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The United States of America Country Update 2015

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ABSTRACT

Geothermal energy is used for electric power generation and direct utilization in the United States. The present installed capacity (gross) for electric power generation is 3,477 MWe (installed) with 2,542 MWe net (running) delivering power to the gird producing approximately 16,517 GWh per year for a 74% net capacity factor. Geothermal electric power plants are located in California, Nevada, Utah and Hawaii with recent installation in Alaska, Idaho, New Mexico and Oregon, with 312 MWe being added the last five years. The two largest concentrations of plants are at The Geysers in northern California and the Imperial Valley in southern California. The Geysers continues to receive waste water from Clear Lake and Santa Rosa, California that is injected into the field and has resulted in the recovery of approximately 200 MWe of power generation. The lowest temperature installed plant is at Chena Hot Springs in Alaska, where binary cycle plants uses 74°C geothermal fluids to run three units for a total of 730 kW (gross). With the recent passing of the production tax credit by the federal government (2.0 cents/kWh) and renewable portfolio standards requiring investments in renewable energy, the annual growth rate for electric power generation over the past three years is 3.6 percent. 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 17,416 MWt and the annual energy use is 75,862 TJ or 21,074 GWh. The largest application is ground-source (geothermal) heat pumps (88% of the energy use), and the next largest direct-uses are fish farming and swimming pool heating. Direct utilization (without heat pumps) remained nearly static over the past five years with gains balancing losses; however, ground-source heat pumps are being installed at a 8% annual growth rate with 1.4 million units (12 kW size) in operation. The energy saving from all geothermal energy use is about 11.2 million tonnes of equivalent fuel oil per year (74.7 million barrels) and reduces air pollution by almost 10.0 million tonnes of carbon and 28.0 million tonnes of CO_2 annually (compared to fuel oil).

1. INTRODUCTION

Geothermal resources capable of supporting electrical generation and/or direct use projects are found primarily in the Western United States, where most of 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 Cascade volcanism are the source of much of the geothermal activity in the United States. However, geothermal (ground-source) heat pumps extend the utilization to all 50 states. The total identified potential for electrical production is estimated at 21,000 MWe (above 150°C) and 42 EJ (between 90° and 150°C) of beneficial heat (Muffler, 1979), and a recent estimate by the U.S. Geological Survey estimates a mean probability of electrical power generation from identified geothermal resources in12 western states during the next 30 years of 8,866 MWe (USGS, 2008), which would nearly triple the existing electrical capacity.

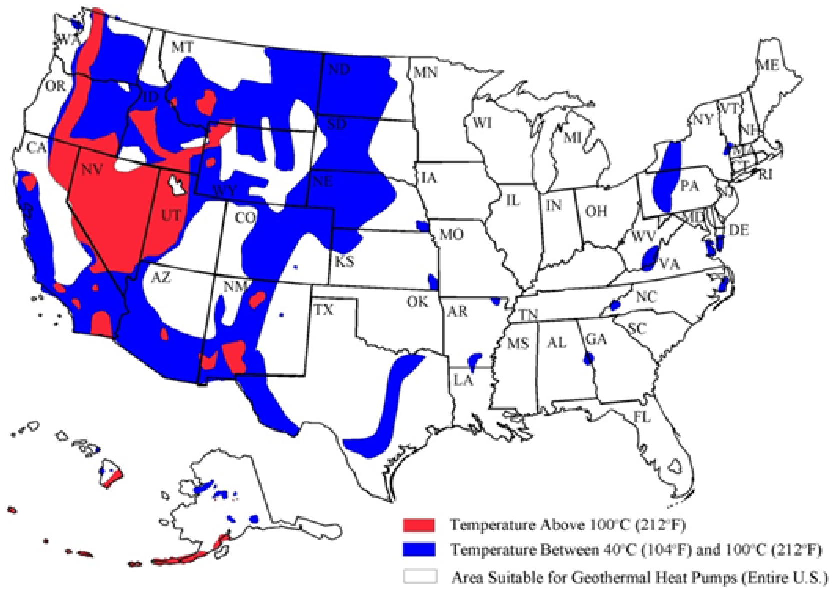

Figure 1: Geothermal resource map of the United States.

Achieving this electric capacity potential will be dependent upon a number of factors including competing prices for energy and incentive programs that encourage development of renewable energy resources. Recently passed Renewable Portfolio Standards (RPS) in a number of states along with the extension of the Production Tax Credit (PTC) by Congress to 2015, which provides a 2.0 cent per kilowatt hour credit, have attracted developers to start new projects. Other incentives are the recent stimulus funds for geothermal energy, at US$400 million, approved by Congress was allocated for various types of geothermal projects, along with a tax credit (30% of the cost up to US$1,500) for geothermal heat pump installations under the 2005 Energy Policy Act and extended by the American Recovery and Reinvestment Act of 2009. All of these measures will greatly improve geothermal's ability to compete with fossil fuel generation, both for electrical energy and direct-use. The federal government has also approved a 30% investment tax credit as a grant for commercial operation of power plants. A recent report by the Energy Information Administration (EIA, 2009), confirms the continued growth of renewables as fossil fuel use plummet and nuclear power stalls.

The United States continues to lead the world in installed geothermal power capacity as well as in electrical generations, and along with geothermal heat pumps, is one of the leaders in direct-use applications.

Geothermal energy remains, however, a small contributor to the electric power capacity and generation in the United States. In 2013, geothermal plants constituted about 0.30 percent of the total operable power capacity, and those plants contributed an estimated 0.41 percent of the total generation.

Since the last U.S. Country Update was completed in 2010 gross geothermal electrical production capacity has increased in the United States by approximately 312 MWe to a total an installed capacity of 3,477 MWe and a net running capacity of 2,542 MWe due to derating of plants in The Geysers, for a capacity factor of 0.74. This low value is due to plants, especially in The Geysers, operating in a load following mode rather than in a base load mode. Total generation in 2013 was 16,517 GWh and the geothermal electric power generation accounted for 3% of the total renewable based electricity consumption in the United States. On a state level, geothermal electric generation is a major player in California and Nevada. It is a minor source of power in the other states. The generation in California provides about 4.4% of the state's energy consumption. It is also significant on the Big Island of Hawaii where it now provides approximately 20% of the electricity requirements. Recent projects have brought several new states into the electricity "club", including, Alaska, Idaho, New Mexico and Oregon. Alaska is most noted, as a 250 kW binary cycle generator installed in 2006 uses the lowest temperature geothermal fluid in the world to produce electricity at 74^{o}C, however, it should be noted that it also has 4^{o}C cooling water from a stream allowing for an acceptable "ΔT" (Lund, 2006). The growth in installed capacity during the 1980s was about 11 percent, however, from 1990-1998 it averaged on 0.14 percent due to a leveling off of new plant construction, and from 2000 to 2004 only approximately 70 MWe of new capacity was added. Since, 2010, the growth has been almost 11 percent.

Direct-use, other than geothermal heat pumps, has remained static with increases being balanced by closing of some facilities. The main increases has been in expanding the Boise City District Heating System from 48 to 58 buildings; adding additional wells for space heating in Klamath Falls; expanding the snow melting system on the Oregon Institute of Technology campus from 316 m^2 to 3,753 m^2, increasing the amount of aquaculture product being produced, mainly Tilapia; starting two biodiesel plants with one having shut down during this reporting period; adding an absorption chiller for keeping the Ice Museum at Chena Hot Springs in Alaska intact during the summer months, and adding additional space heating to the Peppermill Casino in Reno. Losses have been the closing of the district heating systems at the California Correctional Center (now using natural gas) and the New Mexico University heating system (due to difficulty with maintenance), and the closing of the Empire onion dehydration plant (due to competition with imported garlic from China) near Gerlach, Nevada.

Geothermal heat pumps have seen the largest growth, increasing from an estimated 1.0 million to 1.4 million equivalent 12 kW installed units. The estimated installation rate is about 80,000 units per year, or about an 8 percent annual growth, with most of the growth taking place in the mid-western and eastern states. A few states have tax rebate programs for geothermal heat pumps, and as mentioned above, Congress has established a tax credit of 30% of costs up to $1,500 for installations. Otherwise, there is little support for implementing direct-use projects.

Enhanced (Engineered) Geothermal Systems (EGS) is the current R&D interest of the U.S. Department of Energy, Office of Geothermal Technologies as part of a revived national geothermal program. EGS includes the earlier hot dry rock technology, but now includes any other method in which to improve geothermal reservoir performance. EGS is associated with both magmatic and high heat producing crustal sources of geothermal energy commonly at depths of about 4 to 5 km to reach 200^{o}C, but also having applications with normal gradient resources. However, EGC projects are currently at an early experimental demonstration stage. Several technological challenges need to be met for widespread efficient use of EGS. The key technical and economic changes for EGS over the next two decades will be to achieve economic stimulation of multiple reservoirs with sufficient volumes to sustain long term production, with low flow impedance, limited short-circuiting fractures and manageable water loss (Tester et al., 2006). Over the next 10 to 30 years, lessons learned while deploying early EGS power plants can reasonably be expected to facilitate wider, efficient deployment of EGS technologies for both power production and direct use, or as in Europe in a combined heat and power installation. One of the public relations problems associated with EGS projects, is the generation of micro earthquakes (usually <3.5 on the Richter scale), that has slowed, threatened or shut down projects.

In a Massachusetts Institute of Technology (MIT)-led assessment (Tester et al., 2006), the U.S. geothermal resource was estimated to be 14 million EJ with a technically extractable capacity of about 1,200 GWe to depths of 10 km. The report estimated that with reasonable investment in R&D, EGS could provide 100 GWe or more of cost-competitive generating capacity in the next 50 years. It further stated: "*…EGS provides a secure source of power for the long term that would help protect American against economic instabilities resulting from fuel price fluctuations or supply disruptions."* Unfortunately, a current project near The Geysers has been placed on hold due to the inferred generation of micro earthquakes affecting nearby residences.

2. PRODUCTION OF ELECTRICITY

Table 1 presents operable electric production capacity and power generation in the United States from all sources for 2010-2013. All data in this table came from the USDOE Energy Information Administration (EIA, 2014) and the Geothermal Energy Association (GEA, 2013). Geothermal power production is summarized in Table 2 by plant and location. The total installed capacity in 2013 was 3,447 MWe producing 16,517 GWh from a running capacity of 2,542 MWe. A total of 312 MWe has been installed since the WGC2010 report (to 2013), amounting to a 7.2 percent increase or 2.5 percent annual increase over those three years.

2.1 Installed and Future Capacity Update

2.1.1 Alaska

Alaska's first geothermal power plant came online in 2006 in Chena Hot Springs. It produces electricity from the area's low temperature 74°C (165°F) geothermal resource. With recent additions it now has an installed production capacity of 730 kWe (gross).

Alaska currently has 25 to 70 MWe of planned geothermal production coming down the pipeline. Of projects with potential to come online, the Southwest Alaska Regional Geothermal Energy Project of 25 MWe is in an exploratory drilling and resource confirmation phase. Other notable projects are Mt. Spur (50 MWe), Unalaska (10–50 MWe), Akutan (10 MWe), and Chena Hot Springs II (0.7 - 5 MWe). (GEA, 2014).

2.1.2 Arizona

Geothermal power production does not currently occur in Arizona. However, the Arizona Public Service investigated the Clifton geothermal project (Lund et al, 2010). GreenFire Energy is developing a demonstration project at St. Johns Dome, on the central AZ and NM border.

2.1.3 California

Current geothermal electricity production capacity in California is approximately 2,711 MWe. In 2012, 4.4% of California's electricity generation came from geothermal power plants, amounting to a net total of 13,230 GWh. The 50 MWe Hudson Ranch facility is the state's most recent geothermal power plant addition. Generally, geothermal power generation remains concentrated in California with the majority of production occurring at The Geysers in the north and Imperial Valley in the south. The installed capacity at The Geysers I is 1,472 MWe (including 220 MWe from the two NCPA plants). However, only 685 MWe are currently operating in the main field.

California has approximately 607 to 1,412 MWe of planned geothermal resource production in various stages of development. Production drilling and facility construction are underway at US Geothermal's recently acquired former Unit 15 site (26 MWe) at the Geysers as well as EnergySource's Hudson Ranch II (49.9 MWe). Development continues on Ormat Technologies East Brawley project, Calpine Corporations Buckeye-North Geysers and Wildhorse-North Geysers (30 MWe) projects, and CalEnergy's Black Rock 1, 2, and 3 units (GEA, 2014).

2.1.4 Colorado

Although there are no geothermal power plants currently producing electricity in Colorado, exploration is taking place at Mount Princeton Hot Springs, Poncha Hot Springs and Aspen sites. Colorado currently has 20 to 60 MWe of planned geothermal production coming down the pipeline.

2.1.5 Hawaii

There is only one geothermal power plant facility which is comprised of two air-cooled power plants, a combined cycle system and a binary system, in the state of Hawaii, located on the Island and County of Hawaii. Located on the "Big Island", the Puna Geothermal Venture facility had a 35 MWe nameplate capacity, until an 8 MWe expansion in 2011. The plant delivers 33 to 43 MWe of energy on a continuous basis and supplies up to 25% of the electricity demand on the big island. PGV has permits allowing it to expand another 22 MWe in the future at its current location. Possible geothermal energy resources are being explored in West Hawaii and on the island of Maui. (Hawaiian Electric Co., 2014)

2.1.6 Idaho

Idaho's first geothermal power plant, Raft River, came online in January 2008. Raft River is a binary plant that uses a 150°C (300°F) resource and has a nameplate production capacity of 15.8 MWe. Current net production output is between 10.5 and 11.5 MWe. US Geothermal is securing a PPA and final permitting for a 16 MWe expansion of the Raft River plant.

Other companies are developing a number of projects throughout Idaho. Total potential geothermal production for Idaho is 63 to 314 MWe (GEA, 2014).

2.1.7 Nevada

Nevada's electrical generation capacity from its geothermal plants is second only to California. In 2013, Nevada had 24 geothermal power plants with a total nameplate capacity of 596 MWe and with a total gross output of 3,456,382 MWh. Since 2010 Nevada increased its installed geothermal capacity with the addition of the Tuscarora Project 32 MWe (ENEL), McGinness Hills Project 52 MWe (ORMAT), San Emidio "Repower" Project 8.4 MWe (US Geothermal), and Don A. Campbell Project 22.5 MWe (ORMAT). Currently Nevada has more developing projects and it is expected that gross capacity will continue to increase significantly in the future. Many other companies are in the process of securing PPA's and final permitting for a number of projects and other companies are in the early exploratory stages of developing numerous geothermal resources. Nevada currently has 176 to 718 MWe of geothermal capacity in development (GEA, 2014).

2.1.8 Montana

The Dewhurst Group (DG) is collaborating with the State of Montana Governor's Office of Economic Development on a feasibility study for Montana's first geothermal power plant at Warm Springs. The State of Montana donated the test site in June of 2012.

2.1.9 North Dakota

North Dakota has 0.6 MWe of geothermal capacity in development using co-produced hydrothermal and lower temperature resources. (GEA, 2014).

2.1.10 New Mexico

In December of 2013, The Dale Burgett Geothermal Plant was commissioned and started delivering electricity to Public Service Company of New Mexico under a long term power purchase agreement. Located near the city of Animas, the first phase of this binary project has a 4 MWe of capacity. The plant uses geothermal brine at a temperature of 165°C (300°F) from a reservoir depth of 400 to 1,000 meters (1,200 to 3,000 feet). Development of the Lightning Dock No. 2 expansion is underway with an additional 6 MWe of generation planned for installation.

2.1.11 Oregon

Power production today in Oregon occurs at three locations, Klamath Falls, Neal Hot Springs and Paisley. In Klamath Falls the Oregon Institute of Technology is the first campus in the world that uses both heat and power from geothermal resources directly beneath the campus. A first 280 kWe gross power plant using the 89°C (192°F) water was installed in February 2010. The Pure Cycle© unit was supplied by United Technologies Corp. and intereconnected to the grid in April of that year. A new 1.75 MWe geothermal power plant was completed in April 2014. Both new and existing plants use organic Rankine cycle technology. The second plant was supplied by Johnson Controls. The school will meet its goal of supplying all energy needs with geothermal heating, geothermal power and solar power.

Neal Hot Springs, located 23 km (14 mi.) northwest of Vale in eastern Oregon, is the site of US Geothermal Inc. 22 MWe net Neal Hot Springs project. Using 141ºC (287ºF) water the Neal Hot Springs project uses a supercritical R134a refrigerant working fluid process, as well as pre-fabricated modular construction of major plant components. The project was built in three 7.3MWe binary cycle modules by Turbine Air Systems. U.S. Department of Energy (USDOE) supported the project with a $96.8 million project loan guarantee for the Neal Hot Springs project. The Neal Hot Springs project began operating in the fourth quarter of 2012.

The latest plant to come online is at Paisley in Lake County where the Surprise Valley Electrification Corp. completed construction in 2014 of a 2.5 MWe power plant. Two 110°C (230°F) production wells and one injection well supplies the binary plant. The modular plant was built by Turbine Air Systems. This project was operational in June 2014.

Overall there are 58 to 318 MWe of potential geothermal power capacity under development in Oregon (GEA, 2014).

2.1.12 Utah

Currently, Utah has three power plants online. Unit 1 of the Blundell Plant has a gross capacity of 26 MWe and Unit 2 has a capacity of 12 MWe. Utah's third power plant came online in December 2008 and was the first commercial power plant in the state in more than 20 years. The Thermo Hot Springs power plant, a Cyrq Energy (formerly Raser Technologies) operation, came online in 2009 and has a gross capacity of 10.3 MWe. In 2011, Thermo No. 1 solicited proposals and selected Ormat technologies to provide more efficient generation equipment. With the May 2013 upgrade the plant now operates at or near the rated output of 10.3 MWe.

ENEL North America has begun exploratory drilling and resource confirmation operations at its Cove Fort project site. Cyrq Energy and Standard Steam Trust have 12 other potential geothermal prospects in the early stages of planning/development and overall Utah has 20 to 65 MWe of planned geothermal capacity for future production (GEA, 2014).

2.1.13 Washington

Although Washington is not currently producing power from any of its geothermal resources, Gradient Resources is planning to develop the Mt. Baker geothermal resource. AltaRock Energy is pursuing an EGS project in Snohomish County.

2.1.14 Wyoming

In August 2008, a 250 kWe Ormat binary power unit was installed at Rocky Mountain Oil Test Site and a month later it began operating. As of January 2009, the unit had produced more than 485 MWh of power from 413,000 tonnes of hot water annually. The demonstration project operated until 2013 when testing was officially completed. RMOTC investigated developing another site for the installation of a 0.28 MWe GHCP unit in 2010, but nothing has been developed to date (GEA 2011).

3. GEOTHERMAL DIRECT UTILIZATION

3.1 Background

Geothermal energy is estimated to currently supply for direct heat uses and geothermal (ground-source) heat pumps 75,862 TJ/yr (21,074 GWh/yr) of heat energy in the United States. The corresponding installed capacity is 17,416 MWt. Of these values, direct-use is 9192 TJ/yr (2,553 GWh/yr) and 616 MWt, and geothermal heat pumps the remainder. It should be noted that values for the capacity and energy supplied by geothermal heat pumps are only approximate (and probably conservative) since 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.

Most of the direct use applications have remained nearly constant increasing slightly over the past five years; however geothermal heat pumps have increased significantly. A total of three new projects have come on line in the past five years. Agricultural drying has decreased the most due to the closing of the onion/garlic dehydration plant at Empire, Nevada. Two district heating projects have also shut down; the Litchfield Correctional Facility in California and the New Mexico State University system, however one at Boise State University has come on line. There have been a slight increase in snow melting, cooling and fish farming, with a major increase in industrial process heating due to one biodiesel plants (Nevada – the one in Oregon has been shut down), a brewery (Oregon) and a laundry (California) coming on line. In summary, when considering direct-use without geothermal heat pumps, the distribution of annual energy use is as follows: 34% for fish farming, 28% for bathing and swimming pool heating, 15% for individual space heating, 9% for greenhouse heating, 9% for district heating, 3% for agricultural drying, 2% for industrial process heating, <1% for cooling and <1% for snow melting. Geothermal heat pumps accounts for 88% of the annual use, and has increased 1.4 times in the past five years with a 8% annual growth rate.

Figure 2 shows the direct-use development over the past 35 years, without heat pumps. A summary of direct-heat use by category is presented in Table 5.

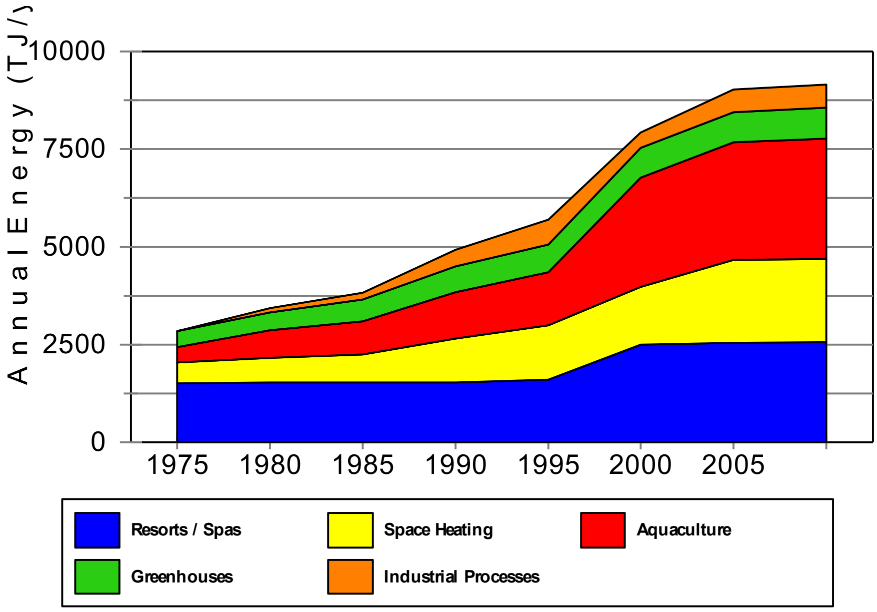

Figure 2. Direct-use growth in the United States (without geothermal heat pumps).

3.2 Space Heating

Space heating of individual buildings (estimated at over 2,000 in 17 states) is mainly concentrated in Klamath Falls, Oregon where about 600 shallow wells have been drilled to heat homes, apartment houses and businesses. Most of these wells use downhole heat exchangers to supply heat to the buildings, thus, conserving the geothermal water (Culver and Lund, 1999). A similar use of downhole heat exchangers is found in the Moana area of Reno, Nevada (Flynn, 2001).

3.3 District Heating

There are 21 geothermal district-heating systems in the United States, most being limited to a few buildings. Two small district heating projects have also shut down; the Litchfield Correctional Facility in California and the New Mexico State University system. The newest is a project in Lakeview, Oregon connecting five schools, the local hospital and health care facility with an annual energy use of 16.35 TJ/yr and installed capacity of 1.6 MWt. In the rural community of Canby, geothermal heat is used for heating buildings, a greenhouse, and most recently driers and washers in a laundry (Merrick, 2009). The city system in Boise, Idaho has a total of 58 buildings on their system consisting of 380,000 m^2 of floor area using 700,000 m^3 of water running through 21 km of pipelines at 77^{o}C. The system was extended across the Boise River in 2012 to Boise State University. At the university nine buildings are heated covering 60,000 m^2 of floor area. The system has an estimated installed capacity of 4.85 MWt producing 50 TJ/yr. Klamath Falls system has expanded by adding an additional greenhouse of 0.4 ha.

3.4 Aquaculture Pond and Raceway Heating

There are 51 aquaculture sites in 11 states using geothermal energy. The largest concentration of this use is in the Imperial Valley in southern California and operations along the Snake River Plain in southern Idaho. There is a report that some of the facilities in the Imperial Valley have closed, but reliable information is lacking. A large facility at Kelly Hot Springs in northern California has been expanding and now produces slightly over half a million kg of tilapia annually. Two unique aquaculture related projects are in operation in Idaho and Colorado – that of raising alligators, the former for their meat and skins, and the latter as a tourist attraction (Clutter, 2002). Recent trends in the U.S. aquaculture industry have seen a decline in growth due to saturation of the market and competition from imports.

3.5 Greenhouse Heating

There are 44 greenhouse operations in nine states using geothermal energy. These cover an area of about 45 ha, have an installed heat capacity of 97 MWt and an annual energy use of 800 TJ/yr (222 GWh). The main products raised are potted plants and cut flowers for local markets. Some commercial tree seedlings and vegetables (organic tomatoes and peppers) are also grown in

Oregon; however raising vegetable is normally not economically competitive with imports from Central America, unless they are organically grown.

3.6 Industrial Applications and Agricultural Drying

One biodiesel plant is still in operation in Nevada whereas the one in Oregon has been shut down. This plant primarily uses geothermal energy for the distillation of waste grease from restaurants. Small industrial uses include clothes driers and washer installed in Canby, California, and a brewery using heat from the Klamath Falls district heating system for brewing beer and heating the building (Chiasson 2006, Merrick, 2009). The main loss is the closing of an onion/garlic dehydration plant at Empire, Nevada due to competition with imported garlic from China. The spider mites raising facility near Klamath Falls has also been shut down. The installed industrial capacity for these applications is 38 MWt and the annual energy use 493 TJ/yr (137 GWh/yr) for eight facilities located in three states.

3.7 Cooling and Snow Melting

The two major uses of geothermal energy are for pavement snow melting, on the Oregon Institute of Technology (OIT) campus, and keeping the Aurora Ice Museum frozen year-round at Chena Hot Springs, Alaska. OIT campus snow melt system is at 3,753 m^2 and the ammonia absorption chiller in Alaska keeps a 1,000 tonnes of ice frozen as the building's walls and roof, even though it reaches 32^oC outside in the summer. Over 10,000 visitors a year visit the facility that has a bar, beds and many ice sculptures (Holdman and Erickson, 2006). The installed capacity for this application is 2.3 MWt and the annual energy use is 48 TJ/yr (13 GWh/yr).

3.8 Spas and Swimming Pools

This is one of the more difficult applications to quantify and even to find all the actual sites, as most owners do not know their average and peak flow rates, as well as the inlet and outlet temperatures. Most of the locations and some of the data have come from a number of hot spring/spa publications available for most states. As a result, we often have to estimate the capacity and energy use based on our experience with similar facilities. There are 242 facilities in 17 states that we have identified, with an estimated installed capacity of 113 MWt and annual energy use of 2,557 TJ/yr (711 GWh/yr).

3.9 Geothermal (Ground-Source) Heat Pumps

The number of installed geothermal heat pumps has steadily increased over the past 15 years with an estimated 80,000 equivalent 12 kWt units installed each of the past five years – a decrease from the 100,000 to 120,000 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 1.4 million units installed, mainly in the mid-western and eastern states. Of these approximately 60% of the units are installed in residences and the remaining 40% in commercial and institutional buildings. The current trend is that most of the newer units are being installed in commercial institutional buildings (60%) and only 40% in residential locations. 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 install. In the institutional and commercial sector, 90% are vertical and only 10% horizontal, constrained by ground space in urban area. Presently, the ratio of new installation to retrofit installations is 3:1. The estimated full load hours in heating mode is 2,000/yr, and in cooling mode is 2,200/yr. The installation cost is estimated at US$6,000 per ton (3.5 kW) for residential and US$7,000 per ton (3.5 kW) for commerical. The units are found in all 50 states and are growing about 8% a year. It is presently a US$2 to US$3 billion annual industry. The current installed capacity is 16,800 MWt and the annual energy use in the heating mode is 66,670 TJ/yr (18,500 GWh/yr). The largest installation (130 tons (455 kW)) currently under construction is for Ball State University, Indiana where 4,100 vertical loops are being installed.

3.9 Conclusions – Direct-Use

The distribution of capacity and annual energy use for the various direct-use applications are shown in Table 5 and are based on records keep at the Geo-Heat Center. We estimate that the estimates are anywhere from 5 to 10% under reported, due to their small sizes, lack of data and often isolated locations.

The growth of direct use over the past five years is all due to the increased use of geothermal heat pumps, as traditional direct-use development has remained almost flat as shown in Figure 2. Unfortunately, there is little interest for direct-use at the federal level, as their interests are mainly in promoting and developing Enhanced (Engineered) Geothermal Systems (EGS). There are few incentives for the traditional direct-use development, but as mentioned earlier, there are tax incentives for geothermal heat pumps at the federal level and in some states such as Oregon. Since, most direct-use projects are small, there are few, if any, developers and/or investors who are interested in supporting these uses.

4. WELLS DRILLED

Most wells drilled for geothermal use were for power generation. Assuming 3 MWe per well, and each approximately 2,500 meters deep (deeper at The Geysers and shallower in Nevada where most of the wells were drilled), the increase of 312 MWe added approximately 258 km (vertical) including exploratory and injection wells, and direct use added approximately 4 km. Most direct-use work concentrated on improving and refurbishing existing wells. See Table 6 for details. Geothermal heat pumps wells, which are not included in this table, probably added 200,000 vertical holes at 75 m each for a total of 15,000 km over the five years.

5. PROFESSIONAL GEOTHERMAL PERSONNEL

Professional geothermal personnel with university degrees are higher mainly due to an increase in the installed capacity of power plants. Geothermal Power plants are estimated to employ 1.7 person/years per installed megawatt (Kagel, 2006). It is assumed that approximately 0.5 person/year is due to professional personnel. Due to an increase in funding from USDOE Office of Geothermal Technologies, personnel in the private industry as well as with the government institutions, as well as National Laboratories and Universities increased. Only about 50 person/years are due to direct-use geothermal. See Table 7 for details.

6. INVESTMENT IN GEOTHERMAL

Again, the majority of the investment in geothermal was for geothermal electric power plants. We estimate that US$4,000 (Western Governor's Association, 2006) is invested for every kilowatt of installed capacity. Thus, for the new 312 MWe of installed capacity over the past five years, US$1.2 billion was invested. Above half of this was for field and plant development and 25% each for R&D and for the operation. Direct-use only added about US$2,000 million; however, not shown in Table 8 is the approximately US$2.5 billion spent annually on geothermal heat pump installations and equipment (personal communication, John Geyer, Oct. 2009).

7. ENERGY AND CARBON SAVINGS

The total electricity produced from geothermal energy in the U.S. is equivalent to savings 28.1 million barrels (4.2 million tonnes) of fuel oil per years (generating at 0.35 efficiency). This produces a savings of 3.69 million tons of carbon annually. The total direct utilization including geothermal heat pump energy use in the U.S. is equivalent to saving 17.8 million barrels (2.70 tonnes) of fuel oil per years (producing heat at 0.70 efficiency). This produces a savings of 2.36 million tonnes of carbon annually. If the savings in the cooling mode of geothermal heat pumps is considered, then this is equivalent to an additional savings of 9.26 million barrels (1.38 million tonnes) of carbon annually.

In total, the savings from present geothermal energy production in the U.S., both electricity and direct-use amounts to 55.2 million barrels (8.28 million tonnes) of fuel oil equivalent (TOE) per year, and reduces air pollution by 7.26 million tonnes of carbon annually. CO_2 reduction is estimated at 20.6 million tonnes

8. ACKOWLEDGEMENTS

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2013	3,477	17	878,340	2,739	78,241	269	107,938	789	76,891	253	1,144,887	4,067
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	4,027											

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2013

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status	Type of Unit	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced (2013) GWh/yr	Total under Constr. or Planned MWe
AK - Chena Hot Springs	Chena	2006	3		B	0.7			
CA-Coso	Navy I	1987	3		2F	102.4			
CA-Coso	BLM	1988	3		2F	99.9			
CA-Coso	Navy II	1989	3		2F	100			
CA-Honey Lake	Wineagle	1985	2		B	0.7			
CA-Honey Lake	Amedee	1988	2		B	1.6			
CA-Honey Lake	Honey Lake	1989	2		B	1.5			
CA-Mammoth	Mammoth II	1990	3		B	30			
CA - Mammoth	Mammoth Complex Repowering	2013	4		B	7.5			
CA-East Mesa	Ormesa I	1986	2		B	20.7			
CA-East Mesa	Ormesa II	1987	1		2F	21.9			
CA-East Mesa	Ormesa IH	1988	1		B	11.8			
CA-East Mesa	Ormesa IE	1988	2		B	11.7			
CA-East Mesa	GEM II	1989	1		2F	18			
CA-East Mesa	GEM III	1989	1		2F	18			
CA-East Mesa	GEM Bottoming Unit	2007	1		B	9			
CA-East Mesa	Ormesa II Upgrade	2007			B	4.3			
CA-Heber	Heber I	1985	2		2F	52			
CA-Heber	Heber II	1993	7		B	51			
CA-Heber	SIGC	1993	7		B	40.2			
CA-Heber	Goulds ll	2005			B	13.3			

CA-Heber	Goulds l	2006	2		B	10			
CA-Heber	Heber South	2008	1		B	13.3			
CA-North Brawley	North Brawley	2008			B	50			
CA-Salton Sea	Salton Sea I	1982	1		1F	10			
CA-Salton Sea	Vulcan	1986	1		2F	40			
CA-Salton Sea	Salton Sea III	1989	1		2F	54			
CA-Salton Sea	Del Ranch (Hoch)	1989	3		2F	49			
CA-Salton Sea	Elmore	1989	1		2F	49			
CA-Salton Sea	Leather	1990	1		2F	49			
CA-Salton Sea	Salton Sea II	1990	3		2F	20			
CA-Salton Sea	Salton Sea IV	1996	1		2F	48			
CA-Salton Sea	Salton Sea V	2000	1		2F	58			
CA-Salton Sea	CE Turbo	2000	1		1F	10			
CA-Salton Sea	John L. Featherstone (Hudson Ranch 1)	2012	1		3F	50			
CA-The Geysers	McCabe (5&6)	1971	2		D	106			
CA-The Geysers	Ridgeline (7&8)	1972	2		D	106			
CA-The Geysers	Eagle Rock (11)	1975	1		D	110			
CA-The Geysers	Cobb Creek (12)	1979	1		D	110			
CA-The Geysers	Sulphur Spring (14)	1980	1		D	109			
CA-The Geysers	Big Geyser (13)	1980	1		D	97			
CA-The Geysers	Socrates (18)	1983	1		D	113			
CA-The Geysers	Sonoma (3)	1983	1		D	72			
CA-The Geysers	Calistoga (19)	1984	1		D	80			
CA-The Geysers	Grant (20)	1985	1		D	113			
CA-The Geysers	Lake View (17)	1985	1		D	113			
CA-The Geysers	Quicksilver (16)	1985	1		D	113			
CA-The Geysers	West Ford Flat (4)	1988	2		D	28			
CA-The Geysers	Bear Canyon (2)	1988	2		D	20			
CA-The Geysers	Aidlin (1)	1989	2		D	20			
CA-The Geysers	NCPA I	1983	2		D	110			
CA-The Geysers	NCPA II	1985	2		D	110			
CA-The Geysers	Bottle Rock	2007	1		D	55			
HI-Puna	Puna	1992	1		B	30			
HI-Puna	Puna Expansion	2011	10		B	8			
ID- Raft River	Raft River	2008	2		B	15.8			
NM- Lightening Dock	Lightening Dock	2013	1		B	4			
NV - Beowawe	Beowave	1985	1		2F	17.7			
NV - Beowawe	Beowawe 2	2011	3		B	2			
NV - Blue Mountain	Faulkner	2009			B	49.5			
NV - Brady Hot Spring	Brady Hot Spring	1992	3		2F	26.1			
NV - Brady Hot Spring	Brady	2002			B	5.3			
NV - Deadhorse Wells (Wild Rose)	Don A. Campbell (Wild Rose)	2013			B	16			
NV - Desert Peak	Desert Peak II	2006	2		B	23			
NV - Desert Peak	Desert Peak II EGS	2013	1		EGS	1.7			
NV - Dixie Valley	Dixie Valley	1988	1		2F	64			
NV - Dixie Valley	Dixie Valley	2012			B	6.2			
NV - Dixie Valley	Jersey Valley	2010			B	19.4			
NV - Florida Canyon Mine	Florida Canyon Mine	2012			Co-production	0.1			
NV - Hazen (Black Butte)	Patua Phase 1	2013			B	30			
NV - Hot Sulphur Springs	Tuscarora	2012			B	32			
NV - McGinness Hills	McGinness Hills	2012			B	52			
NV - Salt Wells (Eightmile Flat)	Salt Wells	2009			B	18.1			
NV - San Emidio (Empire)	San Emidio	1987			B	4.8			

NV - San Emidio (Empire)	San Emidio Repower	2012			B	13			
NV - Soda Lake	Soda Lake 1	1987	4		B	5.1			
NV - Soda Lake	Soda Lake 2	1991	6		B	18			
NV - Steamboat	Steamboat I	1986	7	R	B	7			
NV - Steamboat	Steamboat IA	1988	2	R	B	2			
NV - Steamboat	Steamboat 2	1992	2		B	29			
NV - Steamboat	Steamboat 3	1992	2		B	24			
NV - Steamboat	Galena l (Richard Burdette)	2005	2		B	27			
NV - Steamboat	Galena II	2007	1		B	12.4			
NV - Steamboat	Galena III	2008	1		B	27.5			
NV - Steamboat Hills	Steamboat Hills	1988	1		1F	14.4			
NV - Steamboat Hills	Steamboat Hills	2007	1		B	4.6			
NV - Stillwater	Stillwater	2009	1		B	47.3			
NV - Wabuska	Wabuska I	1984	2		B	1.1			
NV - Wabuska	Wabuska II	1987	1		B	1.1			
OR- Klamath Falls	OIT	2009	1		B	0.3			
OR- Neal Hot Springs	Neal Hot Springs	2012	3		B	33			
UT- Cove Fort	Cove Fort	2013			B	25			
UT- Roosevelt	Blundell 1	1984	1		1F	26.1			
UT- Roosevelt	Blundell 2	2007	1		B	12			
UT- Thermo Hot Spring	Thermo Hot Spring	2009	52		B	10			
Total						3,477		17	550

1F = Single Flash, 2F = Double Flash, 3F = Triple Flash, D = Dry Steam, B = Binary (Rankine cycle), H = Hybrid, O = Other

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

Locality	Type	Maximum Utilization					Capacity	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy (kJ/kg)			Ave. Flow	Energy	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor
Alaska	H,G,B,C						7.8		156.2	0.6
Arkansas	H						0.4		7.3	0.7
Arizona	H,F,B						23.5		317.4	0.43
California	D,H,G,F,B						105.1		2183.6	0.7
Colorado	D,H,G,F,B						29.5		627.6	0.7
Georgia	H,B						0.6		11.0	0.6
Idaho	D,H,G,F,B						94.2		1479.1	0.5
Montana	H,G,F,B						15.8		297.8	0.6
New Mexico	D,H,G,F,B						38.7		335.7	0.3
Nevada	D,H,F,A,B						74.8		1153.6	0.5
New York	H,B						0.9		12.1	0.4
Oregon	D,H,G,F,I,A,S,B						77.8		802.8	0.3
South Dakota	D,H,F,B						66.3		577.6	0.28
Texas	H,B						4.0		27.4	0.2
Utah	H,G,F,B						45.8		449.9	0.3
Virginia	H						0.3		3.1	0.3
Washington	B						1.9		45.5	0.8
West Virginia	B						0.1		3.7	0.8
Wyoming	H,G,F,S,B						28.3		701.0	0.8
TOTAL							615.9		9192.2	0.47

I = Industrial process heat, C = Air conditioning (cooling), A = Agricultural drying (grain, fruit, vegetables), F = Fish farming, S = Snow melting, H = Individual space heating (other than heat pumps), D = District heating (other than heat pumps), B = Bathing and swimming (including balneology), G = Greenhouse and soil heating

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

Locality	Ground or water temp. (°C)[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 (TJ/yr)	Cooling Energy (TJ/yr)
States								
Northeast: 20%	5-25	12.0		V=45%	3.5			
Midwest: 34%	5-25	12.0		H=45%	3.5			
South: 35%	5-25	12.0		W=10%	3.5			
West: 11%	5-25	12.0			3.5			
			1,400,000			2,000	66,670	41,400
TOTAL		16,800,000	1,400,000				66,670	41,400

Ref: www.eia.doe.gov

* Residential: V/H = 30%/70%, Commercial/Institutional: V/H = 90%/10%

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	139.89	1360.6	0.31
District Heating [4]	81.55	839.6	0.33
Air Conditioning (Cooling)	2.31	47.6	0.50
Greenhouse Heating	96.91	799.8	0.26
Fish Farming	141.95	3074.0	0.69
Animal Farming	0.00	0.0	0.00
Agricultural Drying[5]	22.41	292.0	0.41
Industrial Process Heat[6]	15.43	201.1	0.41
Snow Melting	2.53	20.0	0.25
Bathing and Swimming[7]	112.93	2557.5	0.72
Other Uses (specify)	0.00	0.0	0.00
Subtotal	615.91	9,192.2	0.47
Geothermal Heat Pumps	16,800.00	66,670.0	0.13
TOTAL	17,415.91	75,862.2	0.14

[4] Other than heat pumps

[5] Includes drying or dehydration of grains, fruits and vegetables

[6] Excludes agricultural drying and dehydration

[7] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	114	4	5	15	72.13
Production	>150° C	14	0	1	0	20.66
	150-100° C	67	0	0	0	124.34
	<100° C	0	5	2	0	0.21
Injection	(all)	36	1	4		41.03
Total		231	10	12	15	258.37

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	2	2	10	0	0	1,825
2011	6	2	10	0	0	1,875
2012	6	2	10	0	0	1,992
2013	6	2	10	0	0	2,045
2014	2	2	10	0	0	2,049
Total	22	10	50	0	0	9,785

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

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl.	Field Development Including Production	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