ASHRAE, Geothermal Energy, and Heat Pumps

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When ASHRAE published its 2017 Fundamentals handbook in June 2017, the revised "Energy Resources" chapter corrected technical errors relating to geothermal energy and heat pumps from previous editions. Similar errors are in ASHRAE's 2015 HVAC Applications handbook. Its next edition, the 2019 HVAC Applications handbook, is scheduled to be published in June 2019. The corrections in the 2017 handbook got started when I attended the meeting of the handbook subcommittee of Technical Committee 2.8 on June 26, 2016 at ASHRAE's June 2016 annual conference, and my copy of the new handbook arrived on June 1, 2017. I was surprised to see the result and tweeted, "The 2017 ASHRAE Handbook of Fundamentals includes all my suggested changes to Chapter 34 Energy Resources. #Geothermal #Ambient @ashraenews". The next day I started a project to help ASHRAE's Technical Committee 6.8, which has responsibility for revising the "Geothermal Energy" chapter for the 2019 handbook. This project report describes:

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ASHRAE's important role in the energy use of buildings

ASHRAE, formerly the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, is an organization whose members research, design, build, and operate the systems that control the temperature, humidity, air quality, and comfort in buildings and the process loads in those buildings. ASHRAE sponsors research and technical conferences, publishes transactions, journals, handbooks, standards, and other technical documents, and supports its regions and local chapters. At the society level, there are dozens of committees, including technical (TC) and project (PC), on which members serve voluntarily. Most TCs and PCs are responsible for at least one handbook chapter or technical standard, including making periodic revisions and reviewing public comments on those revisions.

Because of ASHRAE's skilled members and open revision process (anyone can submit comments and propose revisions to ASHRAE handbooks and standards), some of its publications are treated similarly to model building codes published by other non-governmental organizations. ASHRAE's standard 90.1, "Energy Standard for Buildings Except Low-Rise Residential Buildings," is specified by federal law as the energy efficiency standard for the design and construction of all federal buildings within its scope. As described at the link, federal law requires that the U.S. Department of Energy (DOE) determine whether each new revision of ASHRAE's standard 90.1 saves energy compared to the previous. When DOE determines that it does and publishes that finding in the Federal Register, the new ASHRAE standard 90.1 becomes the new federal regulation without public comment or possibility of revision, which would normally be done before a final federal rulemaking. ASHRAE's SSPC 90.1 does the public revision process before DOE begins its evaluation. In addition, because many ASHRAE standards relate to the safety and performance of building systems, they do not need to be included in local, state, or federal law, and designers do not need to be ASHRAE members, to be responsible for designing in compliance with other ASHRAE standards, for example ASHRAE's standard 62.1 "Ventilation for Acceptable Indoor Air Quality."

Geothermal Energy

Geothermal energy describes thermal energy sources within the Earth, collectively resulting in a relatively tiny average outward energy flow, with distinct causes unrelated to solar or ocean tidal power at the surface. Geothermal energy adds heat to the millions-of-years-long processes of transforming organic deposits into fossil fuels. In the Earth's crust, heat is generated by the natural fission (decay) of radioactive elements. The mantle is hotter than the crust, and the core is hotter than the mantle, resulting in a net heat flow outward from the mantle up through the crust. While natural radioactive decay may still be present in the mantle and the core, most of the heat from below the crust is the slow cooling of the core from the much higher temperature when the Earth formed over four billion years ago, still making its way out through the thin insulation of the lithosphere. The mantle transfers heat from the core to the crust by convection and conduction. The two main sources of geothermal energy are the heat transfer from hotter regions below the crust and the heat of radioactive decay in the crust, resulting in a mean continental geothermal power flux of 0.062 W/m^2 and a mean oceanic flux of 0.101 W/m^2. The global mean is about 0.09 W/m^2 and the total geothermal power of the Earth at the surface is about 44 Terawatts (TW).

The geothermal power flux at the Earth's surface is insignificant compared to the mean absorbed solar power and atmospheric infrared radiation (IR). If geothermal power was the only source heating the Earth's surface (no Sun or atmospheric IR) the surface temperature would be near 35 K based on the global mean geothermal power flux. Instead, because of solar radiation and the atmosphere with its natural "greenhouse effect," the mean surface temperature of the Earth is about 288 K (15 C) resulting in a mean radiated heat loss of about 390 W/m^2, over 4000 times the geothermal power flux. Geothermal energy has no effect on the surface or near-surface temperature of the Earth, which is a result of the Sun, the "greenhouse effect," and the heat capacity/thermal diffusivity of the soil, water, and rocks near the Earth's surface. Infrared radiation from the surface of the Earth is nearly 200,000 TW.

The primary sources of data on temperatures and thermal properties of the Earth's crust are measurements of the geothermal gradient within continental boreholes and ocean sediment cores, and laboratory analysis of the thermal properties of core samples. For continental temperatures near the surface, diurnal oscillations in ground temperature, due to diurnal oscillations in air temperature, are observed within the top 1 to 2 meters, the amplitude decreasing with depth. Annual oscillations in ground temperature, due to annual oscillations in air temperature, are observed to a depth of 19 to 38 meters, the amplitude also decreasing with depth. Below this depth the annual oscillations at the surface are no longer noticeable and the undisturbed ground temperature is about equal to the local mean air temperature, the midpoint of both the diurnal and annual oscillations.

Without geothermal energy, the mean surface temperature would determine the temperature within the Earth. At some depth below where annual oscillations in ground temperature disappear, climate differences would also eventually decrease to zero, resulting in a uniform deep Earth temperature of 288 K (15 C). Instead, with geothermal energy, below the depth where diurnal and annual temperature oscillations go to zero, the mean continental geothermal gradient of 20 to 30 C/km becomes measurable. For example, for a local climate temperature of 288 K, the temperature at 100 meters depth due to climate temperature would be 288 K. With a local geothermal gradient of 20 C/km, an additional contribution from geothermal energy flux would be 2 K, for a total temperature of 290 K. This is below the depth of the ground loops of most ground source heat pump systems.

Ground source heat pumps

A ground source heat pump (GSHP) is a heat pump which uses the ground as its low-temperature reservoir (heat source) and uses a heating load as its high-temperature reservoir (heat sink). Heat pumps are often reversible, meaning the cycle can be switched from heating to cooling, using a cooling load as its heat source and the ground as its heat sink. Using the ground, rather than air, as a heat pump source/sink for heating/cooling can improve efficiency because local ground temperature (below 19 meters) is relatively constant and about the local mean air temperature (the local climate temperature), in contrast to the outdoor air temperature, which changes with the weather and experiences diurnal and annual hot and cold extremes.

Being decoupled from weather extremes, a GSHP's higher installed cost can often be justified by its higher efficiency, with resulting lower energy cost and/or lower peak power demand, when compared to an air source heat pump (ASHP). Building heating and cooling loads follow the weather, meaning heating loads increase when the outdoor air gets cooler and cooling loads increase when the outdoor air gets hotter. The highest heating and cooling loads occur during the lowest and highest outdoor air temperatures, respectively, when ASHP heating and cooling capacities and efficiencies are at their lowest. A GSHP can use the ground, groundwater, or surface water at a relatively constant temperature because those source/sinks have a high heat capacity which dampens and time shifts the effects of diurnal and annual outdoor air temperature oscillations over days (below 1 meter) and years (below 19 meters). For most climates, GSHPs are among the most efficient, and lowest peak demand, space heating and cooling systems compared to other systems using the same source of work (for example, electricity).

A GSHP is usually a packaged, space conditioning, reversible, all-electric heat pump connected to the ground by a buried, closed-loop, polyethylene piping system of supply and return headers connected to one, or usually more, U-tubes, dropped and grouted into uncased vertical wells spaced about 7 meters apart and drilled to a depth of 30 to 120 meters. This formula estimates the pipe friction heating power:

Watts = 746 x GPM x deltaP / 3960.

For example, one U-tube made of nominal 3/4-inch diameter pipe, serving a one ton cooling load, has a flow of 3 GPM. For a U-tube 75 meters deep (150 meters of pipe), the deltaP is 8 feet of water column. Using the formula, the frictional heating of the heat transfer fluid in one U-tube is 4.52 Watts. For a grid with 49 m^2 per well, the average frictional heat gain per square meter of well field is 0.092 W/m^2. This formula is based on a loop filled with water and neglects any heat from the circulating pump or the pressure drop through the heat pump evaporator, so it is a low estimate. Usually the ground loop contains a mixture of water and anti-freeze and its higher viscosity will result in a greater deltaP and more frictional heating power.

Coefficient of performance (COP) is a measure of efficiency for a heat pump for a given set of operating conditions, the ratio of useful heating energy supplied divided by useful energy used (for example, electricity), and GSHP manufacturers publish performance data for GSHPs. For example, the WaterFurnace model NS036 (ECM blower option, p.35) with an entering water temperature (EWT) of 60 F at 9 GPM and an entering air temperature of 70 F, has a heating capacity (HC) of 36,200 BTU/H, an electric input of 2030 W, heat extracted (HE) of 29,200 BTU/H, and a COP of 5.23. Interpolation with data for 70 F EWT implies increasing the EWT by 1 K (1.8 F) to 61.8 F would increase HC, HE, kW, and

COP values to 36,900 BTU/H, 29,900 BTU/H, 2.04 kW, and 5.31, implying a 1 K average increase in ambient ground temperature from the geothermal gradient might make a 0.07, or 1.5%, improvement in the COP.

The reason for the discrepancy between this predicted performance improvement (1.5%) from an average 1 K geothermal gradient boost over the depth of the ground loop and what is really happening in a closed-loop system is because elevated ground temperature from the geothermal gradient near the surface is a result of the ground being undisturbed by thermal effects other than climate and geothermal power flux over thousands of years. The heat extracted by the NS036 (3-ton nominal) GSHP at 60 F is 29,200 BTU/H (8560 W). For a 49 m^2 per ton well field, the average annual power flux of the GSHP heat extracted by this single-speed heat pump is 13 W/m^2, 1.5 orders of magnitude less than the climate power flux, but over two orders of magnitude greater than the geothermal power flux. The GSHP ground flux includes a load factor correction for 2000 hours in heating mode and 1000 in cooling mode. In cooling mode the NS036 rejects 41,900 BTU/H (12,280 W) to the ground loop field. This is an annual average power flux of about 10 W/m^2 of surface area into the ground and also two orders of magnitude greater than the geothermal power flux. The GSHP annual cycle of extracting heat in the winter and rejecting heat in the summer is so large it obliterates any effect geothermal power flux had on steady-state undisturbed temperatures in the ground loop field. Local undisturbed temperature at a depth below annual oscillations is the integration of thousands of years of the local climate boundary condition at the surface, and geothermal energy no longer affects ground temperature when a GSHP begins disturbing it on diurnal and annual timescales with its powerful heating and cooling loads.

How "geothermal" is used incorrectly to describe ground source heat pumps

The word "geothermal" is used incorrectly to describe ground source heat pumps, ignoring one or both of these two facts,

1. Geothermal power has no effect on local ambient ground temperature.
2. A heat pump's low-temperature reservoir isn't useful energy.

Ignoring either fact leads to false claims. The first is making the false claim that the Earth's geothermal power flux affects local ground (climate) temperature, a widespread confusion. The second is making the false claim that a heat pump's low-temperature reservoir, like the work done by its compressor, is a useful energy resource by itself, a direct contradiction of the second law of thermodynamics. Here's further detail on fact 1, fact 2, and reservoirs.

Fact 1: The undisturbed temperature of a GSHP ground loop field is climate dependent. The effect of geothermal power is insignificant. Joseph Fourier determined this 200 years ago:

> For a globe made of iron, a rate of increase of a thirtieth of a degree per meter would yield only a quarter of a centessimal degree of excess surface temperature at the present. This elevation is in direct ratio to the conductivity of the material of which the envelope is formed, all other things being equal. Thus, the surface temperature excess of the actual Earth caused by the interior heat source is very small; it is certainly less than a thirtieth of a centessimal degree. It should be noted that this last conclusion applies regardless of the supposition which one may make about the nature of the internal heat source, whether it be regarded as local or universal, constant or variable.
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> ...
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> Though the effect of the interior heat is no longer perceptible at the surface of the Earth, the total quantity of this heat which dissipates in a given amount of time, such as a year or a

century, is measurable, and we have determined it; that which traverses one square meter of surface during a century and expands into celestial space could melt a column of ice having this square meter as its base, and a height of about 3m.

("On the Temperatures of the Terrestrial Sphere and Interplanetary Space," Joseph Fourier, 1827, translation by R. T. Pierrehumbert, 2004, p.14-15)

Here is Pierrehumbert's footnote to the second quoted paragraph (which is separated by six paragraphs from the first, before the ellipsis):

Equivalent to 318 mW/m^2, which is 3-4 times modern estimates of geothermal heat flux. As Fourier implies, the overestimate arises from using the conductivity of iron.

Geothermal power flux (W/m^2) in localities with typical geothermal gradients is the same order of magnitude as the example of ground loop pipe friction power, 0.092 W/m^2, calculated under the previous heading, "Ground source heat pumps," (does not account for ground loop pump cycling).

Fact 2: A heat pump is not a heat engine. A heat engine is heated by a useful high-temperature reservoir, converts some of that heat to work, and rejects the remaining heat to a low-temperature reservoir. A heat pump's low-temperature heat source cannot be a useful energy resource because it is colder than the useful heat sink temperature made by the compressor; if the heat source temperature is useful relative to the heating load served by the heat sink, a heat pump and its work resource will not be needed. The energy a heat pump extracts from the ambient environment is not useful; the ambient low-temperature heat naturally transfers through the ground into the lower temperature ground loop. The compressor uses work to chill its ground loop, then pressurizes and heats that extracted cold energy from the ground up to a useful temperature in the condenser, there rejecting the energy from the cold ground mixed with the hot energy from the compressor to its heat sink and the heating load. All thermodynamics textbooks confirm this in discussions of heat engines, heat pumps, and the second law of thermodynamics (for example, Thermodynamics, Joseph H. Keenan, 1941, p.63). If the local geothermal gradient had a useful effect on GSHP heating output and efficiency, it would also have a significant negative effect on GSHP cooling output and efficiency.

"Reservoir" has both thermodynamic and general definitions as differentiated by Keenan (1941 footnote, p.59), "The term reservoir is used here to mean a heat source or a heat sink of uniform temperature. It should not be inferred from the more general definition of the term that heat can be stored. When heat is received from a reservoir the internal energy of the system which constitutes the reservoir is reduced."

Some examples of ASHRAE using "geothermal" to describe ground source heat pumps

The shocks of oil price increases in the 1970s improved the prospects for alternative energy resources because higher prices for conventional energy resources improves the economics for alternative energy projects. The Geothermal Resources Council (GRC) was founded in 1971; its mission is to, "advance geothermal development through education, outreach, and dissemination of research." In early 1979 it hosted, "A symposium of geothermal energy and its direct uses in the Eastern United States," under DOE contract number ET-78-G-03-2118. GRC published the symposium papers in Special Report No. 5, dated April 1979. This was two months after the Iranian revolution, one month after the Three Mile Island disaster, at the beginnings of the 1979 oil panic with its spring and summer of long lines at gasoline stations, and when everybody started pumping their own gasoline except in New Jersey and Oregon.

The theme of GRC's 1979 symposium was based on theory and data reporting that while accessible geothermal resources useful for generating electricity (that is, hot enough to power a heat engine) are rare, accessible deep aquifers with a capacity and temperature useful for process or space heating loads are less rare, with "accessible deep aquifers" meaning "conventional energy costs are high enough to justify drilling and pumping costs." Most of the papers describe research and projects relating to the direct use of aquifers which are at a useful temperature as a result of their depth, age, and the local geothermal gradient. Several papers describe the direct use of hydrothermal resources with useful temperatures at or near the surface, the main subject of ASHRAE's 1982 "Geothermal Energy" chapter. Two papers describe research on generating electricity from hot deep rock resources. One paper, "Utilization of Geothermal Energy with an Emphasis on Heat Pumps," (R. C. Niess, p.73-80), presents economic comparisons for heating process water using three basic system options:

1. Drill through a normal geothermal gradient deep enough to get to an aquifer with a useful temperature (for example, 7700 feet, 170 F).
2. Drill into a shallower aquifer with an elevated, but not useful temperature (for example, 3000 feet, 100 F), but deep enough that a water-to-water, non-reversible, heat pump can heat the process water to a useful temperature.
3. Drill the same depth as 2., but use a boiler to heat the process water to a useful temperature.

One paper reports the estimated effects on efficiency, capacity, and resource use load factor for hot well water from useful aquifers (about 80 C) to power a lithium bromide-water absorption cycle originally modified for use with solar heated hot water. In the application the paper describes, it could be called a geothermal powered chiller, or a geothermal air conditioner, differentiating it from both gas and electric powered air conditioners.

>> ASHRAE published papers presented at its 1980 semiannual meeting in Transactions, 1980, volume 86 part 1, including "High Temperature Heat Pumps Can Accelerate the Use of Geothermal Energy," (R. C Niess, p.755-762). This paper references the Niess 1979 GRC symposium paper and reports on a similar economic comparison, using either a heat pump or an oil-fired boiler to heat process water from the not-hot-enough aquifer temperature to the necessary process temperature. The option of drilling deep enough to get to a useful temperature is not compared (p.756), "The cost of drilling wells to these depths could be prohibitive considering the present (and even the 10-yr projected) cost of conventional energy sources to heat process water and to supply space heating."

>> ASHRAE published its first edition of "Geothermal Energy" as chapter 56 in the <u>1982 Applications</u> handbook, assigned to TC 6.8, Geothermal Energy Utilization. In the endnotes are four papers from the 1979 GRC symposium part of a total of 56 papers by some of the same authors and others, describing the direct use of geothermal energy; neither the 1979 GRC Niess paper nor the 1980 ASHRAE transactions Niess paper are referenced. The chapter uses "heat pump" four times when describing how to use geothermal energy at temperatures greater than 15 C and less than 90 C (p.56.2, 56.8, 56.17). It uses "heat pump" one more time as an example of how a cleanable heat exchanger made of special materials can be used to isolate a heat pump from corrosion and scaling by the geothermal fluids from shallow sources or deep aquifers which were the focus of the chapter (p.56.12). One paragraph in this first edition of the "Geothermal Energy" chapter describes the nature of both shallow and deep geothermal fluids as being localized, limited resources, and the maintenance or renewal of these resources by the local geothermal power flux as insignificant compared to the power and timescales of human use of energy resources (p.56.3):

> Life of the Resource
> Although the radioactive decay that appears to be the ultimate source of geothermal energy continues, and can be expected to continue, for many thousands of years, geothermal energy in a specific locality is generally not renewable. Only in areas that are volcanically active would a particular resource be expected to be renewed. The energy to be mined, from what are now

considered geothermal resources, was built up over a period of many millions of years and could not be restored at the rate at which it would be withdrawn in any economic application. As a result, each resource must be developed with a certain life of the development in mind. The usual procedure is to expand the area that is developed as additional capacity is required and/or initial energy production rates start to drop off.

In its December 1982 Bulletin the GRC published "Geothermal heat-pump systems are competing today against conventional fuels," by R. C. Niess (p.9-14). The introductory paragraphs end with (p.9), "The cost of drilling wells to these depths could be prohibitive considering the present (and even the ten-year projected) cost of conventional energy sources." The paper presents case studies of three installations:

> A northern plains municipal power agency office building with an open loop well water source heat pump heating and cooling system, with reinjection of well water (55 F pumped, 50 F reinjected). It also has a bypass feature to avoid using the heat pump as a chiller when well water temperature is cold enough to handle cooling loads on its own.

> The temperature of water from 1800-foot-deep wells supplying a western city varies from 65 F to 86 F. A county courthouse converted from an oil- and gas-fired boiler to an electric water-to-water industrial heat pump. In the winter, the heat pump chills city water before returning it to the community water mains. In the summer the heat pump cycle is reversed, cooling the courthouse and returning heated water to the city's mains.

> A northern plains school campus central plant serving nine buildings converted from an oil-fired boiler to industrial electric heat pumps with 1000 foot deep wells producing 935 GPM at 75 F for a low-temperature reservoir and a 790 GPM heating water distribution system at temperatures up to 190 F as its heat sink. The system configuration is described as a "heat-pump cascade system" at design conditions, when both "heat pumps extract 10 F in cooling the 935 gpm of geothermal water" to produce 7.7 million BTU/H of heating capacity at a temperature of 190 F (p.13). The system can idle one heat pump and reset the heating water supply temperature to 130 F (p.14) when the heating load drops below the need for 190 F at the various campus building terminal units. The system was not designed for changeover to provide chilled water in the cooling season.

>> ASHRAE published a revision of "Applied Heat Pump Systems" as chapter 10 in the 1984 Systems handbook, assigned to TC 9.4, Applied Heat Recovery/Heat Pump Systems. The revision added this paragraph to the subheading Heat Sources and Sinks, Water (p.10.4):

The recent interest in geothermal energy has led to the identification of many geothermal energy sources with temperatures compatible with heat pump systems. They range from the typical shallow well temperatures mentioned above to temperatures where direct use for heating is possible. When using these temperatures which are higher than typical ground water temperatures, special attention should be given to designing the system for the proper fluid temperature drop. This is necessary since increasing the temperature drop decreases the fluid flow requirements for a specified heating rate. When the available temperature is high enough for direct use, but the available water resource flow is insufficient to satisfy the heating, load, the heat pump can be used to meet the load by achieving a greater drop in the resource temperature than the temperature necessary for direct use. Geothermal system designs are presented in more detail in Chapter 56 of the 1982 Applications Volume.

This text addition has endnotes for the Niess 1979 GRC symposium paper, a May 1980 DOE report "Heat pumps for geothermal applications: availability and performance" (G. M. Reistad and P. Means), and the Niess 1982 GRC Bulletin paper. ASHRAE's false claim, "... the identification of many geothermal energy sources with temperatures compatible with heat pump systems. They range from the typical shallow well temperatures mentioned above ..." confuses "many geothermal energy sources" with the climate effects on "typical shallow well temperatures," in a section about heat pump sources and sinks. ASHRAE's false claim ignores fact 1,"geothermal power has no effect on local ambient ground temperature." In the next subheading, Heat Sources and Sinks, Earth, ASHRAE describes ground source heat pumps and lists endnotes for twelve references from the 1940s and 1950s, plus two from 1964, without using the word "geothermal."

>> ASHRAE published a revision of "Geothermal Energy" as chapter 45 in the 1987 HVAC Systems and Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The revision included the Life of the Resource paragraph, which replaced "generally not renewable" with "limited," and deleted text describing hot water from deep aquifers as "The energy to be mined, from what are now considered geothermal resources, was built up over a period of many millions of years and could not be restored at the rate at which it would be withdrawn in any economic application." (p.45.3)

> Life of the Resource
> Although the radioactive decay that appears to be the ultimate source of geothermal energy continues, geothermal energy in a specific locality is limited. The limiting factor is usually thermal water, the medium used to transfer the energy from the rocks to the surface. If production rates of thermal water exceed natural recharge rates, water levels can decline and the resource should be developed with a reservoir management plan that includes injection wells to maintain reservoir pressure. Reservoir life is difficult to determine and involves expensive reservoir engineering techniques. The usual procedure is to expand the area to be developed to stages, monitoring the water levels in wells, then apply proper reservoir management methods as additional capacity is required and/or initial energy production rates start to decline.

>> ASHRAE published its first edition of "Energy Resources" as chapter 31 in the 1991 HVAC Applications handbook, assigned to TC 4.8, Energy Resources. A list of energy resource forms includes the text, "Solar energy and wind energy are also available at most sites, and geothermal energy (earth heat) is available at some." A list of nondepletable sources of energy includes: "Earth heat (geothermal)" and "Atmosphere or large body of water (as used by the heat pump)" (p.31.1). The "Earth heat (geothermal)" likely refers to the limited useful energy resource form listed on the same page. ASHRAE's false claim that "Atmosphere or large body of water (as used by the heat pump)" is a nondepletable source of energy like hydropower, solar, wind, tidal, and ocean thermal ignores fact 2, "a heat pump's low-temperature reservoir isn't useful energy."

>> ASHRAE published a revision of "Geothermal Energy" as chapter 29 in the 1991 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The revised subsection, Equipment and Materials, Downhole heat exchangers (p.29.12) begins with:

> The downhole heat exchanger (DHE) consists of an arrangement of pipes or tubes suspended in a wellbore. A secondary fluid circulates from the users system through the exchanger and back to the system in a closed loop. The primary advantage of a DHE is that only heat is extracted from (and with heat pumps, heat is rejected to) the earth eliminating the need for disposal of spent fluids.

The text, "and with heat pumps, heat is rejected to," makes the false claim that a geothermal downhole heat exchanger can double as the heat sink for a heat pump, which ignores this alternate wording of fact 2, "a useful geothermal resource is a poor high-temperature reservoir for a heat pump." This 1991 revision also adds an example of an artesian well distribution system, with a temperature of 190 F at 300 GPM, designed to heat a fixed number of customers. The return water from these highest temperature customers then circulates to the municipal pool. The water rejected from the pool is used as the low-temperature reservoir for a loop heat pump system at a school. This cascade design results in the production from the hydrothermal resource being rejected at near ambient temperature, maximizing the temperature drop for the large fixed cost of the designed supply flow and temperature (p.29.16).

>> ASHRAE published a revision of "Energy Resources" as chapter 31 in the 1995 HVAC Applications handbook, assigned to TC 1.10, Energy Resources. Revisions include changing part of the list of energy resource forms from one sentence in 1991 (p.31.1), "Solar energy and wind energy are also available at most sites, and geothermal energy (earth heat) is available at some." into two sentences (p.31.1):

> Solar energy and wind energy are also available at most sites, as is low-level geothermal energy (energy source for heat pumps). Direct-use (high-temperature) geothermal energy is available at some.

ASHRAE's false claim " ... available at most sites, as is low-level geothermal energy" ignores fact 1, "geothermal power has no effect on local ambient ground temperature." ASHRAE's false claim that "low-level geothermal energy (energy source for heat pumps)" is an energy resource form ignores fact 2, "a heat pump's low-temperature reservoir isn't useful energy." This revision essentially added the ground to the list started when the 1991 edition falsely claimed "Atmosphere or large body of water (as used by the heat pump)" as a nondepletable source of energy.

>> ASHRAE published a revision of "Geothermal Energy" as chapter 29 in the 1995 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The revised chapter included " ... and ground-source heat pump applications (generally < 90 F)." in its first sentence as one of three categories of geothermal resources (29.1). References to heat pumps were also added to the Resource (renamed Resources) section of the geothermal chapter. The “low temperature” geothermal energy classification, which had been defined as 15°C to 90°C, had its lower bound removed; previously warm and hot springs were considered low temperature geothermal resources, this change added cold springs to the classification, a false claim ignoring facts 1 and 2 (29.2). The remainder of the chapter is split into two headings: Direct Use Systems including content from the 1991 chapter (p.29.3-29.14) and Ground-Source Heat Pump Systems. Under Direct Use Systems, The Life of the Resource subsection is replaced by the Resource Life subsection (p.29.4):

> Resource Life
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> The life of the resource has a direct bearing on the economic viability of a particular geothermal application. There is little experience on which to base projections of resource life for heavily developed geothermal resources. However, resources can readily be developed in a manner that will allow useful lives of 30 to 50 years and greater. In some heavily developed direct-use areas, major systems have been in operation for many years. For example, the Boise Warm Springs Water District system (a district heating system servicing some 240 residential users) has been in continuous operation since 1892.

Under Ground-Source Heat Pump Systems, a new section (p.29.14-29.24), the first paragraph under the Terminology subheading states (p.29.14):

> The term ground-source heat pump (GSHP) is applied to a variety of systems that use the ground, groundwater, and surface water as a heat source and sink. Included under the general term are ground-coupled (GCHP), groundwater (GWHP), and surface water (SWHP) heat pump systems. Many parallel terms exist [e.g., geothermal heat pump (GHPs), earth energy systems, and ground-source (GS) systems) and are used to meet a variety of marketing or institutional needs.

The new GSHP heading includes new application guidance for ground-coupled heat pump systems, local ground water temperatures, and closed-loop-to-ground heat transfer sizing calculations for the nonsteady-state annual climate and heat pump system effects on a ground field for vertical, horizontal, and spiral loop designs. Local geothermal gradient isn't an input for these calculations (p.29.16-29.17).

Detailing examples of ASHRAE using "geothermal" to describe ground source heat pumps in handbooks or other publications from 1996 through 2014 is beyond the scope of this project. The handbook revisions of the "Geothermal Energy" and "Energy Resources" chapters retain the errors added in 1991 and 1995. Further reading of the GSHP sections in the "Geothermal Energy" chapter revisions over the decades reveals the societal benefits ASHRAE and others have contributed through the expanded knowledge and improvement of the design and installation of GSHPs, which are among the most efficient, and lowest peak demand, all-electric, space heating and cooling systems. Here are lists of the two sets of intervening chapters, grouped by chapter.

>> ASHRAE published a revision of "Geothermal Energy" as chapter 31 in the 1999 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The ground source heat pump heading expands (p.31.14-31.25).
>> ASHRAE published a revision of "Geothermal Energy" as chapter 32 in the 2003 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The ground source heat pump heading expands (p.32.11-32.27).
>> ASHRAE published a revision of "Geothermal Energy" as chapter 32 in the 2007 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The ground source heat pump heading expands (p.32.9-32.29).
>> ASHRAE published a revision of "Geothermal Energy" as chapter 34 in the 2011 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The ground source heat pump heading expands (p.34.9-34.32).

ASHRAE did not publish a revision of " Energy Resources " in the 1999 HVAC Applications handbook. A revision of the "Thermal Storage" chapter is moved up to its place as chapter 33.
>> ASHRAE published a revision of "Energy Resources" as chapter 17 in the 2001 Fundamentals handbook, assigned to TC 1.10, Energy Resources, retaining the fact 1 and fact 2 errors added in 1991 and 1995.
>> ASHRAE published a revision of "Energy Resources" as chapter 17 in the 2005 Fundamentals handbook, assigned to TC 2.8, Energy Resources, retaining the fact 1 and fact 2 errors added in 1991 and 1995.
>> ASHRAE published a revision of "Energy Resources" as chapter 34 in the 2009 Fundamentals handbook, assigned to TC 2.8, Energy Resources, retaining the fact 1 and fact 2 errors added in 1991 and 1995.
>> ASHRAE published a revision of "Energy Resources" as chapter 34 in the 2013 Fundamentals handbook, assigned to TC 2.8, Energy Resources, retaining the fact 1 and fact 2 errors added in 1991 and 1995.

>> ASHRAE published a revision of "Geothermal Energy" as chapter 34 in the 2015 HVAC Applications handbook, assigned to TC 6.8, Geothermal Energy Utilization. The ground source heat pump heading expands (p.34.10-34.41). Producing and delivering draft revisions to correct errors in this chapter and the 2017 Composite Index were major tasks completed early in Energy-PE's project to help ASHRAE publish a 2019 handbook describing ground source heat pumps without false "geothermal" claims in either the "Geothermal Energy" chapter or the 2019 Composite Index.

>> ASHRAE published a revision of "Applied Heat Pump and Heat Recovery Systems" as chapter 9 in the 2016 HVAC Systems and Equipment handbook, assigned to TC 6.8, Geothermal Heat Pump and Energy Recovery Applications. This revision of the chapter uses "geothermal" in the text four times in the last section, 3.4 Heat Pumps In District Heating And Cooling Systems.

>> ASHRAE published a revision of "Energy Resources" as chapter 34 in the 2017 Fundamentals handbook, assigned to TC 2.8, Building Environmental Impacts and Sustainability, correcting decades of false claims ignoring fact 1 and fact 2. This revision removed "low-level geothermal energy (an energy source for heat pumps)" as an energy resource form (p.34.1), removed "earth heat" as an ambiguous synonym for geothermal energy (twice, p.34.2), "atmosphere or large body of water" as a renewable resource energy resource used by heat pumps (34.2), and removed "high-temperature" as qualifier for "geothermal energy, which is not universally available, ..." (34.1).

>> ASHRAE Journal, (p.16-27) published the article "Geothermal Conversion for Of a Commercial Office" in its June 2017 issue describing a conversion from natural gas boilers and furnaces with electric air source condensing units to all-electric horizontal ground loop GSHP heating and cooling. The word "geothermal" should not have been in this article, on the front cover of the Journal, or in the Journal editor's glowing introduction to the article.

How ASHRAE's technical errors matter

This report has described ASHRAE's important role in the energy use of buildings. Since the 1980s ASHRAE has produced various technical publications which use the word "geothermal" to describe the ground source heat pump. From 1991 until 2017 ASHRAE's "Energy Resources" chapter confused the low-temperature reservoirs of air and water source heat pumps with useful nondepletable and renewable energy resources.

Describing GSHPs as "geothermal" confuses people. Confused people repeat or create false claims about "geothermal" and GSHPs. Because of ASHRAE's important role in energy it is likely its continued repetition of false claims about GSHPs and "geothermal" reinforces this confusion. DOE also spreads the false claim that GSHPs use geothermal and renewable energy through its marketing and Energy Information Agency (EIA) reporting. For example, here is how DOE answers its own FAQ question 3: Where Is Geothermal Energy Available?

> Answer: Hydrothermal resources - reservoirs of steam or hot water - are available primarily in the western states, Alaska, and Hawaii. However, Earth energy can be tapped almost anywhere with geothermal heat pumps ..."

At the end of this webpage's false claim (which ignores fact 1) the words "heat pumps" link to DOE's "Geothermal Heat Pumps" webpage where DOE makes more two false claims (which ignore fact 2):

> "The benefit of ground source heat pumps is they concentrate naturally existing heat, rather than by producing heat through the combustion of fossil fuels."
>
> "The geothermal heat pump takes advantage of this by transferring heat stored in the earth or in ground water into a building during the winter, ..."

The heat pump is producing it temperature and heat with electricity, not the naturally cold ground, and it almost certainly is using electricity from fossil fuels. Heat is not stored in the ground, or anywhere. Thermal energy is constantly flowing into, through, and out of the ground through diurnal and annual changes in solar radiation, infrared radiation, convection, conduction, precipitation, and evaporation. The GSHP uses electricity to extract energy from the environment at a temperature which is unaffected by the geothermal power flux. See also, "The False Claims of Ground Source Heat Pumps" for a report of EIA's false claims about the direct use of geothermal energy.

Some buyers of GSHPs for existing buildings are switching their fuel from direct use, for example fuel oil, to indirect fuel use of the grid supplying their incremental electric heating load; some buyers are upgrading from less efficient all-electric heating and cooling systems, and are decremental loads from the grid. As long as there are fossil fuel generators supplying electricity to the grid, any incremental electric load delays the retirement of the worst one, and is responsible for that incremental fuel use, and any decremental electric load hastens the retirement of the worst generator and avoids that decremental fuel use. From an electric load perspective, a GSHP can be either load building or load shaving for heating or cooling loads, depending on an application's original and retrofitted system loads and the energy resources used. Electric ground source heat pumps are not geothermal or renewable. They are an all-electric heating and cooling load.

Using its thermal renewable energy certificate (REC) program, New Hampshire law takes money from rate payers to purchase thermal RECs, credited to GSHP owners for the low-temperature energy extracted from their backyards. The Clean Energy States Alliance reports on New Hampshire and other states with thermal REC programs, many of which include solar (New Hampshire is one) and real geothermal, in "Renewable Thermal In State Renewable Portfolio Standards," updated July 2018.

Other examples of the confusion and false claims made for GSHPs are detailed in some project task descriptions below. ASHRAE's errors matter because while making false claims from its position of authority, it is reinforcing the confusion and other consequences from those false claims.

My revisions in the 2017 Fundamentals handbook

The "Energy Resources" chapter first edition, in the 1991 HVAC Applications handbook, was written by TC 4.8, Energy Resources. Responsibility for revisions was assigned to TC 1.10, Energy Resources, for the 1995 HVAC Applications and 2001 Fundamentals handbooks. Responsibility changed to TC 2.8, Building Environmental Impacts and Sustainability, for revisions in the 2005 Fundamentals, 2009 Fundamentals, and 2013 Fundamentals. In June 2016 ASHRAE held its annual conference in Saint Louis, Missouri, so my attendance didn't require travel, only commuting.

I went to the handbook subcommittee meeting of TC 2.8 on June 26, 2016. This was the last in-real-life meeting before the deadline for the final revision of the "Energy Resources" chapter for the 2017 Fundamentals handbook. I brought copies of the first three pages of the 2013 edition of the chapter with lineouts and inserts removing “low-level geothermal energy (an energy source for heat pumps)” as an energy resource form, “earth heat” as an ambiguous synonym for geothermal energy, and “atmosphere or large body of water” as a renewable energy resource used by heat pumps.

Two days later I attended the full committee meeting of TC 6.8, Geothermal Heat Pump and Energy Recovery Applications. My notes of the handbook subcommittee chair's report on the draft revision of the "Geothermal Energy" chapter for the 2019 HVAC Applications handbook are, "moving GSHP to front of Chapter, Direct use pushed to back." I signed in on the attendance sheet and didn't say anything.

I don't know what happened to my three pages of revisions I handed to someone two days earlier at the TC 2.8 "Energy Resources" chapter subcommittee meeting. I had also signed in on the attendance sheet there and initiated a discussion of how the Earth is insulation and thermal mass and how geothermal energy makes almost zero contribution to local ground temperature, which depends on the climate. In August 2016 I was on the list of recipients of an email to the subcommittee from the chair with a draft of the revised "Energy Resources" chapter and a request for final review. My printed revisions I'd left at the meeting weren't there so I edited the file and emailed it back. In October 2016 I received another email from the subcommittee chair asking for clarification on which revisions I'd added to the file. I replied to the email, started a project for the accumulating work papers, and waited until June 1, 2017 when my brand new ASHRAE handbook arrived and all my recommended revisions had been printed.

Energy-PE's project to help ASHRAE avoid using "geothermal" to describe ground source heat pumps in its 2019 HVAC Applications handbook

Energy-PE, LLC, is my sole proprietor business founded about three months after my retirement from Laclede Gas Company, the local natural gas distribution utility in Saint Louis, Missouri (Laclede hired Energy-PE in 2013 to consolidate legacy rate calculation spreadsheets into a new spreadsheet and that project was completed in 2014). Participation in ASHRAE committee activities is by individuals who usually are there with some support from their employer. Energy-PE did not reimburse travel expenses, but budgeted 100% unbillable hours for this project.

Unlike my 2017 ASHRAE handbook project, this 2019 handbook project has been a work project from the start, with a projected two year span. The 2017 handbook project started in 2016 with an email from the TC 2.8 handbook subcommittee more than three months after I'd attended its meeting in Saint Louis, while this 2019 project started in 2017 with my receipt of the 2017 handbook. The rest of this report is a chronology (dates in parentheses) of major project tasks and some ancillary tasks:

- > Received (June 1, 2017) 2017 Fundamentals.
- > Started (June 2, 2017) project folder for 2019 handbook.
- > Contacted (June 5-8, 2017) local energy professionals and discussed my project scope and immediate tasks to help ASHRAE. They agreed my first task was to email the chair of TC 6.8.
- > Emailed (June 8, 2017) TC 6.8 chair describing the revisions to "Energy Resources" chapter and their effect on the "Geothermal Energy" chapter revisions already underway for the 2019 handbook. A chronology of, and text similar or identical to, many of my communications with ASHRAE for this project are on Energy-PE's project webpage.
- > Received (June 9, 2017) a response from TC 6.8 chair with cc: to the "Geothermal Resources" chapter subcommittee chair starting with:

  > Thank you for your comments. The roughly one page introduction to geothermal energy was (to my understanding) added in order to provide some background about what is, and is not, to be addressed in the chapter. I have not thoroughly reviewed the 2017 Handbook as I have not yet received my copy.
  > However, assuming the Energy Resources adequately covers the same material, we can certainly look at simply referencing that chapter and streamlining our chapter.

- > Emailed (June 13, 2017) TC 1.3 chair about typo (p.4.3) in "Heat Transfer," chapter 4 in the 2017 Fundamentals. The equation for heat transfer rate from a hollow sphere, in Table 2, One-Dimensional Conduction Shape Factors, has a plus sign instead of a minus sign between the two radius terms in the denominator. ASHRAE published this correction in General Handbook Corrections - I-P Edition, July 20, 2017 (p.A.1), "p. 4.3, Table 2, 1st equation for hollow sphere. In the denominator, change the + to a -."
- > Completed (June 23, 2017) my hand edited draft revisions of printed copies of 2015 "Geothermal Energy" chapter and 2017 "Composite Index." Emailed scans to the TC 6.8 chair and handbook subcommittee chair on that Friday morning before ASHRAE's annual meeting

began in Long Beach, California. My transmittal email explained I would not be in Long Beach, but I'd be available by phone for both the upcoming Sunday handbook subcommittee and Tuesday full committee meetings. No one called or responded to this email.

> Emailed (June 23, 2017) letter to the ASHRAE Journal editor about false geothermal claims.
> Observed (August 21, 2017) a total eclipse of the Sun at Energy-PE world headquarters.
> Having received no feedback from TC 6.8, I submitted (August 26, 2017) a similar comment on ASHRAE's handbook comment webpage and received confirmation from ASHRAE's handbook manager, September 12, 2017.
> Uploaded (September 7, 2017) the first edition of Energy-PE's "Geothermal Energy" webpage to provide easy access to my comments and tweeted the link. Reply emailed (September 13, 2017) to the ASHRAE handbook manager with the link to this webpage and easy access to the scans of my draft revisions I'd emailed the TC 6.8 chairs, since I had found no option to upload them with my August 2016 online comment, which the handbook manager's email was acknowledging.

At this point the project was idle, expecting responses from TC 6.8. Since I'd already used Energy-PE's website for posting my revisions and project status, I began using @energy_pe to search and troll Twitter for "geothermal" which, as often as not, finds confusion about geothermal energy and GSHPs. I also continued reviewing notes and references related to the false claims of ground source heat pumps. The partial list of completed project tasks continues:

> Replied (October 5, 2017) to a tweet about proposals in Alberta to circulate water through abandoned oil wells to provide space heating. I selected a quote from the article to which it linked and plugged my own webpage:

"Banks draws a distinction between ground source heat pumps in common use and true geothermal energy."
#geothermal
http://energy-pe.com/geothermal.htm

On October 6, 2017 @_Geothermal_ followed me Twitter. I don't know who or what this is.

> Replied (November 9, 2017) to a tweet by the author of a citylab.com article "Welcome to the Steam-Powered Suburbs." That headline appears under a photo of Hellisheidi geothermal electric power plant in Iceland and the article describes planned housing developments with GSHP systems.

On November 10, 2017 @GRC2001 followed me on Twitter. This is the Geothermal Resources Council.

> Began (November 13, 2017) adding #NotGeothermal to tweets where its 15 characters could fit.
> Learned (November 17, 2017) and tweeted about Ginsberg's Theorem.
> Posted (November 22, 2017) "The False Claims of Ground Source Heat Pumps" based on notes, references, expanded and updated research of EIA and other source data, new analysis methods, and review of recent false claims.

On December 1, 2017, the Geothermal Resources Council blogged a link to my post, "The False Claims of Ground Source Heat Pumps" with this comment:

In the following article a professional engineer weighs in on the problem of differentiating between geothermal energy and heat pump technologies. What do you think? Join the conversation in the comments below.
Ted Reinhart, Professional Engineer, Energy-PE, LLC, University of Missouri-Columbia

The GRC post promoting my post was deleted by December 4, 2017 after I'd already posted (December 3, 2017) a thankful comment which also clarified " ... Neither myself nor Energy-PE, LLC are affiliated with the University of Missouri-Columbia, other than I received my M.S. degree there 30+ years ago."

> Learned (December 6, 2017) about geothermal climate science denial and tweeted (December 30, 2017) about it with a link to Skeptical Science's webpage, "Heat from the Earth's interior does not control climate," by Andy Skuce, posted on September 17, 2011.

> Downloaded (January 18, 2018) TC 6.8 full committee draft minutes from the June 2017 Long Beach ASHRAE meeting. Included in the handbook subcommittee chair's report was the item "Ted Reinhart email on term 'geothermal'. We will crisp up our terminology, but not make the major division that he suggests. [Chair] and [subcommittee chair] will make a reply to Ted." Neither the "crisp up our terminology" nor the "reply to Ted" tasks were completed.

> Quote-tweeted (January 18, 2018) Rupert Darwall's geothermal climate science denial quote-tweet of a climate scientist after seeing @_Geothermal_'s retweet of his trolling. I added it as a reply without comment to my earlier tweet about geothermal climate science denial.

> Travelled (January 21, 2018) to ASHRAE's 2018 winter conference in Chicago, Illinois, visited the ASHRAE bookstore, and attended TC and PC meetings. The task requiring the trip was to participate in the TC 6.8 handbook subcommittee meeting and discuss my draft edits from June 2017. The subcommittee chair participated by phone because of federal government shutdown travel restrictions. I handed copies of my draft revisions from June 2017 to the subcommittee member with a cell phone on speaker. The recollection of Chicago meeting attendees, who had listened to discussion at the Long Beach meeting, was that going ahead with my revisions would confuse people. No one in the room defended false claims that the ground is at ambient temperature because of geothermal energy. No one in the room defended false claims that ground source heat pumps extract useful energy from the ground.

> Emailed (January 23, 2018) the TC 6.8 chair, subcommittee chair, and two others whose email addresses I received at the Sunday handbook meeting, with these two draft sentences to add to the end of the 3.1 Terminology paragraph (p.34.10), "Geothermal energy has no effect on local ground temperature or climate. A ground source heat pump uses neither geothermal nor renewable energy unless the work used by the heat pump is from a geothermal or renewable energy resource." I received no response.

> Received (February 5, 2018) neither a call during the Tuesday, January 23, 2018 TC 6.8 full committee meeting nor a response to my email sent just before the meeting, so I emailed the TC 6.8 chair requesting, "a summary of any discussion, votes, or other actions relating to the Geothermal Energy chapter which took place at the TC 6.8 meeting on Tuesday, January 23, 2018 during the ASHRAE winter conference in Chicago. If draft minutes are available for either the subcommittee or committee meetings, please send those. Also, please arrange for me to have read access to the online draft of the geothermal energy chapter so I can review changes being proposed for the 2019 HVAC Applications handbook." The TC 6.8 chair replied February 6, 2018, "Ted, You will receive the information sent to the full TC."

> Replied (February 6, 2018) to my own tweet with a link to Rupert's desmogblog.com profile, and noting that Rupert's geothermal climate science denial is usually marginalized, even by climate science deniers. Rupert hit my bait.

> Emailed (February 7, 2018) the TC 6.8 handbook subcommittee chair asking for access to the latest draft revision of the "Geothermal Energy" chapter, which they sent as a word document. It still used "geothermal" to describe GSHPs in all the same places. I notified (February 8, 2018) the subcommittee chair that the errors I'd identified in June 2017 were still there. The subcommittee chair's reply:

> I chose not to change the terminology after our TC voted "no" to changing the words at the June 2017 Long Beach CA ASHRAE conference. There were many changes for me to manage for the handbook, and many "last minute" change requests that occupied a lot of my time. Changing the terminology requires more TC support than I had, and more time than I had. I understand your frustration with the process and the time it takes to resolve the issue, but it's just not something I can address at this time. I will pass the information and your suggested changes on to the next chapter chair.

> Posted (February 11, 2018) "Order of Magnitude, A Fish Story" about Rupert Darwall's geothermal climate science denial.

> Tweeted (February 12, 2018) "Geothermal is like the Clarence Beeks of ground source heat pumps (GSHPs not F.C.O.J.), who then tried to do climate denial too. GSHPs are #NotGeothermal. F.C.O.J is frozen concentrated orange juice." It's a reference to the movie "Trading Places" in which Clarence Beeks is an overly-confident hoodlum hired by the Dukes.

> Found (February 20, 2018) an @Advanced_Energy tweet after @_Geothermal_ made a similar tweet including a link to and graphic from an Advanced Energy Center Blog post "A Closer Look at Geothermal Systems" about Brooklyn Botanic Garden's GSHP system. The blog post's false claims about the system ignore fact 1 and fact 2, for example:

    As geothermal capacity expands in the United States to meet increasing demand for renewables, we examine the impact of these installations through the example of the Brooklyn Botanic Garden in New York. While much of the nation's geothermal capacity is located on the west coast, this infographic highlights the exciting possibilities of geothermal in a dense urban environment.

  I replied (February 20, 2018) to the @Advanced_Energy tweet:

    The @bklynbotanic 60 ton heating and cooling system described is a ground source heat pump system. It uses neither geothermal nor renewable energy unless its electric power is from geothermal or renewable generation resources.
    #NotGeothermal #NotRenewable

> Reviewed (February 23, 2018) the AEC2018 program, the last agenda item is "Heat Pumps: Utilities, Emerging Business Models and Enabling R&D."

> Tweeted (March 1, 2018) criticism of the false claims in CBS News article "Geothermal heat is slowly gaining steam in homes," 7 tweets.

> Tweeted (March 1-2, 2018) about the Earth's geothermal power and showed how small it is. Followed up with a tweet about the internal energy of Jupiter's moon Europa and how the surface flux from Europa's internal power source does have an effect its surface temperature.

> Reply tweeted (March 5, 2018) to a tweet by Reforming the Energy Vision, Governor Andrew M. Cuomo's comprehensive energy strategy for New York (@Rev4NY):

    The #Geothermal Clean Energy Challenge is a $3.8M initiative to encourage ground-source #HeatPump systems in government buildings, healthcare facilities & schools across NY.
    Successful applicants will receive free analysis & unlock access to funding http://on.ny.gov/2nxxZ7Q"

  The tweet had an image including NYDERDA's logo, a home with a GSHP, heading text "In The Wintertime," and body text "The earth is warmer than your home, so heat from the ground is transferred to the house through the water pipe system to warm you up" a false claim ignoring fact 2.

> Started (March 6, 2018) a tweet folder for Dandelion.

> Tweeted (March 6, 2018) about my hashtags. #NotGeothermal #NotRenewable #NotUtilityIndependent #NotSteam #NotLikeAPowerPlant #TotallyElectric (turns out this one was already popular) #TheEarthIsNotWarmerThanYourHome #NotACauseOfGlobalWarming.

> Trolled (March 6, 2018) the Union of Concerned Scientists by tweeting a link to its geothermal webpage and then mockingly quoting some text from the UCS's first paragraph by writing "Ground source heat pumps don't use geothermal energy because it's not 'the dirt in our backyards,' ..." Here's the first paragraph of, "How Geothermal Energy Works":

    Heat from the earth can be used as an energy source in many ways, from large and complex power stations to small and relatively simple pumping systems. This heat

> energy, known as geothermal energy, can be found almost anywhere—as far away as remote deep wells in Indonesia and as close as the dirt in our backyards.

The scientists' webpage ignores fact 1 and fact 2. I went on and on with four replies to myself.

\> Replied (March 6, 2018) to a tweet linking to a greentechmedia.com article about Dandelion with the comment "Curious to see where Dandelion goes with making direct use #geothermal more accessible in residential applications." My reply said: "@DandelionEnergy is marketing ground source heat pumps and this acquisition will have no impact on direct use of geothermal energy. The Sun and atmospheric infrared radiation maintain local ground temperatures. Geothermal energy is 1000+ times smaller." This got helpful replies from the original tweeter who seems to have learned geology in college. I was last taught geology in grade school.

\> Created (May 8, 2018) @NotGeothermal twitter account to avoid cluttering @energy_pe with #NotGeothermal after this project. While looking for a profile page banner image, I found @ENERGY's "Get Current" coloring book which makes the false claim "GEOTHERMAL We can use energy from the earth to heat and cool our homes" (p.7) for a drawing of a home with a ground loop and a chimney, in an all-electric coloring book. I have a difficult time understanding how people could become more confused than that, as TC 6.8 claims would happen if ASHRAE corrects its own technical errors with its 2019 HVAC Applications handbook edition.

\> Tweeted (May 9, 2018) about 200th anniversary of industrial geothermal use in Larderello, Italy.

\> Replied (May 30, 2018) to a tweet linking to a Bloomberg.com article about Dandelion with the comment "The #geothermal industry spans a wide spectrum from deep electricity generation to residential heat pumps like Dandelion and all have an important part in our energy future." My reply said:

> Ground source heat pumps don't use geothermal energy. "Geothermal heat pump" is a lie.
>
> 1. The local ambient ground temperature of a heat pump field is climate dependent. It is #NotGeothermal
>
> 2. Heat pumps are not heat engines. Heat pump reservoirs are not useful energy resources.

This got a reply from the original tweeter, which lead to another. Bob Wyman of Dandelion jumped in and replied to my reply twice, for example:

> The US government calls these things "geothermal heat pumps." While those in the industry are well aware that they are more solar thermal than geothermal, we gave up on fighting the name game to focus on more important problems like deployment.

"While those in the industry are well aware that they are more solar thermal than geothermal ..." is sort of understanding fact 1 while ignoring fact 2.

\> Tweeted (June 1, 2018) the cat and refrigerator model of heat pumps, 3 tweets, which includes a screenshot of Bob's reply, my response, and Bob's last reply of that subthread. I paraphrased what Bob's two replies together say to me: "those in the industry are well aware that many consider ambient ground temperature to be partly of geothermal origin."

\> Replied (June 22, 2018) to a tweet linking to a Treehugger article "Many smart people are saying Electrify Everything! I wonder if instead of the fancy heat pumps and tech we should Reduce Demand!" Here's my reply which included a quote tweet of my June 1 tweet:

> Great article. I had a recent exchange with @bobwyman of @DandelionEnergy. I was surprised by his candor that most people making money repeating this lie know they are lying, but only lie because @ENERGY makes them. I hear the same excuse from #MyASHRAE.

Bob Wyman replied with "You lie ..." (June 24, 2018). I replied with a question about the depth of Dandelion's ground loops, then added a reply to myself since Bob didn't.

> Emailed (June 24, 2018) the TC 6.8 chair and handbook subcommittee chair after not receiving a call during the "Geothermal Energy" chapter subcommittee meeting at the June 2018 annual conference in Houston, Texas. I asked if there had been any committee communications since February, as I had received none, and I asked the TC 6.8 chair to call me during the handbook subcommittee chair's report at the full committee meeting. The chair replied that my request was unreasonable and I wouldn't be called. My next reply (June 26, 2018) included the following text and I asked the chair to read my full reply at the meeting:

    ... A year ago, the 2017 Fundamentals handbook corrected the lies which were in the original Energy Resources chapter in the 1991 Applications handbook. The 2019 Geothermal Energy chapter revision is TC 6.08's opportunity to fix the lies added to the Geothermal Energy chapter in 1995. The term "geothermal heat pump" is a lie to confuse potential customers into thinking they will be using renewable energy resources. ASHRAE will not be confusing people by correcting this, it will be sharing its superior knowledge. ASHRAE will be knowingly repeating a lie if it publishes this again in 2019. Claiming the U.S. Department of Energy made it lie does not sound like a very good defense.

  The chair's reply began, "Your tone and accusations are inappropriate and unappreciated. My assumptions were that you were signing up as a corresponding member to be engaged with the committee. Your comments were discussed during the subcommittee. I have stated to you that I work and communicate through those who engage through the appropriate channels. ..." I tweeted about this reply ahead of the full TC 6.8 meeting in Houston, "I emailed this message to the chair ... I don't think he is going to read it. #MyASHRAE" with a screenshot of part of my email to the chair.

> Researched (June 26, 2018) thermal renewable energy certificates ("Renewable Thermal In State Renewable Portfolio Standards," Clean Energy States Alliance). I tweeted twice about the New Hampshire scheme. GSHP owners there are getting more thermal RECs for chilling their backyards than they would need to purchase solar or wind RECs for the electricity powering their heat pump. A comprehensive review of thermal RECs for GSHPs was beyond the scope of this project.

> Researched (June 28, 2018) the direct use of geothermal energy in Sweden ("World Energy Resources Geothermal 2016," World Energy Council, p.46), because it had been mentioned in the CBSNews article "Geothermal heat is slowly gaining steam in homes." It turns out Sweden's direct use of geothermal energy is almost all GSHPs, and I tweeted about it, 5 tweets. A comprehensive review of false claims about GSHPs in other countries was beyond the scope of this project.

The 2019 HVAC Applications handbook is scheduled to be published and available in the ASHRAE Bookstore beginning in June 2019. The scope of this project was helping ASHRAE correct its false claims about geothermal energy and heat pumps with its revision of the "Geothermal Energy" chapter from the 2015 HVAC Applications handbook.

October 14, 2018
Saint Louis, Missouri