National Laboratory and Sandia National Laboratories are enabling the deployment of Reservoir Thermal Energy Storage and Deep Direct-Use.

6.3 Deep Direct Use

Starting in FY 2017, GTO has been supporting 6 projects to conduct feasibility studies of large-scale, low-temperature deep-well geothermal systems coupled with advanced direct-use applications and cascaded surface technologies. Direct-use geothermal applications have the potential to provide cost-effective, renewable thermal energy in large portions of the U.S. In particular, this Deep Direct Use initiative looked to determine the techno-economic feasibility and extend the reach of geothermal into geologically distinct parts of the country beyond the western U.S., with projects covering the Appalachian Basin (NY/WV), Columbia River Basalt Group (OR), Cotton Valley Group (TX), and the Illinois Basin (IL) in addition to a project in the Wassuk Range (NV). The feasibility studies will be finalized in the fall of calendar year 2019. DOE has requested funds from Congress in FY 2020 to continue work in Deep Direct Use as part of the Advanced Energy Storage Initiative.

GTO has invested $4.0 million in these DDU projects since 2017.

6.4 Efficient Drilling for Geothermal Energy (EDGE)

Early-stage R&D in drilling technologies presents an opportunity for innovation that can have a significant impact on improving the economics of geothermal development. Drilling operations can account for up to half of the cost to develop a geothermal project. Given that much of the drilling occurs in the early stages of a project, complications from drilling failures can lead to cascading consequences resulting in overall project failure. Enabling the geothermal industry to drill more efficiently will reduce both the risk and cost and can help spur industry to expand capacity in the near-term.

In the EDGE initiative (started in FY 2018 and currently underway), DOE GTO solicited projects to enable the geothermal industry to double the average penetration rate for a geothermal well and improve the industry standard drilling vs. depth to 250 feet per day by 2025. A total of 11 projects were selected for award in three research areas: 1) reducing non-drilling time; 2) advanced drilling technologies; and 3) innovative partnership models. The Funding Opportunity Announcement (FOA) is available here. $15.4 million has been awarded to date (mid-2019).

6.5 Other GTO initiatives

GTO is engaged with several other initiatives whose R&D results will likely impact on the direct use sector as well as the electric sector. Among these are the Frontier Observatory for Research in Geothermal Energy (FORGE), EGS Collab, and Machine Learning for Geothermal for Geothermal Energy. GTO has also funded related National Laboratory research and Small Business Innovative Research (SBIR) projects. For additional information on these initiatives, please see www.energy.gov/geothermal.

6.6 International Geothermal Projects

6.6.1 Statement of Principles for Cooperation with New Zealand:

In 2018, GTO and New Zealand's Ministry of Business, Innovation and Employment (MBIE) announced an agreement to collaborate on the advancement of geothermal technologies. The overarching goal of the Statement of Principles for Cooperation agreement is to establish a framework for cooperation in the development of advanced, cost-effective geothermal energy technologies; accelerate the availability of geothermal technologies worldwide; and identify and address wider issues relating to geothermal energy, such as induced seismicity and mineral recovery. The proposed areas for collaboration include the joint development and improvement of modeling tools, mineral recovery, direct use applications, and supercritical geothermal systems.

6.6.2 The GEOTHERMICA Consortium

The United States has recently joined the GEOTHERMICA Consortium. GEOTHERMICA's objective is to combine the financial resources and know-how of 18 geothermal energy research and innovation program owners and managers from 14 countries and their regions. GEOTHERMICA will launch joint projects that demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to commercial large-scale implementation. Membership in this Consortium will allow the U.S. researchers to leverage massive investment from Europe in geothermal research on Enhanced Geothermal Systems and low temperature applications, and facilitate access to world-class researchers and their facilities, demonstration sites, and data. With each research call, each member country funds only applicants from their nation. A GEOTHERMICA research call was released in May 2019, with full proposals due in January 2020.

6.6.3 Participation in International Geothermal Groups

The U.S. geothermal industry can learn from international work across the geothermal spectrum. The U.S government takes the lead in engaging in international collaborations; investing in international participation can propel the industry forward across all geothermal energy sectors and technology applications. The U.S. is active in several international geothermal groups, as described below.

- International Energy Association (IEA) Geothermal. IEA Geothermal, with a mission to foster and promote sustainable use of geothermal energy worldwide and communicating geothermal energy's benefits, currently comprises 16 members, including 13 Country Members: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Switzerland, United Kingdom and the United States; the European Commission; and two Sponsors (Ormat Technologies and the Spanish Geothermal Technology Platform Geoplat). DOE GTO is a member of the Executive Committee of IEA Geothermal.

- International Partnership for Geothermal Technologies (IPGT). The purpose of the IPGT is to accelerate the development of geothermal technology through international cooperation. Five countries make up the IPGT: Australia, Iceland, Switzerland, New Zealand, and the United States. DOE is a member of the Steering Committee and is therefore a voting member of IPGT.

- Global Geothermal Alliance (GGA). Developed under the auspices of the International Renewable Energy Agency (IRENA), the GGA is a coalition for action to increase the use of geothermal energy, both in power generation and direct use of heat. It calls on governments, business and other stakeholders to support the deployment of realizable geothermal potential. The Alliance has an aspirational goal to achieve a five-fold growth in the installed capacity for geothermal power generation and more than two-fold growth in geothermal heating by 2030. The Alliance has 46 member countries and 36 Partners: Argentina, Bolivia, Burundi, Chile, Colombia, Comoros, Costa Rica, Djibouti, Ecuador, Egypt, El Salvador, Ethiopia, Fiji, France, Germany, Guatemala, Honduras, Iceland, India, Indonesia, Italy, Japan, Kenya, Kingdom of the Netherlands, Malaysia, Mexico, Nicaragua, New Zealand, Pakistan, Papua New Guinea, Peru, Philippines, Poland, Portugal, Romania, Saint Vincent & the Grenadines, Switzerland, Solomon Islands, United Republic of Tanzania, United States of America, Tonga, Turkey, Uganda, Vanuatu, Zambia, and Zimbabwe.

7.0 CONCLUSIONS

The distribution of capacity (MWt) and annual energy used (TJ/year) for the various direct-use applications are shown in Table 5 and are based primarily on records kept by NREL and the Geo-Heat Center. We estimate that the numbers are anywhere from 5 to 10% under reported, due to their small size, lack of data and often isolated locations. In many instances, we had to estimate the direct-uses based on individual web sites and our knowledge of the location and use.

The growth of direct-use over the past five years is all due to the increase use of geothermal (ground-source) heat pumps, as the traditional direct-use developments has decreased as shown in Figure 2 due to closing of many sites. This is most likely due to cost and lack of experts who can main the various systems. Unfortunately, there is little interest for direct-use at the federal level, as their interest are mainly in promoting and developing high risk R&D that the geothermal industry does not have the technical capabilities or institutional knowledge to conduct, especially in the early stages of research (see the GTO/USDOE description earlier in this paper). The main direct-use interest by the government is for developing Enhanced (Engineered) Geothermal Systems (EGS) along with deep drilling on the mid-western and eastern states for temperatures that can support direct-use projects. However, there are still some tax incentives for geothermal heat pumps at the federal level and in some states such as Oregon, Arizona and many eastern states. Since, most direct-use projects are small there are few, if any developers and/or investors who are interested in supporting these uses. Development of the projects is usually left to the property owner or local communities.

7.1 WELLS DRILLED (Table 6)

Most wells drilled for geothermal use were for power generation. Most direct-use work concentrated on improving or refurbishing existing wells. Geothermal heat pump wells, which are not included in this table, probably added 95,000 vertical holes at 75 m each for a total of about 7,125 km.

7.2 PROFESSIONAL GEOTHERMAL PERSONNEL (Table 7)

The number of professional geothermal personnel with university degrees is mainly due to the development of power generation. Only about 20 person/years are due to direct-use geothermal projects.

7.3 INVESTMENT IN GEOTHERMAL (Table 8)

Again, the majority of the investment in geothermal was for power generation. Direct-use added only about US$5.0 million, however, not shown in Table 8 is the approximately US$1.0 billion spent annually on geothermal heat pump installations and equipment (modified, based on communications with John Geyer in 2009).

7.4 ENERGY AND CARBON SAVINGS

The energy savings from all direct-uses including geothermal heat pumps, is about 25.4 million tonnes of equivalent oil per years (168 million barrels) and reduces air population by about 22.6 million tonnes of carbon and 63.2 million tonnes of CO2 annually (compared to fuel oil).

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APPENDIX

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Alaska	B,H,G						3.04		62.2	0.65
Arizona	B,F,G						30.13		407.4	0.43
Arkansas	B,D						0.47		7.9	0.53
California	B,F,D,H,I						78.78		1,481.7	0.60
Colorado	B,F,D,H,G,K						28.23		537.6	0.60
Florida	B						0.07		2.1	1.00
Georgia	B,H						0.61		11.0	0.57
Hawaii							0		0	0
Idaho	B,F,D,H,G						119.54		1,661.0	0.44
Montana	B,F,H,G,I,S						12.38		247.0	0.63
Nevada	B,D,H,A						34.47		378.8	0.35
New Mexico	B,F,D,H,G						19.25		254.7	0.42
New York	B						0.29		7.4	0.80
North Carolina	B						0.25		6.3	0.80
Oregon	B,F,D,H,G,A,S						68.37		930.9	0.43
South Dakota	B,F,D,H						6.25		106.3	0.54
Texas	B,H						4.62		42.2	0.29
Utah	B,F,H,G						42.29		419.6	0.31
Virginia	B						0.75		23.8	1.00
Washington	B,H						2.24		49.9	0.71
West Virginia	B						0.6		10.8	0.80
Wyoming	B,F,H,G,S						29.91		700.9	0.74
TOTAL							482.52		7,349.5	0.48

[1)] I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

Locality	Ground or Water Temp. (ºC)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used[5)] (TJ/yr)	Cooling Energy[6)] (TJ/yr)
States								
Northeasr: 20%	*5-25*	*12.0*	*337,160*		*3.5*	*2,200*	*32,000*	*35,200*
Midwest:: 34%	*5-25*	*12.0*	*573,172*		*3.5*	*2,200*	*54,400*	*59,800*
South: 35%	*5-25*	*12.0*	*590,030*		*3.5*	*1,700*	*43,060*	*47,400*
West: 11%	*5-25*	*12.0*	*185,438*		*3.5*	*2,000*	*16,000*	*17,600*
				V=51%				
				H=47%				
				W=2%				
TOTAL		*20,230,000*	*1,685,800*		*3.5*	*2,000*	*145,460*	*160,000*

Residential: V/H = 30%/70%; commercial/institutional: V/H = 90%/10%

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] ($TJ/yr = 10^{12}$ J/yr)	Capacity Factor[3)]
Individual Space Heating[4)]	89.43	1,073.2	0.38
District Heating [4)]	89.60	958.3	0.34
Air Conditioning (Cooling)	0	0	0
Greenhouse Heating	79.78	730.2	0.29
Fish Farming	122.13	2,241.9	0.58
Animal Farming	2.34	59.0	0.80
Agricultural Drying[5)]	6.45	97.5	0.48
Industrial Process Heat[6)]	0.90	17.6	0.52
Snow Melting	2.06	18.6	0.29
Bathing and Swimming[7)]	89.85	2,153.2	0.76
Other Uses (specify)	0	0	0
Subtotal	482.54	7,349.5	0.48
Geothermal Heat Pumps	20,230	145,460	0.23
TOTAL	20,712	152,810	0.23

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	13				
Production	>150° C	13				
	150-100° C	11				
	<100° C	0	10			
Injection	(all)	31				
Total		68	10			

1) Include thermal gradient wells, but not ones less than 100 m deep

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with 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)
2015	32	34	10	0	0	1549
2016	32	34	10	0	0	1613
2017	32	34	10	0	0	1673
2018	32	34	10	0	0	1726
2019	32	34	10	0	0	1725
Total	169	170	50	0	0	8286

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN 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$	%	%
1995-1999	N/A	N/A				
2000-2004	250	200	100	200	80	20
2005-2009	500	100	2	500	95	5
2010-2014	713	750		375	70	30
2015-2019	360.4	249		348		