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Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers

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List of Acronyms and Abbreviations

AMT	Alternative minimum tax
ASHP	Air-source heat pump
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BHEX	Borehole heat exchanger
DoD	Department of Defense
DOE	U.S. Department of Energy
DSM	Demand-side management
EEI	Edison Electric Institute
EERE	DOE Office of Energy Efficiency and Renewable Energy
EIA	DOE Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESCO	Energy service company
ESPC	Energy savings performance contract
EU	European Union
FEMP	DOE Federal Energy Management Program
G&Ts	generation and transmission cooperatives
GHG	Greenhouse gas
GHP	Geothermal heat pump
GHPC	Geothermal Heat Pump Consortium, Inc.
GSHP	Ground-source heat pump
GS-IHP	Ground-source integrated heat pump
HDPE	High-density polyethylene (pipe)
HVAC	Heating, ventilating, and air conditioning
IGSHPA	International Ground Source Heat Pump Association
IOU	Investor-owned utility
LCC	Life-cycle cost
NGWA	National Ground Water Association
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
REC	Rural electric cooperative
UESC	Utility energy services contract
USDA/RUS	U.S. Department of Agriculture Rural Utilities Service
WLHP	Water-loop heat pump
WSHP	Water-source heat pump

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Abstract

More effective stewardship of our resources contributes to the security, environmental sustainability, and economic well-being of the nation. Buildings present one of the best opportunities to economically reduce energy consumption and limit greenhouse gas emissions. Geothermal heat pumps (GHPs), sometimes called ground-source heat pumps, have been proven capable of producing large reductions in energy use and peak demand in buildings. However, GHPs have received little attention at the policy level as an important component of a national strategy. Have policymakers mistakenly overlooked GHPs, or are GHPs simply unable to make a major contribution to the national goals for various reasons? This brief study was undertaken at DOE's request to address this conundrum. The scope of the study includes determining the status of global GHP markets and the status of the GHP industry and technology in the United States, assembling previous estimates of GHP energy savings potential, identifying key barriers to application of GHPs, and identifying actions that could accelerate market adoption of GHPs. The findings are documented in this report along with conclusions and recommendations.

1. Executive Summary

More effective stewardship of our resources contributes to the security, environmental sustainability, and economic well-being of the nation. Buildings present one of the best opportunities to economically reduce energy consumption and limit greenhouse gas (GHG) emissions.

Geothermal heat pumps (GHPs), sometimes called ground-source heat pumps, have been proven capable of producing large reductions in energy use and peak demand in buildings.

If the federal government set a goal for the U.S. buildings sector to use no more non-renewable primary energy in 2030 than it did in 2008, based on previous analyses (updated and summarized in this report), it is estimated that 35 to 40 percent of this goal, or a savings of 3.4 to 3.9 quads annually, could be achieved through aggressive deployment of GHPs.

GHPs could also avoid the need to build 91 to 105 GW of electricity generation capacity, or 42 to 48 percent of the 218 GW of net new capacity additions projected to be needed nationwide by 2030. In addition, $33 to 38 billion annually in reduced utility bills (at 2006 rates) could be achieved through aggressive deployment of GHPs.

However, GHPs have received little attention at the policy level as an important component of a national strategy. Have policymakers mistakenly overlooked GHPs, or are GHPs simply unable to make a major contribution to the national goals for various reasons?

This brief study was undertaken at DOE's request to address this conundrum. The scope included determining the status of global GHP markets and the status of the GHP industry and technology in the United States, assembling previous estimates of GHP energy savings potential, identifying key barriers to application of GHPs, and identifying actions that could accelerate market adoption of GHPs.

Although the U.S. was once the world leader in GHP technology and market development, European markets now absorb 2 to 3 times the number of GHP units annually as do the U.S. domestic markets. Market growth rates in Europe, parts of Asia (China, South Korea), and Canada exceed those in the United States. In terms of installed base of GHPs, the United States still has the largest absolute number, but on a per capita basis many European countries are ahead.

Today's domestic GHP industry is better positioned for rapid growth than ever before. The technology is proven, with an installed base in the United States exceeding 600,000 GHP units. Tax credits for home and business owners investing in GHP systems were enacted in October 2008 through 2016. Since 2007 one segment of the utility industry, the rural electric cooperatives (RECs), have been able to obtain long-term loans with terms of up to 35 years at the cost of government funds from the U.S. Department of Agriculture Rural Utilities Service (USDA/RUS) to provide the outside-the-building portion of GHP systems to customers in exchange for a tariff on the utility bill, which would be more than offset by the GHP system's energy cost savings. In December 2007 Congress directed the General Services Administration (GSA) to establish a program to accelerate the use of more cost-effective energy-saving technologies and practices in GSA facilities, starting with lighting and GHPs. A growing number of States offer tax credits or other forms of incentives for GHP systems

The most important trade allies of the GHP industry, electric utilities, today are better able to focus on peak load reduction and improved load factor, two key GHP system benefits, than they were in the past when restructuring was looming. The industry's support organizations ─ the International Ground Source Heat Pump Association, Geothermal Heat Pump Consortium, Inc., American Society of Heating, Refrigerating, and Air Conditioning Engineers, and National Ground Water Association ─ are mature and robust.

If the domestic GHP markets were to expand rapidly most of the segments of the industry would be able to expand accordingly without creating bottlenecks. However, the GHP system design and installation infrastructure would require special attention. Currently these infrastructures only exist in some localities, and elsewhere customers lack access to the technology.

The primary GHP market failure is the expectation that building owners finance the "GHP infrastructure," or outside-the-building portion of the GHP system, such as the ground heat exchanger. GHP infrastructure will outlive the building and many generations of heat pumps, and is akin to utility infrastructure (poles and wires, underground natural gas piping). This begs the question ─ why do we expect building owners to finance GHP infrastructure, but not other utility infrastructure? The outside portion of the GHP system can be half or more of the overall GHP system cost, and if this cost is excluded, GHP systems have about the same price as competitive alternatives and could cost less in volume production.

As mentioned above, Congress has already granted the authority for USDA/RUS to provide long-term financing to RECs nationwide to provide GHP infrastructure to residential and commercial customers. So far one REC has taken a loan under this new program and one other REC has filed an application. The RECs are able to recover the cost of repaying the funds through a tariff on customer electricity bills. Apparently the GHP loop tariff would be $15 to 30 per month for most homes, which is less than the energy cost savings. Also already in place are GHP residential and commercial federal tax credits through 2016, and Congressional direction that GSA accelerate GHPs. Initiatives to capitalize on the leverage these new federal policies can provide, plus any additional federal policies that may be established in the future, would appear to be worth considering.

The key barriers to rapid growth of the GHP industry, in order of priority (1 being the most important barrier), are the following:

1. High first cost of GHP systems to consumers
2. Lack of consumer knowledge and/or trust or confidence in GHP system benefits

3. Lack of policymaker and regulator knowledge of and/or trust or confidence in GHP system benefits
4. Limitations of GHP design and business planning infrastructure
5. Limitations of GHP installation infrastructure
6. Lack of new technologies and techniques to improve GHP system cost and performance.

The following actions would address the barriers and facilitate rapid growth of the GHP industry:

1. Assemble independent, statistically valid, hard data on the costs and benefits of GHPs
2. Independently assess the national benefits of aggressive GHP deployment
3. Streamline and deploy nationwide REC programs to provide GHP infrastructure
4. Develop and deploy programs to provide universal access to GHP infrastructure
5. Develop the data, analysis, and tools to enable lowest life-cycle-cost GHP infrastructure
6. Expand geographic areas where high-quality GHP design infrastructure exists
7. Expand geographic areas where high-quality GHP installation infrastructure exists.

Given the need to rein in our nation's energy consumption and carbon emissions, while at the same time stimulating the economy out of its most serious downturn since the Great Depression, the author recommends that federal policymakers seriously consider aggressive nationwide deployment of GHPs, with programs commencing as soon as possible. If this recommendation is pursued, the author further recommends that the above-listed actions be seriously considered as part of the overall implementation strategy. In addition, future policies should ensure that GHP systems are not excluded from renewable portfolio standards and goals and related environmental initiatives.

To make rapid headway on the energy/carbon front in the buildings sector, existing buildings must be improved with single comprehensive deep-savings retrofits, because repeated incremental touches to the same buildings would result in large and wasteful transaction costs. GHPs are proven to be an excellent technology for anchoring comprehensive deep-savings retrofits. GHPs can play an important role within a new national energy strategy, but this is unlikely to happen without federal emphasis and leadership.

2. Introduction

The built environment – consisting of residential, commercial, and institutional buildings – accounts for about 40 percent of primary U.S. energy consumption and GHG emissions, 72 percent of U.S. electricity consumption, 55 percent of U.S. natural gas consumption, and significant heating oil and propane consumption in the Northeast and elsewhere.[1]

Recent trends indicate that the large energy and emissions footprint of buildings in the United States is getting larger relative to the transportation and industry sectors. The all-fuels energy consumption graph in Figure 1 indicates that since 1980 energy use by industry has been stable, and use by buildings has risen faster than transportation energy use.[2] Electricity consumption only, shown in Figure 2, has been flat in industry for about 15 years while growing more than 50 percent in buildings.[3] Essentially all growth in U.S. electricity consumption and peak demand since 1985, as well as the investment in the infrastructure required to generate, transmit, and distribute electricity to serve that growth, is accounted for by buildings.

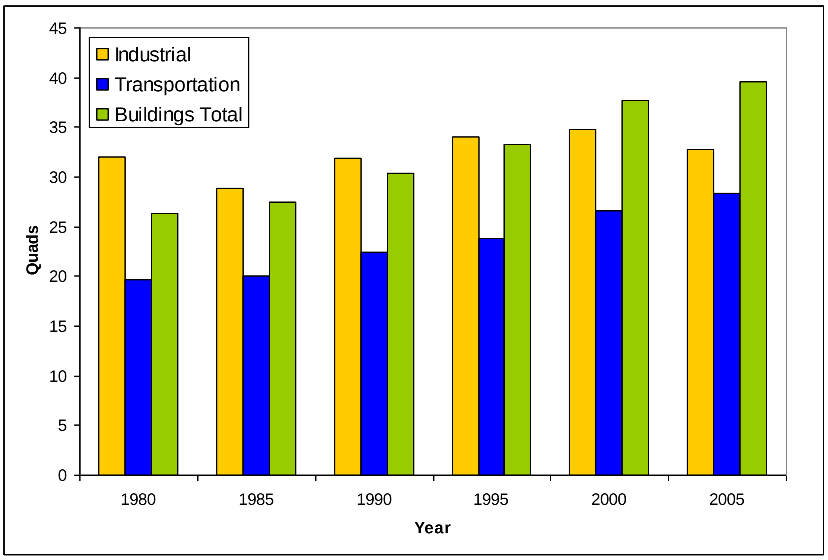

Fig. 1. Buildings energy use has grown faster than industrial or transportation energy use.

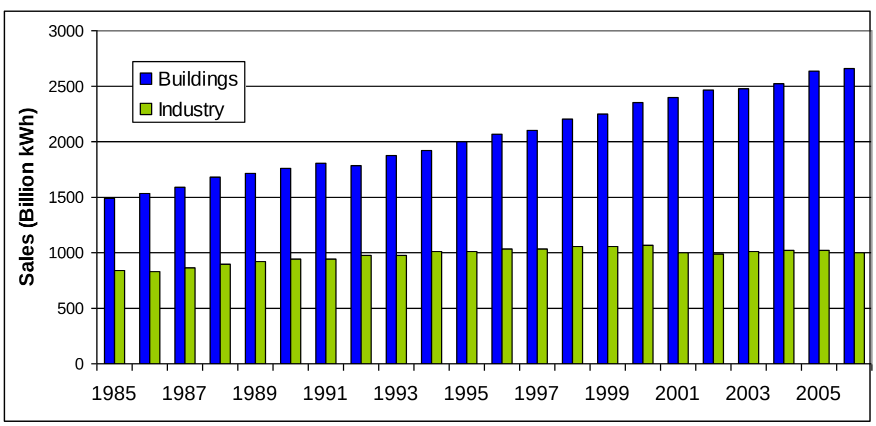

Fig. 2. Energy use in buildings drives electricity supply investment. Source: EIA Annual Energy Review, Table 8.9, June 2007.

More effective stewardship of our resources contributes to the security, environmental sustainability, and economic well-being of the nation. Buildings present one of the best opportunities to economically reduce energy consumption and limit GHG emissions. A recent study by McKinsey & Company found that reducing the consumption of energy in buildings is the least costly way to achieve large reductions in carbon emissions.[4]

GHPs have been proven capable of producing large reductions in energy use and peak demand in buildings. However, GHPs have received little attention at the national policy level as an important component of a strategy to achieve security, environmental sustainability, and economic well-being.

Have policymakers mistakenly overlooked GHPs, or are GHPs simply unable to make a major contribution to the national goals? There are different perspectives on the answer but one thing is certain: Hundreds of millions of dollars are being spent annually by federal taxpayers and utility ratepayers on more costly renewable energy technologies than GHPs, such as power generation from solar, wind, geothermal, and biomass resources, as well as on strategies to reduce our dependence on foreign oil through biofuels, hydrogen, the electrification of transportation, and the de-carbonization of electricity generation. Have we overlooked the part of the solution that is everywhere in the ground we stand on?

Over the last several decades GHP systems have improved gradually and achieved a small but growing share in U.S. building heating, cooling, and water heating equipment markets. This has occurred without much policy emphasis, and without much effort to understand the potential magnitude of the contribution of GHPs to the security, sustainability, and economy of the United States. Nor has there been much effort to identify or address the barriers preventing GHPs from making the maximum contribution, or inhibiting GHPs from being adopted in more applications where they are cost-competitive.

The objectives of this report are to:

- summarize the status of global GHP markets (Section 3),
- summarize the status of the GHP industry and technology in the United States (Section 4),
- estimate energy savings potential for GHPs in the United States (Section 5),
- identify key barriers to application of GHPs in the United States (Section 6), and
- identify policies or initiatives that could accelerate market adoption of GHPs in the United States (Section 7).

Subsection 2.1 clarifies the definition of GHP technology, since there is confusion about this at the policy level and among the general public. Subsection 2.2 identifies studies and documents that have acknowledged the potential importance of GHPs. Subsequent sections of the report will document findings, objective by objective.

2.1 GHP Technology — What It Is

The basics of GHP technology have changed very little over the decades but a geothermal identity crisis has been detrimental to fostering awareness, understanding, and acceptance of the technology. Depending on the perspective, GHPs have been cast as an energy source by many names (renewable, geothermal, solar, earth, alternative, recycled), as energy efficiency or energy conservation, or as an option within a broader category such as utility demand-side management.

GHPs are often confused with geothermal power production, in which the extreme heat of subsurface geological processes is used to produce steam, and ultimately to generate electricity. GHPs are also sometimes confused with the direct use of geothermal heat in which greenhouses, aquaculture ponds, and other agricultural facilities are heated using lower-temperature sources such as hot springs. While GHPs can be used almost anywhere, high temperature and low temperature geo-heat sources can be exploited economically at only a limited number of locations in the U.S., with current technology.

In general the vast majority of the nation's building stock is distant from economical sources of geo-heat. Furthermore, to be economical in the buildings sector, geo-heat would need to serve concentrated loads, such as in commercial buildings. The cooling, refrigeration, and other systems in the vast majority of the nation's commercial buildings transfer more heat to the building's outdoor environment on an annual basis than is required to satisfy heat loads within the building. GHP systems compete with these wasteful conventional systems by storing and recycling some of the wasted heat and making up the difference from the ground near the building. Heat transferred from the ground or recycled from waste streams by a GHP system is just as "renewable" as geo-heat and far more economical except in rare occasions, such as a resort hotel and spa sitting on top of a natural hot spring.

At any building in America, you will always see one or more of the following:

- metal boxes with louvered or grilled air intakes or discharges on the ground around the building or on the roof,
- areas of the building envelope (shell that separates indoor areas from the outside) or small adjacent buildings with louvered or grilled air intakes or discharges, and
- various side-wall and roof penetrations to enable air intake or discharge, or the discharge of the gaseous products of combustion of fossil fuels.

You see these features on buildings because the equipment that controls the temperature and humidity within and supplies hot water and fresh outdoor air must exchange energy (or heat) with the building's outdoor environment.

Equipment using the ground as a heat (energy) source and heat sink consumes less non-renewable energy (electricity and fossil fuels) because the earth is cooler than outdoor air in summer and warmer in winter. Heat pumps are always used in GHP systems. They efficiently move heat from ground energy sources or to ground heat sinks as needed. Although heat pumps consume electrical energy, they move 3 – 5 times as much energy between the building and the ground than they consume while doing so. If there were a market-driven reason to do so, the GHP industry could integrate the most advanced commercially available components into their heat pumps and increase this multiplier effect to 6 – 8, and theoretically the multiplier could be as high as 14.[5]

Every building in America sits on the ground, and the ground is always cooler than outdoor air in summer and warmer in winter. GHPs use the only renewable energy resource that is available at every building's point of use, on-demand, that cannot be depleted (assuming proper design), and is potentially affordable in all 50 states. The GHP industry contends that they are the most affordable renewable energy resource, especially considering the investments in electrical transmission that will be necessary to deliver many of the best wind, solar, and geothermal power generation resources to market.

As shown in Figure 3, there are a number of GHP system options. Systems using closed-loop, vertical-bore ground heat exchangers are by far the most common, especially in commercial buildings. However, for the technology to reach its potential, affordability will be of utmost importance, and other cost-effective options may have growing roles.

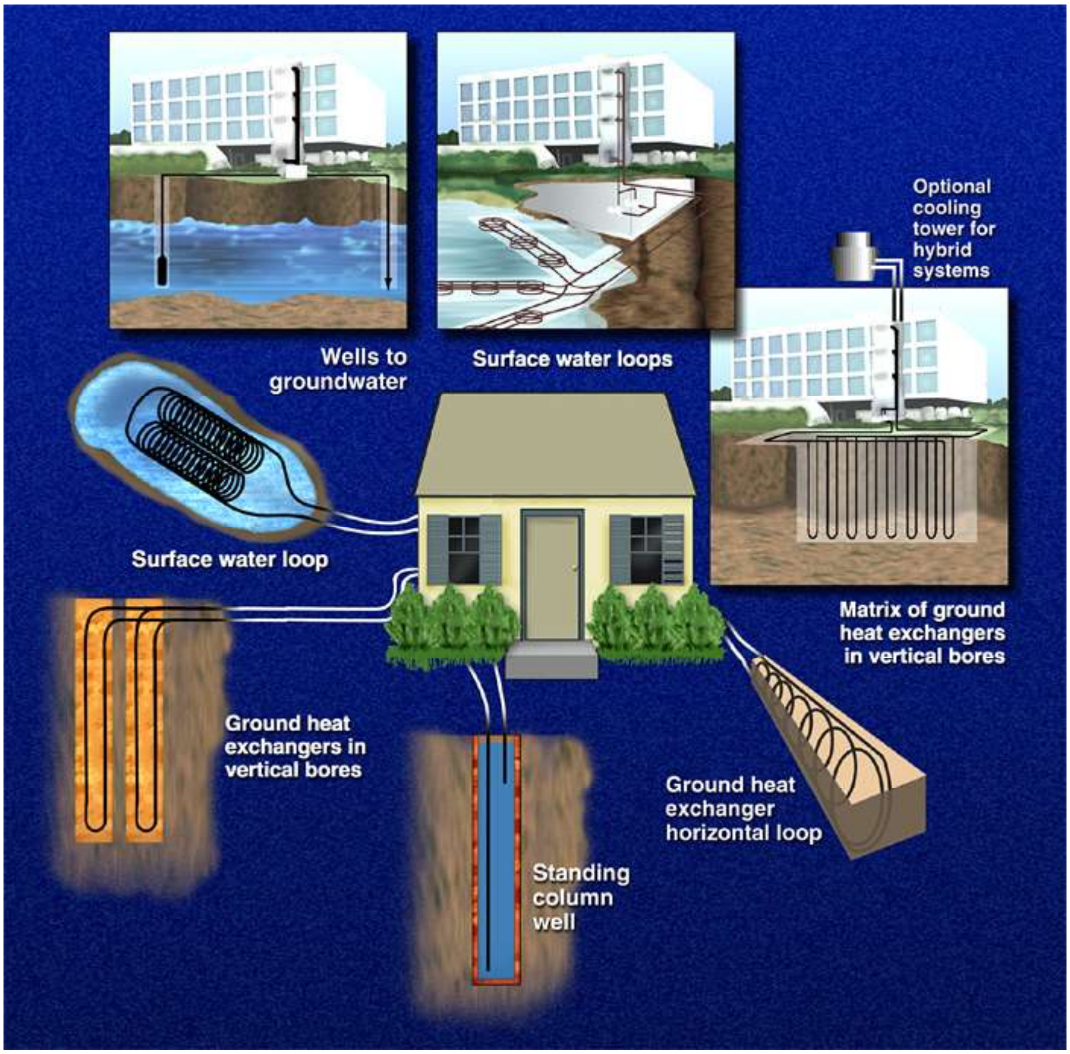

Fig. 3. GHP systems are adaptable to a number of different configurations.

Ground resources — including the Earth, surface water, recycled gray water, sewage treatment plant effluent, retention basin storm water, harvested rainwater, and water from a subsurface aquifer — whether alone or in combination with outdoor air in a hybrid configuration, have great potential. GHP infrastructure can be designed at the scale of a community or a building, and can serve new construction or retrofits of existing communities and buildings. In many areas it may be possible to serve the modest heating, cooling, ventilation, water heating, and refrigeration loads of near-net-zero-energy new homes and commercial buildings with efficient heat pumps coupled to ground loops placed in the construction excavations, without any extra digging or drilling whatsoever.

2.2 Studies Considering the Importance of GHPs

- A 2005 report by the Pew Center on Climate Change suggested that six expanded market transformation policies—in combination with invigorated R&D—could bring energy consumption and carbon emissions in the building sector in 2025 back almost to 2004 levels. The invigorated R&D scenario considered five technologies including research focused on cost reduction of GHP systems.[6]
- In 2007 an American Solar Energy Society report suggested that through maximum deployment of energy efficiency and renewable energy, it was feasible to be on a carbon reduction path by 2030 that would lead to 2050 levels 60 to 80 percent lower than 2005 levels.[7] This is the scale of carbon reductions that climate experts say is necessary to avoid catastrophic climate change. The scenario considered energy efficiency (buildings, transportation, and industry separately), wind, biofuels, biomass, solar photovoltaics, concentrating solar power, and geothermal power. The single largest contributor to carbon reduction was energy efficiency in buildings, and the buildings analysis was predicated on the Pew Center study,[8] whose projections were based in part on GHP systems.
- In 2007 the Nobel-Prize-winning Intergovernmental Panel on Climate Change identified the building sector as having the highest GHG emissions, but also the best potential for dramatic emissions reductions.[9] GHPs were specifically identified as a solution that is "economically feasible under certain circumstances" in continental and cold climates (Table 6.1), and cases were cited where total electricity use decreased by one third (p. 404) and heating energy use by 50 to 60 percent (p. 397).
- A 2007 United Nations Environmental Programme report highlighted the potential use of the ground in conjunction with heat pumps to reduce non-renewable energy use several times (p. 17, 27), and noted the existence of subsidies for such systems in Finland and elsewhere (p. 53).[10]
- The Executive Office of the President's National Science and Technology Council issued a 2008 report designed to establish the federal R&D agenda for buildings.[11] This report makes the point that energy-efficient and direct-use renewable energy technologies still have enormous potential for energy savings at lower cost than acquiring supplies from non-renewable or renewable power sources, and enhanced use of ground energy sources and heat sinks at the building or community level is highlighted (p. 29) as a promising option.
- A 2008 American Physical Society (APS) report recommended, among many other things, that the federal government should set a goal for the U.S. building sector to use no more primary energy in 2030 than it did in 2008, rather than increase energy use by 30 percent by 2030 as currently projected.[12] This report also referred several times (p. 56, p. 73) to GHP systems as being among the options that could help achieve this goal. A September 2008 PNNL report concludes that aggressive, but plausible, market penetration scenarios for technologies applied to buildings could cause total primary energy consumption in the buildings sector to level off by 2025,

but this “lost opportunities” case will not be realized at current federal investment levels.[13] The PNNL report implies that the APS “level off buildings” goal is realistic.

- A November 2008 NREL report, whose objective was to provide an overview of the key residential technology opportunities and barriers that must be addressed to successfully develop cost neutral net Zero Energy Homes (ZEH), categorized GHPs as a low risk technology for achieving ZEH.[14] However, the report assigned a low benefit to GHPs because the analysis considered neither an appropriate match between financing term and service life for ground loops, nor advanced integrated styles of emerging GHPs that provide water heating as well as space conditioning.

3. Status of Global GHP Markets

A 2005 review of the global market status of GHP systems estimated that the United States had the largest installed base of GHP systems (approximately 600,000 units at the time) but that Sweden, Denmark, Switzerland, and other countries ranked higher on a per capita basis.[15] Since then additional information has come to light suggesting that both the European and Asian markets may currently exceed the United States in annual shipments of GHP units, as summarized below. This is disappointing given that the United States was clearly the world leader in GHP technology when the first ever International Energy Agency conference focused on this topic convened in Albany, NY, in 1987.[16]

3.1 Europe

The market for GHPs in Europe has reached a state where the technology can no longer be labeled as unimportant, unavailable or negligible. The European Union (EU) heads of state adopted new energy savings and climate protection goals to reduce GHG emissions from all sources (not just buildings) 20 percent compared to 1990 levels by 2020.[17] The subsequent proposed European Commission Directive on the use of renewable energy sources includes GHPs as a contributor to reach the goals.[18] A scenario analysis that foresees 20, 30, and 100 percent of the EU building stock being heated by GHPs in 2020 has concluded that GHPs could potentially account for 5, 7.1, and 20 percent of the goal, respectively, assuming the EU-25 (meaning 25 countries) average electricity generation fuel mix.[19]

The basis for these policy events in Europe appears to be the strong GHP market development in central Europe over recent years.[20] Sweden is by far the largest heat pump market in Europe, with sales having grown strongly every year during the last decade. GHPs have been the most popular style of heat pump in Sweden in nine of the last twelve years. Sales in other European markets such as Germany, France, Finland, Switzerland, Austria, and Norway are also starting to increase. For example, the Austrian heat pump market grew by 45 percent in 2006, and the most popular (71 percent) are GHP systems. The German heat pump market grew 120 percent in 2006, and growth would have been even greater if it had not been held back by bottlenecks in drilling capacity and, at times, capacity of heat pump production facilities to keep up with the demand. GHPs have been 60 to 70 percent of the German market in recent years. Separately, a residential market study for GHPs across all of Europe estimated about

92,000 units shipped in 2004.[21] If the entire market has been growing in the range of 10 to 20 percent annually, European shipments would be in the range of 135,000 to 190,000 units in 2008.

3.2 Asia

Although details are limited, it is reported that demand for GHPs is expanding rapidly in Asia, especially in China and South Korea.[22] In South Korea, the capacity of shipped GHP equipment is reported to have increased by a factor of 5.5 from 2005 to 2007. Supportive government policies are noted as a primary reason for GHP market growth in China and South Korea, including GHPs being highlighted at the 2008 Beijing Olympic Games. In China the 2007 GHP growth rate is reported to have tripled over the previous year's value. As of the end of 2007 it is reported that over 30 million m^2 of floor space in China is conditioned with GHP systems.[23] If this is true, at a typical value of 60 m^2 per ton, the installed base in China is about 500,000 tons of GHP capacity, or 143,000 typically sized GHP units.

3.3 Canada

The Canadian market is currently experiencing dramatic growth, fueled partly by Canadian Federal grants,[24] supplemented in some cases by additional Provincial Government grants and utility incentives for retrofitting residences with GHP systems. The grant programs were justified by independent studies such as one by the highly regarded David Suzuki Foundation.[25] Estimates of the installed base of GHP units in Canada of 35,000[26] in 2004 and 37,000[27] in 2005 were found. A good recent estimate of Canadian installations of GHPs is believed to be about 10,000 units annually.

3.4 United States

There are at least 16 manufacturers of GHPs in the United States serving the residential and commercial markets.[28] The GHP market began to develop in the late 1970s, and has had its ups and downs due to the cyclic nature of the buildings industry and volatility in government and utility support and the prices of competing forms of energy. According to a survey by the U.S. Department of Energy's (DOE's) Energy Information Administration (EIA),[29] in 2006 about 64,000 GHP units were shipped, with 53 percent of the units going to residential and 47 percent to commercial applications. A very credible industry source estimates that about 50,000 GHP units were shipped in 2007,[30] with 63 percent going to residential applications and 37 percent to commercial. The latter source also estimates that of the residential shipments, about 75 percent go to new construction and 25 percent to retrofits of existing homes.

Both of these sources are probably close to correct since EIA includes exports and the industry source does not, and the industry source only surveyed the largest heat pump manufacturers. All data considered, it would probably be accurate to assume that about 60,000 units are placed domestically per year, with 50 to 60 percent of those going to residences and with new residential applications exceeding retrofits by a factor of 3 to 1. Both sources of industry shipment data suggest that growth has been strong over the last three years due to rising fossil fuel prices. Industry participants believe the growth rate in the U.S. market will trend upward because of the recent legislation described below.

The federal 2007 Farm Bill[31] authorizes USDA/RUS to provide 35-year loans at the cost of government funds to RECs for the purpose of installing GHP loops for customers, making the loops analogous to utility plant investments such as poles and wires, with the RECs recovering the cost of repaying the funds through a tariff on customer electricity bills.

The federal Economic Stimulus Bill,[32] which became law on October 3, 2008, provides a new 10 percent investment tax credit to businesses that install GHP systems. The bill extends these credits through 2016 and allows them to be used to offset the alternative minimum tax (AMT). By including GHPs within the definition of "energy property" in the energy credit language, GHP systems placed in service by businesses after October 3, 2008, will now also be subject to a 5-year depreciation period. The bill also provides taxpayers a tax credit of 30 percent of the cost of a GHP system applied to their residence, capped at $2000, and extends these credits through 2016 and allows them to be used to offset the AMT.

The federal 2007 Energy Bill[33] directs the General Services Administration (GSA) to establish a program to accelerate the use of more cost-effective energy-saving technologies and practices in GSA facilities, starting with lighting and GHPs. The legislation also provides guidance for implementation and monitoring progress.

4. Status of GHP Industry and GHP Technology in the United States

4.1 Status of the GHP Industry in the United States

A brief history of the U.S. GHP industry is provided below, followed by a summary of its current status.

4.1.1 Brief History of the GHP Industry in the United States

Water-source heat pumps (WSHPs) have been manufactured as a commercial product in the United States since the late 1950s.[34] The original markets for WSHPs were primarily residential. The first market was in southern Florida, and these early systems used groundwater or canal water as the energy source/sink. Water was pumped from the source and discharged directly through the heat pump to the surface (canal, ditch, etc.).

In the early 1960s, systems for commercial applications using separate heat pumps for each building zone, but connected to a common two-pipe water loop, began to appear on the West Coast. Referred to as the California heat pump system, the closed common loop was conditioned with an indirect closed-circuit fluid cooler or cooling tower for heat rejection and a boiler for heat addition to keep WSHP entering-water temperatures within design limits. This concept quickly spread to the East Coast and elsewhere in North America. Today this system configuration is commonly referred to as the water-loop heat pump (WLHP) system.[35]

In the late 1970s and early 1980s the GHP industry began evolving from the older WSHP industry. With minor refinements WSHPs were made operable over an extended range of entering-fluid temperatures. This enabled closed-loop ground heat exchangers to replace groundwater "pump and dump" as the geothermal source/sink in residential applications, and enabled ground heat exchangers to replace the boilers and coolers or towers in commercial applications. Unlike in WLHP systems, in GHP systems the indoor two-pipe water loop needs to be insulated to prevent condensation due to the extended range of operating temperatures. Depending on the application, the extended temperature range may require additives to the water for freeze protection, such as propylene glycol.

The vast majority of GHPs in the United States are installed with the closed-loop system using continuous high-density polyethylene (HDPE) pipe buried in the earth, in either a vertical or horizontal configuration. The closed-loop technology permits GHPs to be applied effectively almost anywhere. The HDPE piping technology had previously been perfected by the natural gas industry for underground natural gas gathering in the production fields and distribution to customers.

The GHP industry started with very industrious entrepreneurs, including contractors and manufacturers, who built viable enterprises before there was any government or utility involvement. Since the early 1980s the utility industry has sponsored many modest but successful GHP programs in their service territories that clearly boosted the small industry in some localities. Dating back to 1978, DOE and utilities and their associations [the National Rural Electric Cooperative Association (NRECA) and the Electric Power Research Institute (EPRI)] sponsored modest R&D efforts in support of the fledgling GHP industry.

Some of the earliest and perhaps most widespread utility support of the GHP industry came from RECs because of their unique circumstances. Most RECs are electric distribution companies that buy their power from statewide generation and transmission cooperatives (G&Ts) or investor-owned utilities (IOUs) on the wholesale market. The aggregate pattern of the electric loads they serve influences how economically RECs can procure wholesale power for resale to their customers. Lower peak demands and higher annual load factors are preferred. This pricing signal often encouraged RECs to seek ways to shave the peak loads.

Support of the GHP industry by IOUs came later, but their resources were orders of magnitude larger than RECs', so even a few successful IOU programs were able to have a noticeable impact. Since at the time they could simply roll the cost of new power plants into the rate base, IOUs had less incentive to aggressively reduce peak loads and improve load factors.

By the 1990s policymakers in Washington, D.C., noticed GHPs. EIA, in a report supporting development of the National Energy Strategy, estimated GHP energy savings potential at 2.7 quadrillion Btu by 2030, up from less than 0.01 quad in 1990.[36] A study by the U.S. Environmental Protection Agency (EPA) comparing the major HVAC options for residential applications determined that GHPs were the most energy efficient and environmentally benign option.[37] It became recognized that if — a big if — GHP technology were commonplace throughout the nation, the energy savings and emissions reductions would be significant.

This set the stage for initiation of two notable federal GHP programs—the National Earth Comfort Program and the Federal Energy Management Program's (FEMP's) GHP technology-specific program—both described below. More detailed histories of these programs are available elsewhere.[38]

4.1.1.1 National Earth Comfort Program

In October 1993 the Clinton administration launched the Climate Change Action Plan as well as the voluntary Climate Challenge, a partnership between DOE and major electric utilities who pledged to reduce their GHG emissions. The Climate Challenge attracted more than 50 utilities, whose chief executive officers sent letters to the Secretary of Energy stating their intent to either stabilize their greenhouse gas emissions at or below their 1990 levels or reduce their emissions to some other measurable performance level.[39] The Edison Electric Institute (EEI), supported by NRECA and EPRI, selected GHPs as one of its five initiatives under the President's Climate Change Action Plan.

In 1994 DOE, EEI, NRECA, EPRI, the International Ground Source Heat Pump Association (IGSHPA), EPA, and several utilities initiated a collaborative effort for GHP market mobilization and technology demonstration called the National Earth Comfort Program.[40] The program goals were to (1) reduce greenhouse gas emissions by 1.5 million metric tons of carbon annually by the year 2000, (2) increase GHP annual unit sales from 40,000 to 400,000 by the year 2000, saving over 300 trillion Btu annually, and (3) create a sustainable market for GHPs, a market not dependent on utility-provided rebates or government incentives.

Initially GHP shipments were estimated at about 40,000 units per year. A subsequent DOE-EIA survey established 1994 baseline sales at only 28,094.[41] This represented about 0.5 percent of national sales of HVAC equipment (boilers, furnaces, air conditioners, and heat pumps).

The Geothermal Heat Pump Consortium, Inc. (GHPC) was formed to implement the National Earth Comfort Program and was registered as a non-profit corporation.[42] The GHPC was organized around three operating committees, with each expected to address one of the three primary barriers to market penetration. These committees were (1) First Cost Competitiveness Committee, (2) Technology Confidence Building Committee, and (3) Infrastructure Strengthening Committee.

The original National Earth Comfort Program plans called for 6 – 12 large regional utility market mobilization programs, cost-shared by the GHPC but heavily leveraged by electric utility investments. It was envisioned that major utilities, operating in large cities and states, would sell as many as 25,000 GHPs per year in their service areas. Once a number of major utilities had demonstrated success this would be shared with other utilities, who would develop their own programs without GHPC cost-sharing. Program success would be measured on the basis of the number of GHPs sold annually and the number of utilities that joined the program without cost-sharing.

These GHP market mobilization concepts had been successful during the demand-side management (DSM) era of the late 1980s and early 1990s. But by the time major support from the utilities and government was developed for the National Earth Comfort Program in 1995, the restructuring of the U.S. electric utility industry was already underway. With restructuring pending, utilities largely backed away from implementing the DSM programs that their regulators had approved. The utilities feared that the coming regulatory changes and restructuring would result in DSM program costs becoming stranded costs not recoverable from rate payers.

When utility market mobilization programs did not go as planned, a major mid-course change was made in the GHPC business model, starting in part at their 1998 strategic planning session. It was decided to target commercial and institutional markets with two time-honored approaches — strategic outreach and design assistance.

To launch strategic outreach, GHPC subcontracted several market-sector experts to work directly with trade allies and utilities. Their job was to communicate GHP benefits to customers and influential players in their market segments. They were to utilize existing contacts, develop new leads, and respond to GHPC leads. Their mission was to help potential customers or market influencers (builders, developers, engineers, architects, etc.) become comfortable with GHP. They were not to make direct sales, but rather to open doors, qualify leads, and lay the foundation for trade allies to close deals.

An essential complement to strategic outreach for commercial and institutional markets is design assistance. The GHPC strategic outreach subcontractor may create some genuine interest in a developer or building owner, and the manufacturer's representative or other trade ally may build on that foundation, but sooner or later the owner's independent and trusted design engineer must be educated and convinced. GHPC found that providing small grants to pay for GHP design experts to mentor engineers in design had several benefits and settled on that approach.

Three measurable components of the National Earth Comfort Program — utility market mobilization programs, strategic outreach, and design assistance — were tracked in terms of GHP capacity shipments resulting from or influenced by program activities. According to the GHPC's final report to the DOE, these totaled about 150,000 tons over the 5-year period 1995 – 1999.[43]

Table 1. Annual GHP shipments according to EIA

Calendar year	Unit shipments (no.)	Capacity shipments (tons)
1994	28,094	109,231
1995	32,334	130,980
1996	31,385	112,970
1997	37,434	141,556
1998	38,266	141,446
1999	49,162	188,536

Government tracking of industry shipment data provides an independent means of verifying the GHPC estimate of the impact of the National Earth Comfort Program. Data from EIA based on a manufacturer's survey methodology are summarized in Table 1.[44,45] In the 1994 baseline year GHP capacity shipments were placed at 109,231 tons. Assuming shipments would have remained at the 1994 level without the program, 169,333 tons of above-baseline GHPs were shipped during the years 1995 – 1999. Therefore, it is theoretically possible that 150,000 of the 169,333 tons, or 89 percent of the above-baseline shipments, were influenced in some way by the GHPC program.

Over the 1994 – 1999 period, a total of $23.7 million flowed directly through the GHPC, 80 percent from DOE. It is believed that utilities directly spent an additional $37 million on GHP market mobilization programs in their service territories, bringing total program spending to about $60 million.[46]

At the beginning of the Bush administration in January 2001, the emphasis at DOE became expanding energy supplies of all types. In this context, the new leadership at the DOE's Office of Energy Efficiency and Renewable Energy (EERE) embarked on a major reorganization away from sectors (buildings, transportation, industry, power, etc.) to programs. Then the programs were refocused on long-term, high-risk research wherever possible, with funding emphasis placed on the renewable power generation programs. After all of this reinvention was done, the GHPC's DOE sponsor—the Office of Power Technologies Geothermal Division within EERE—no longer existed. In its place was the current Geothermal Technologies Program, with an exclusive focus on geothermal power generation.

The GHPC continued to operate for a number of years after the last of the funds received from DOE were utilized, surviving by seeking funding from states, utilities, and the GHP industry. As of October 2008 the GHPC is strictly an advocacy and government relations organization sponsored by the GHP industry and no longer seeks to implement programs for sponsors.

4.1.1.2 FEMP's GHP Technology-Specific Program

At about the same time as the National Earth Comfort Program was getting underway, FEMP was formed "to reduce the cost and environmental impact of the government by advancing energy efficiency and water conservation, promoting the use of renewable energy, and improving utility management decisions at Federal sites."

At the time, FEMP was one of the sectors within DOE's Office of EERE. The primary mission of all the sectors within EERE except for FEMP was technology R&D. FEMP's mission was multi-faceted, but its most relevant aspect to this report is its effort to help all U.S. federal agencies meet their mandates to reduce non-renewable energy use in U.S. federal buildings. The mandate that drove agencies during most of FEMP's GHP program was Executive Order 13123 issued by President Clinton.[47]

U.S. federal energy goals are expressed in terms of intensity of non-renewable energy use (site usage in Btu per building area). Based on the executive order, the goals for 2005 and 2010 were 30 and 35 percent reductions in energy use intensity, respectively, in comparison to 1985 energy consumption.

Over the years leading up to the executive order, FEMP had developed a portfolio of strategies for helping agencies meet their goals. These included design assistance to help agencies design and construct new buildings right the first time, technical assistance to help agencies maximize savings per dollar invested in retrofit projects, and guidelines making it easy for agencies to select equipment from among the most efficient available in each product category when making purchases. However, agencies projected that over 80 percent of the annual savings required by the executive order would need to come from retrofits of existing buildings, and appropriations would fall far short of being able to fund all of the retrofit projects necessary to meet the goal. To close this gap FEMP accelerated efforts to make private funds and expertise available to agencies through Energy Savings Performance Contracts (ESPCs) and Utility Energy Services Contracts (UESCs).

The executive order goals were also aggressive enough so that simply churning out retrofit projects to install mainstream technologies would also fall short. FEMP began looking for technologies that were commercially available, that were proven but underutilized, that saved energy and money, had strong constituencies and momentum, and were wanted by but not readily accessible to agencies. GHPs met these criteria, so FEMP initiated a technology-specific program.

FEMP did not reinvent itself or seek incremental appropriations to sponsor its emphasis on GHPs. Instead, it allocated a small portion of its existing funding to help agencies implement GHPs through its ongoing agency assistance programs. For example, retrofits of existing buildings represented the largest opportunity to implement GHPs, with ESPCs and UESCs, as well as appropriations, providing the funding. FEMP was able to cost-effectively support agency use of GHPs in ESPC, UESC, and appropriations-funded energy projects by supplementing its nationwide teams, which were already providing specialized assistance with energy projects to agencies, with the “GHP core team,” which consisted of a few GHP technical experts at DOE’s Oak Ridge National Laboratory (ORNL).

When FEMP’s GHP program was being planned, only a small percentage of federal sites were served by electric utilities offering GHP projects through UESCs. And FEMP was not sure that the regional “all-purpose” energy service companies (ESCOs) offering ESPC projects would emphasize GHPs either. Therefore, FEMP decided to include a special worldwide GHP Super ESPC procurement as a component of its GHP program. This step ensured that every federal site worldwide would have access to several quality sources for development, financing, and implementation of GHP projects. Since every project implemented under these umbrella contracts was required to include GHPs, these ESCOs were highly motivated to find agency sites where pay-from-savings GHP projects were feasible.

The GHP core team provided technical support to the DOE procurement officials who competitively awarded the GHP Super ESPC contracts. Then through FEMP’s ongoing nationwide energy project assistance programs, the core team provided direct technical assistance to agency customers and to the ESCOs, utilities, and subcontractors who were implementing GHP projects. During the four years from 1998, when FEMP established its GHP emphasis program, through 2001, FEMP spent $1.05 million on these endeavors.

FEMP’s GHP emphasis was highly successful at leveraging agency investments in GHP projects, and a key ingredient was hard data proving the benefits of GHPs in terms of reducing maintenance and energy costs. A rigorous evaluation of a 4000-home GHP retrofit at Fort Polk, Louisiana, provided the evidence that tipped the scales toward agency confidence in the technology.[48] The overall electricity consumption of Fort Polk’s city of 12,000 people was reduced by 26 million kWh per year (33 percent), summer peak electric demand was reduced by 7.5 MW (43 percent), and the annual electric load factor increased from 0.52 to 0.62. The Army carried out small GHP demonstrations and worked diligently for years at Fort Polk to justify the large, 4000-home project and make it happen. After the fact, the rigorous, unbiased, and statistically valid evaluation of the project, and efforts by many others, won over skeptical agencies and accelerated the pace of federal GHP projects.

In another study of about 50 schools in the Lincoln Nebraska school district, 4 of which had GHPs, it was determined that competitive first cost plus annual savings in energy and maintenance costs made GHPs the district’s lowest life-cycle-cost HVAC option.[49]

Independent studies like these contributed greatly to agency confidence in the technology.

GHP shipments to the federal market increased more than ten-fold from FY 1999 to FY 2001. FEMP examined contract documents and interviewed agencies to determine that about 24,000 tons of GHP capacity were placed in FEMP-assisted projects during those years. The Department of Defense (DoD) was by far FEMP's largest customer for its GHP emphasis program.

Congress requested a report from DoD on the use of GHP systems in Defense facilities in 2006.[50] A data call was issued to relevant DoD installations in March 2006, and based on a 93 percent response rate an inventory of GHP projects was assembled. This inventory indicated that a total of 52,000 tons of GHP system capacity had been installed through 2005.[51] Forty-two percent of the GHP capacity had been installed using UESCs, 38 percent using ESPCs, and 20 percent using appropriations. Figure 4 shows the year-by-year capacity additions and cumulative installed capacity of GHPs from 1988 through 2005, along with GHP capacity then in the financing and construction phases and expected to become operational during 2006 through 2009. DoD represents about 66 percent of all federal building floor space,[52] so if GHP uptake across all federal agencies was similar to DoD, the total federal GHP installed capacity in 2005 would be about 79,000 tons.

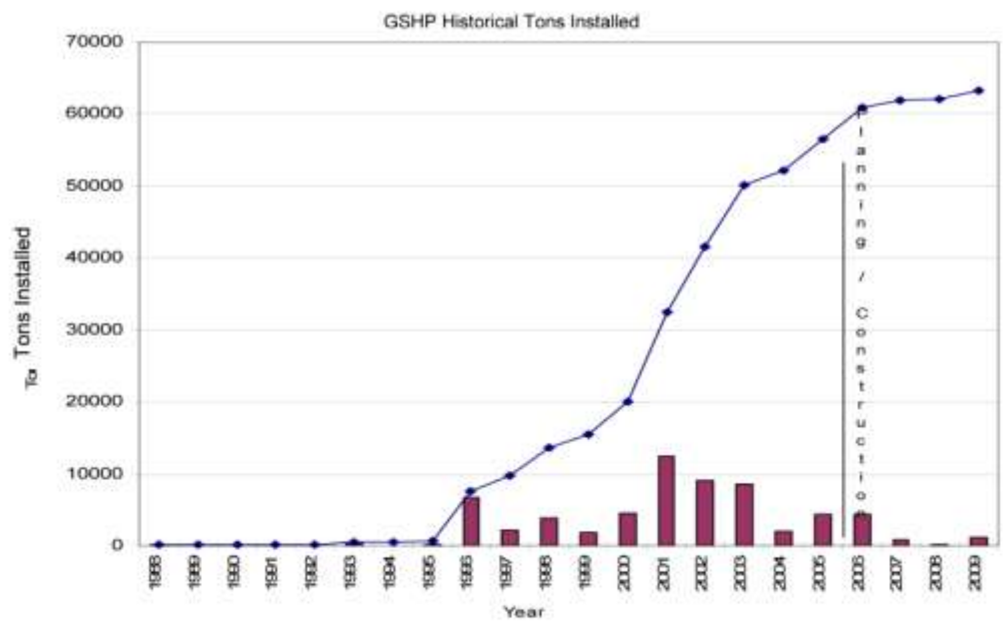

Fig. 4. Annual and cumulative capacity tons of installed and planned (or in construction) GHPs.

If not for several federal policy lapses DoD's use of GHPs may have continued to this day at rates established from 2001 to 2003. First, federal ESPC authority was allowed to lapse on October 1, 2003. Although DoD took the initiative to restore ESPC authority 14 months later in the 2005 Defense Authorization Bill,[53] by then much of the GHP project pipeline had diffused away. A second policy mistake damaging to federal agency use of GHPs occurred in 2005 when the Energy Policy Act[54] defined renewable energy that counted toward agency renewable goals as power generation only, excluding thermal forms of renewable energy such as GHPs.

The success of FEMP's GHP program is most obvious in the fact that GHPs are no longer regarded by agencies as a "bleeding-edge" technology. FEMP still provides technical assistance to agencies implementing GHP projects (as well as for other renewable technologies), but virtually all energy services contractors (UESC and ESPC) are willing and able to accommodate the demand for GHPs in federal energy projects, and no technology-specific contracts are included in the second generation of DOE's Super ESPCs. It remains true, however, that GHPs do not count toward agency renewable goals and experienced and competitive GHP installation infrastructure is not available locally to many federal sites, and in these instances projects must be large enough to attract contractors from afar.

4.1.2 Current Status of the GHP Industry in the United States

The GHP industry is comprised of manufacturers of water-source heat pumps (WSHPs), high-density polyethylene (HDPE) pipe and fittings, circulating pumps, and specialty components, as well as a design infrastructure, an installation infrastructure, and various trade allies, most notably electric utilities. The following review of the industry's current status pays special attention to where bottlenecks could occur if the GHP industry were to expand rapidly.

Some of the WSHP manufacturers have been in business since the late 1950s serving the original Florida residential "pump and dump" market, or since the early 1960s serving the California market that quickly spread nationwide and became known as the water-loop heat pump (WLHP) market. Today the WSHP manufacturers serve both the WLHP and GHP markets. A total of about 230,000 WSHP units are shipped annually for domestic applications,[55] of which about 60,000 serve GHP applications. Given their long history, most of the manufacturers are stable and have well-established supply chains and paths to market.

A small group of manufacturers including ClimateMaster (a unit of LSB Industries), Florida Heat Pump (a unit of Bosch), WaterFurnace International, Inc., and Trane (a unit of Ingersoll Rand) are believed to produce most of the GHP units, supplemented by McQuay International (a unit of Daikin), Mammoth, and several regional manufacturers. Other major brands such as Carrier participate in the WLHP and GHP markets by sourcing WSHP units from other manufacturers.

WSHP manufacturers would have no problem scaling up production to support a rapidly expanding GHP industry. In fact if this were to occur, considerable economies of scale, manifesting as lower unit prices, may be possible. The largest of the WSHP manufacturers ship on the order of 100,000 units annually, whereas the largest of the air-source heat pump (ASHP) manufacturers ship on the order of 1 million units annually. This difference of a factor of 10 in shipment volume, plus the higher selling and training costs of GHPs explain why GHP units are currently 50 – 100 percent more expensive at retail than ASHPs of comparable capacity and component quality. (Note that top-of-the-line gas furnace and air conditioner combinations are about the same price as GHPs).

The greater selling and training costs for GHPs merit some explanation. In the case of selling, in residential markets for example, consumers already want air conditioning but GHPs are a more expensive and different way of obtaining it than ASHPs or furnace and air conditioner combinations, so consumers must be educated about GHPs and sold on them. The GHP supply chain (original equipment manufacturers or OEMs, distributors, dealers) must bear these extra selling costs and include them in the price of their product.

The GHP supply chain also bears extra training costs in a number of areas compared to conventional equipment alternatives. The typical new HVAC design engineer learns on the job from practicing engineers who only know how to design conventional systems. The typical trade school grad also learns HVAC installation and service largely on the job where the mentors only know conventional systems. Breaking into these networks important to both conventional and GHP systems, and developing non-existent infrastructure for installing the ground loops, involves extra education and training costs born by OEMs, OEM-sponsored associations, or others in the GHP supply chain.

Compared to the typical single-package indoor WSHP used in GHP systems, a split-system ASHP requires indoor and outdoor units, must be capable of operating against a much higher lift between the heat source and sink temperatures, and requires a defrost cycle and controls to prevent frosting of the outdoor coil. Theoretically, at the same shipment volumes, WSHP units should have lower prices than ASHP units because they require less sheet metal, copper and aluminum, a smaller compressor, and significantly fewer electronic controls. If GHPs became a standard high-volume option, the premiums paid at retail versus ASHPs could disappear due to the inherent lower manufacturing costs at comparable scale, and gradual reduction of selling and training cost premiums as GHP systems infiltrate curriculums at engineering and trade schools, and the base of GHP design and installation practitioners grows and supports its own on the job training.

In addition to serving GHP applications, HDPE pipe is used in oil production fields and for natural gas gathering, natural gas distribution, sewerage gathering, potable water distribution, landfill gas gathering, industrial applications, and irrigation. The manufacturing base is large and well established. It is believed that Performance Pipe (a unit of Chevron-Philips), ISCO Industries, and Centennial Plastics are the largest suppliers of HDPE to the GHP market. If the GHP industry were to rapidly expand, the current suppliers plus others would have no problem keeping up with demand, and greater scale would likely enable price reduction.

Circulating pumps, propylene glycol anti-freeze, plate heat exchangers, fluid coolers, and many other products used in GHP systems are already mass produced to serve markets much larger than the GHP market. Greater scale in the GHP market may have only modest downward pressure on pricing, but manufacturers would have no problem keeping up with demand.

There are some specialty products unique to the GHP market such as flow centers, flush carts, purge pumps, pump stations, headers, vaults, hose kits, thermally enhanced grouts, specialty installation equipment, and surface water immersion heat exchangers. It is believed that if demand for these items expanded rapidly the existing firms plus new entrants would be able to keep up with demand.

Design infrastructure is an area that would require significant attention to enable the GHP industry to expand rapidly in commercial applications. There are now a significant number of competent and experienced designers of commercial GHP vertical-bore systems but the number is still a small percentage of HVAC design engineers in general. Many developers and building owners (i.e., the owners) have established relationships with their individual independent and trusted design engineers, so even if the owner becomes interested in GHP the engineer must be educated and convinced. Designers are wary of liability, and the industry's fee structure does not accommodate a lot of learning time, so off-the-shelf solutions from past jobs are common because they are safe.

An additional issue is that the commercial GHP industry has become a one-trick pony to some extent, promoting mainly vertical-bore systems. This is because robust commercial design tools for anything else do not exist. Ground resources — including the Earth, surface water, recycled gray water, sewage treatment plant effluent, retention basin storm water, harvested rainwater, and water from a subsurface aquifer — whether alone or in combination with outdoor air in a hybrid configuration, all merit consideration during the design process. Much progress is needed to develop a design infrastructure capable of expeditiously finding and designing the best-value GHP infrastructure for every project.

There has always been a strong argument that GHP infrastructure should be classified as utility-owned plant, since loops (like other utility plant) will outlive the building and many generations of heat pumps. How much positive GHP market impact this can have will be tested shortly when RECs begin using their new authority to borrow money from USDA/RUS at the cost of government funds over 35 years for the purpose of installing loops for customers. RUS anticipated that increased penetration of GHPs in REC service territories would have a positive effect on load shapes and reduce peak demands, thereby reducing average cost per kWh for all consumers.

For utility-owned GHP infrastructure, the design requirements may shift somewhat, placing greater emphasis on having adequate capacity for a building, or in an area or community, to accommodate anticipated future growth, or to design in provisions for future expansion. Utility ownership could potentially spur the development of a design infrastructure that routinely considers all of the options, not just vertical-bore configurations.

Any rapid expansion of the GHP industry would be more likely with the enthusiastic support of the electric utility industry and their regulators and ratepayers. RECs remain electric distribution companies keenly interested in shaving peak loads and fostering higher annual load factors on their systems. The electric industry restructuring frenzy that came and went has changed other types of electric utilities forever, and in general demand-side activities to shave peak loads and achieve higher load factors are on the upswing. Whether expanding the GHP industry would achieve "top five" status among potential areas of emphasis by IOUs, as was the case in 1993, remains to be seen. Compared to GHPs, one hears more in the media lately about utility interest in strategies such as electrification of the transportation sector, de-carbonization of electricity, demand-response, renewable power generation, and smart grid.

Installation infrastructure is another area that would require significant attention to enable the GHP industry to expand rapidly. Currently experienced and competitive installation infrastructure exists only in portions of some states. Top-tier states are mostly in the Midwest and East. Listed in no particular order, other than West to East, they are Texas, Oklahoma, Nebraska, Missouri, Iowa, Illinois, Indiana, Michigan, Ohio, Kentucky, Tennessee, New York, Pennsylvania, Maryland, Virginia, and Florida. Second-tier States with activity, this time East to West, include Massachusetts, New Jersey, North and South Carolina, Georgia, Alabama, Wisconsin, Minnesota, North and South Dakota, Colorado, Utah, and California.

Just because a state is listed does not mean high-quality GHP installation infrastructure exists everywhere in that state. For example, experienced and competitive infrastructure exists in Dallas-Fort Worth but not Houston, in Tulsa and Oklahoma City but not in Edmond, and in Indianapolis and Fort Wayne but not in Gary. Residential infrastructure especially is restricted to strong pockets in a few states, whereas large commercial and institutional projects can generally attract bids from contractors willing to travel. The cost of installing GHP infrastructure for projects where experienced and competitive installation infrastructure cannot be accessed can be 100 to 400 percent higher for the ground heat exchanger.

In residential markets, ample HVAC contractors can be found and trained, because in many ways GHPs are simpler than air-source heat pumps, but there is a lack of loop specialists. Customers get excited about the technology but then cannot find the infrastructure to get GHPs affordably installed. HVAC contractors are generally not capable of doing their own loops until they start doing a large quantity of jobs and can justify such diversification. This is especially true for jobs involving vertical or horizontal bores as opposed to horizontal trenching.

In commercial markets also the mechanical contractors are generally not capable of installing their own loops, and currently the vast majority of projects involve drilling. Experienced GHP drillers are in rather short supply. The drilling side of the GHP industry is not organized in any meaningful way, and unless the situation changes it may be difficult for the GHP industry to expand rapidly. There may be significant slack capacity among water well drillers in some parts of the country due to the construction slump, and these rig operators would be excellent converts to the GHP industry because they already understand ground water protection and the local geology.[56] However, training would be required because the drilling requirements are significantly different, and some aspects of the job totally new, such as working with HDPE pipe, loop insertion, thermally enhanced grouting, and construction of loop headers by connecting pipes with thermal fusion. Fortunately several quality training programs already exist for voluntary certification of vertical borehole heat exchanger drilling and installation contractors.

Today's GHP industry is better positioned for rapid growth than it was in 1993 in many respects. Not only has the industry grown with the help of past federal and utility programs, but it has proven that it can stabilize and grow on its own again when such programs disappear. The technology is proven, with an installed base in the U.S. exceeding 600,000 GHP units. Tax credits for home and business owners investing in GHP systems were enacted in October 2008 through 2016. Since 2007, RECs have been able to obtain loans from USDA/RUS with terms of up to 35 years, at the cost of government funds, to provide the outside-the-building portion of GHP systems to customers in exchange for a tariff on the utility bill, which would be more than offset by the GHP system's energy cost savings. In December 2007 Congress directed the General Services Administration (GSA) to establish a program to accelerate the use of more cost-effective energy-saving technologies and practices in GSA facilities, starting with lighting and GHPs. A growing number of States offer tax credits or other forms of incentives for GHP systems.[57]

The diverse segments of the GHP industry are better able to work with each other as a cohesive whole, than ever before. The installed base of systems is much larger today and can serve to inform best practices. The most important trade allies to the GHP industry, electric utilities, today are better able to focus on peak load reduction and improved load factor, two key GHP system benefits, than they were in 1993 when restructuring was looming.

The infrastructure of support organizations is also much stronger now than it was in 1993. IGSHPA, which represents all segments of the industry, has matured, provides the nation's only major conferences and exhibitions totally focused on GHP technology, and has developed respected training for drillers and installers. GHPC has been reconstituted as an advocacy and government relations organization sponsored by the GHP industry. The ASHRAE Technical Committee, TC 6.8 Geothermal Energy Utilization, has made great strides in the development of the technical foundation for sound design of commercial GHP systems. The National Ground Water Association (NGWA) is more engaged than ever. National laboratory and university expertise persists, even though there have never been reliable funding sources to sustain GHP programs at these institutions.

4.2 Status of GHP Technology in the United States

The following review of the GHP industry's current technology status pays special attention to areas where technologies and techniques could be improved to reduce first cost and/or improve performance. Recent surveys of GHP technology and techniques are available elsewhere and are not summarized here.[58, 59]

Today's GHPs move 3 – 5 times as much energy between the building and the ground than they consume while doing so. If there were sufficient motivation, the GHP industry could integrate the most advanced commercially available components into their heat pumps and increase this multiplier effect to 6 – 8, and theoretically the multiplier could be as high as 14.[60] The Asian manufacturers in particular are mass producing concepts such as variable-speed compressors, variable-refrigerant-flow systems, integrated heat pumps that serve multiple uses (e.g., heating, cooling, and water heating) and heat pumps using CO_2 as the refrigerant.

The size of the European and Asian GHP markets has surpassed the U.S. market, and part of the reason may be that other countries are more aggressively pursuing system cost reduction and performance increases through research. Chinese reports state that GHP technical literature and patents are up by a factor of 5, comparing 1999 and annual averages from 2000 through 2003.[61] At the 2008 International Energy Agency Heat Pump Conference there were 37 technical papers and presentations in the "Ground and Water Source Heat Pump Systems" track, and only three were by U.S. authors,[62] presumably because the United States has no GHP research program.

Topics being researched in other countries include single-well groundwater supply and return systems, use of foundation piles as ground heat exchangers, compact horizontal loops reloaded via heat exchange with exhaust air, and development of devices to test borehole heat exchanger installation quality.

Research is a common strategy to achieve price reduction and performance enhancement, and the United States is under-investing compared to the rest of the world. To the author's knowledge, the only ongoing federal GHP research consists of two modest projects sponsored by the DOE Building Technologies Program and conducted by ORNL with industry and university partners. One project is developing a ground-source integrated heat pump (GS-IHP) — a single unit replacing separate heating and cooling, water heater, and dehumidifier — based in part on advanced Asian components. The other project is developing and validating design tools and models for ground heat exchangers installed in the excavations needed anyway to build the building. Extremely energy efficient buildings can now be built (high-R, airtight envelope, GS-IHP or other extremely efficient equipment) with remaining thermal loads so low that in some climates, these so-called foundation heat exchangers will be all a GHP system needs.

ASHRAE-sponsored GHP research was fairly active in the early 2000s but has dwindled in recent years because of the lack of federal or other co-sponsorship. One project addressing some aspects of hybrid system design was recently completed.[63] Also notable, industry recently sponsored the integration of improved vertical ground heat exchanger and GHP system representations into eQUEST, a building energy analysis method that is credible (based on DOE-2) but also relatively easy to use.[64]

The dominant GHP system configuration, especially in commercial applications, is based on the vertical borehole heat exchanger (BHEX). In these systems the BHEX accounts for a large share of the GHP system price. One step design practitioners could take immediately to reduce GHP system price without sacrificing performance would be to design hybrid systems instead of pure BHEX systems for applications where the amount of heat to be moved from the building to the ground far exceeds the amount to be moved from ground to building on an annual basis. In a hybrid system, shallow surface water or a fluid cooler is generally added to reject excess heat to ambient air, enabling the BHEX to be significantly reduced in size.

Another important cost-reduction technique that could be considered immediately would be to mobilize markets in a way that enabled the drilling to be done in a more organized fashion. Significant price reduction is possible through improved driller asset utilization and competition. For example, when a driller is competitively awarded a contract for hundreds of boreholes in hard limestone with no mobilization other than moving between holes, BHEX systems can be installed for $5 – 6 per bore-foot. However, if there is no aggregator in the market to create opportunities with hundreds of boreholes, and if the local GHP installation infrastructure is inexperienced, these costs can run as high as $20 – 24 per bore-foot even with competition. An unsteady stream of small one-off projects is insufficient to either develop local high-quality installation infrastructure or attract experienced contractors from outside the area. The absolute value of the high- and low-end pricing will vary for drilling conditions other than hard limestone, but aggregation can push pricing in the right direction regardless of drilling condition.

BHEX cost reduction could be achieved through research and development leading to optimization of driller's equipment to automate the entire installation process. The process involves more than just drilling, and other functions such as loop insertion, grouting and heat fusing of pipe must also be considered. Optimal driller's equipment for BHEX installation would likely vary by drilling condition.

There also appears to be significant GHP infrastructure cost reduction potential through inclusion with emerging integrated approaches for design of the infrastructures for water supply, use, and management (drinking water, rainwater, gray water, collected condensate, wastewater, storm water) in general, including low-impact development approaches that are becoming more commonplace.[65] Rather than brute force BHEX systems, in many parts of the country it may be possible to achieve more affordable GHP heat sources and sinks of equal quality through integration with these other systems and the natural hydrological cycle at the scale of the site, neighborhood or community. For example, low-impact permeable pavements and soil-based vegetative practices to filter runoff, reduce surface runoff, and infiltrate water into the ground to recharge streams, wetlands and aquifers could channel the infiltrating waters through horizontal ground heat exchangers.

While there is a litany of things that could be done to reduce cost and improve performance, it is important not to lose sight of where the GHP industry's technology and techniques currently are with respect to the value proposition that can be offered customers. For residential new construction and retrofits and commercial retrofits, GHP systems tend to be the most expensive of the alternatives considered and must justify themselves on the basis of superior amenities (comfort, zone control, quiet operation) and energy, demand, and maintenance savings over the life-cycle. In commercial new construction, such as in K-12 schools, it is possible for GHP systems to have first costs similar to at least some of the conventional alternatives, but even here a higher first cost is most common.

DoD, perhaps the largest single customer for GHP retrofit projects, reports that in 2006 dollars housing and commercial retrofits cost $4600 and $7000 per ton respectively, and simple paybacks in the two regions with the most installed capacity averaged 8.6 to 12 years.[66] Retrofits in the private sector would likely be similar in cost and payback. New construction has the potential to be more economical because part of the first cost is offset by the avoided cost of the displaced conventional system, but simple paybacks exceeding 5 years are still common.

First cost and long payback periods clearly limit GHP system acceptance in many markets. Today in the commercial markets, GHPs are primarily limited to institutional customers (federal, state and local governments, K-12 schools, etc.) that take the life-cycle view. In residential markets, GHPs are limited to a small subset of newly constructed homes where the homeowner builds to occupy and wants the best available system, and to home retrofits where the owner plans to occupy the premises long enough to justify the investment. In all of these cases the building owner must have the financial wherewithal to use their own credit to finance the system.

5. Energy Savings Potential for GHPs in the United States

This study was not afforded the time or resources to support new modeling efforts, so this section of the report summarizes past estimates of the energy savings potential of GHPs in the existing building stock. In some cases where enough detail on the previous methodologies was available, the previous estimates have been updated by using more recent data. A simple “back of the envelope” estimate of savings potential in new construction out to 2030 has also been added.

EIA, in a report supporting development of the National Energy Strategy, estimated GHP energy savings potential at 2.7 quadrillion Btu by 2030, up from less than 0.01 quad in 1990.[67]

The next estimate is based on previously published methodologies for estimating the energy savings potentials of GHPs in commercial[68] and residential[69] applications, but using the most current data to generate updated estimates. Then the commercial and residential estimates were added to obtain a total savings potential. It should be noted that these estimates are technical energy savings potential estimates, defined as the annual energy savings that would occur relative to “typical new” equipment if GHPs were installed overnight in all reasonable applications in existing buildings. It does not consider that the actual ultimate market penetration into the existing building stock would be less than 100 percent. Neither does it consider the time required for GHPs to diffuse into the market or additional energy savings potential in new construction.

In a nutshell, the commercial methodology assumes that high loads per building footprint area and building density will limit GHPs in downtown areas; and since about 28 percent of the population lives in towns with 100,000 or more people, the estimate assumes that 28 percent of the otherwise reasonable applications are off-limits. Other applications ruled unreasonable include displacing rotary screw and centrifugal chillers, room air conditioners, boilers (since they generally pair up with the aforementioned chillers), and infrared radiant and district heat. The remaining reasonable applications consume 1.6 quads annually based on data at the time of the study and 2.6 quads today. TIAX estimated that GHPs would save 30 percent relative to “typical new” equipment, which is reasonably consistent with internal ORNL analysis based on data from a recent ASHRAE research project[70] and a detailed case study.[71]

The residential methodology assumes that the reasonable applications for GHPs were heating, cooling, and water heating in homes that were heated and cooled with either combinations of furnace and central AC, or ASHPs. These applications consume about 3.7 quads annually, and the study estimated 45 percent savings relative to typical new equipment. These savings levels are reasonably consistent with several ORNL detailed case studies of very large projects in military family housing,[72,73] when one considers the GHP efficiency levels available today and emerging equipment that satisfies the entire water heating load.

The sum of commercial (0.8 quad) and residential (1.7 quad) estimates totals approximately 2.5 quads of primary energy that could be saved by GHPs annually, if fully deployed to the existing building stock. The estimate is remarkably similar to the 2.7 quads estimated by EIA in 1990.

On May 16, 2006, the National Renewable Energy Laboratory (NREL) hosted a workshop with experts from the geothermal community.[74] The goal of the workshop was to gather and summarize expert opinions about the potential of various geothermal resources for generation of electricity and utilization of heat energy. The workshop was not a formal assessment, but a recorded discussion by a group of experts who collectively stated their opinions based on their experiences, knowledge, and interpretations of various detailed assessments. The report estimates 7385 MWt of GHP capacity existing in the United States at that time, which is consistent with Rybach's estimate of 7200 MWt (or 600,000 units, since the typical GHP size is about 12 kWt) the previous year. The report defines "estimated developable resource" as the subset of the accessible resource base that the workshop experts believed likely to be developed in future years. For GHPs, the estimated developable resource was stated as 18,400 MWt in 2015, 66,400 MWt in 2025, and >1,000,000 MWt in 2050.

The value of 1,000,000 MWt corresponds to 83.3 million typically sized GHP units in service. The report includes a conversion to delivered geothermal energy annually via GHPs of 15 quads in 2050 based on the assumption that all 83.3 million GHPs run 50 percent of the time (4380 hours per year) in heating mode, which is unrealistic.

Needed is an estimate of the quads of non-renewable energy that can be saved annually through use of GHPs, rather than an estimate of the renewable geothermal energy available to be supplied whether it is needed or not. It would be difficult to determine a per-unit savings for the previously cited commercial analysis by TIAX because of the way the analysis was structured, but if the per-unit savings (36 million Btu/yr) from the previously cited residential analysis (Fischer, et al.) were applied to the 83.3 million units, the result would be about 3 quads annually, which is comparable to the other estimates.

These three savings estimates are comparable, ranging from 2.5 to 3 quads annually, but none of them explicitly address the additional savings potential in new construction. For the sake of completeness the author generated a back-of-the-envelope estimate for new construction.

For the residential new construction savings estimate, a simple spreadsheet was constructed that calculates the savings (quads/year) for EIA-base-case household additions each year, and then adds them to obtain the savings in 2030 due to all household additions between now and then. Not all the quads EIA would project for heating, cooling, and water heating in each year's household additions, represent reasonable applications for GHPs. Following the Fischer, et.al., methodology, the proportion of the total where households were heated and cooled with either furnace and central AC combinations, or air-source heat pumps, was deemed reasonable. The proportion that was reasonable based on 2006 data was assumed to continue through 2030. Again, the estimate assumed 45 percent GHP savings relative to "typical new" equipment in reasonable applications.

For the commercial new construction savings estimate, a second simple spreadsheet was constructed that calculates the savings (quads/year) for EIA-base-case floor space additions each year, and then adds them to obtain the savings in 2030 due to all floor space additions between now and then. Again, not all the quads EIA would project for heating, cooling, and water heating in each year's floor space additions, represent reasonable applications for GHPs. Following the TIAX methodology, the proportion that was reasonable based on 2006 data was assumed to continue through 2030. For the projection out to 2030, it was also assumed that in new construction, GHP systems could address refrigeration and ventilation end uses, as well as heating, cooling, and water heating. However, the same proportional value was used to reduce the EIA refrigeration and ventilation quad projections, to those reasonable for GHPs to address. The estimate assumed 30 percent GHP savings relative to typical new equipment in reasonable applications.

Data from EIA[75] and DOE[76] were used to generate the new-construction GHP savings estimates, which came in at 0.42 and 0.48 quads respectively for residential and commercial, for a total of 0.9 quads by 2030. Adding the 2.5 to 3 quads annually for GHP retrofits and presuming they also could be accomplished by 2030, the total GHP energy savings potential ranges from 3.4 to 3.9 quads annually in 2030. Since buildings are projected to be consuming 49.5 quads of non-renewable primary energy in 2030,[77] the estimated GHP potential savings range from 7 to 8 percent of the total. Expressed in another way, between 2008 and 2030 non-renewable primary energy use in buildings is expected to grow from 40 to 49.5 quads, and by saving 3.4 to 3.9 quads over this time frame GHPs have the potential to reduce this growth by about 35 to 40 percent. It should be noted that GHPs may also have savings potentials in agriculture and industry that are not included in these estimates.

The energy savings of 3.4 to 3.9 quads corresponds to $33 to 38 billion annually in reduced utility bills at 2006 rates. GHPs displace a variety of fuels, therefore to estimate the utility bill savings it was assumed that the average residential and commercial buildings fuel mixes were displaced.[78]

The energy savings of 3.4 to 3.9 quads also corresponds to a 91 to 105 GW reduction in summer peak electric utility demand, assuming the same relationship between demand reduction and primary energy savings as was measured as a result of retrofitting 4000 military family housing units with GHPs at Fort Polk, LA. Expressed in another way, GHPs could potentially avoid 42 to 48 percent of the nation's 218 GW net electricity generation capacity additions projected to be needed by 2030.[79]

It should be noted that the above estimates of the technical potential for GHP energy savings are calculated versus a baseline of typical new equipment, not the existing stock. This approach conforms to the traditional view that new equipment has higher efficiency than the existing stock (minimum efficiency standards rise over time), some energy savings will occur through normal replacement cycles without further federal action, and this portion of savings would be double counted if the existing stock were used as the baseline in our estimates. Further, the above estimates only consider GHPs displacing incumbent systems in "reasonable" applications.

If stimulating the economy or climate change or other policy drivers were urgent and, for example, as a matter of public policy every building in America had GHP infrastructure available to it for connection, then the above technical energy savings potentials would be conservative for two reasons. First, waiting for normal replacement cycles would not be acceptable because action is urgent, so the proper efficiency baseline for the savings calculation would become the installed base, rather than typical new equipment. Second, the existence of GHP infrastructure that was financed at favorable rates over 35-years would dramatically expand GHP's "reasonable" applications.

Out of curiosity a residential GHP technical energy savings potential estimate was made using the installed base as the efficiency baseline and assuming all applications were reasonable for GHPs. Under these assumptions the residential savings potential previously estimated as 2.12 – 2.46 quads approximately doubled. Presuming commercial savings also doubled, the 3.4 to 3.9 quads would become 6.8 to 7.8 quads annually in 2030.

The author makes no claim that these very large energy savings potentials are economically achievable, but it does appear that achievable savings would be greatly influenced by whether, as a matter of public policy, a significant portion of the nation's buildings gained access to GHP infrastructure on an expedited basis.

6. Key Barriers to GHPs in the United States

When applied to buildings, GHPs face many of the same barriers to adoption as other direct-use renewable energy and energy efficiency technologies. However, these general buildings sector barriers, as well as what can be done about them, are described elsewhere.[80] This section of the report focuses on the barriers that are specific to GHPs.

In 1994 the National Earth Comfort Program[81] identified first cost, confidence or trust in the technology, and design and installation infrastructure as the primary barriers, and the GHPC organized implementation of the program around three operating committees, with each expected to address one of the three primary barriers. These committees were (1) First Cost Competitiveness Committee, (2) Technology Confidence Building Committee, and (3) Infrastructure Strengthening Committee.

In 1998 in federal markets, first cost was less of an issue due to greater tolerance for the life cycle view, but FEMP[82] identified the primary barriers as confidence or trust in the technology, lack of technical foundation and data needed to conduct a credible life-cycle analysis and design and specify GHP systems, and inadequate appropriations to direct-fund projects. To address confidence and trust, FEMP sponsored a small GHP core team at ORNL to evaluate a number of large GHP projects based on statistically valid hard data. To address the technical issues, FEMP sponsored ORNL to work on them collaboratively with IGSHPA, ASHRAE, federal agency customers, and others. To address the lack of direct funding, FEMP put in place the GHP-specific Super ESPCs and sponsored ORNL to assist agencies with GHP projects under ESPC and UESC contracts. The retrospective DoD study of their own GHP deployment experience identifies many of the same barriers as FEMP targeted.[83]

In 2003 NGWA surveyed the ground water industry's perceptions of the barriers to GHPs.[84] Participants were asked to respond to the question: "What do you see as the single most important or significant market entry barrier to the ground water industry's participation in the construction of geothermal heat pump systems?" NGWA defined market entry barrier as any circumstance or feature of a market which inhibits or deters a firm from entering it. The survey resulted in the following list of barriers in order of priority (1 being the most important barrier):

1. Promotion to increase potential end-user awareness of GHP technology (i.e., marketing, promotion, tax credits, energy cost rebates, etc.)
2. Costs to the end-user when purchasing GHP technology
3. Prices payable to industry professionals (i.e., subsurface geophysical surveys, borehole drilling, etc.)
4. Training and education of industry professionals who could be or are involved in installing GHP technology
5. Alternate energy option affordability (i.e., natural gas, electric, fuel oil, propane, etc.)
6. Reputation of technology among end-users and their experiences
7. Volume of existing and potential GHP work within a service territory that an industry professional would desire to roam over
8. Commitment to GHP technology
9. Real-property issues (i.e., landscaping risk, lot sizes, lot access, etc.)
10. Regulation of GHP technology and installations

As part of this study the author informally surveyed GHP industry experts. Participants included individuals who: founded companies and associations that pioneered the GHP industry; focus on GHP markets on behalf of today's major suppliers of equipment, materials and services to the GHP industry; were intimately involved in the National Earth Comfort Program and FEMP's GHP emphasis program; sponsored those programs; were customers of those programs; design commercial GHP systems or provide specialized services to support such design; and who represent existing or potential installers of GHP systems. Although the author makes no claim that this survey was representative of the GHP industry and its customers, the survey was broadly based, and only people knowledgeable of the industry were asked for their input.

Participants were asked to respond to the question: "What are the key barriers to rapid growth of the GHP industry?" After the list of barriers was assembled the same group was asked to prioritize them. This new survey, conducted in October and November of 2008, resulted in the following list of barriers in order of priority (1 being the most important barrier):

Tier 1—

1. High first-cost of GHP systems to consumers

Tier 2—

2. Lack of consumer knowledge and/or trust in GHP system benefits
3. Lack of policymaker and regulator knowledge and/or trust in GHP system benefits
4. GHP design and business planning infrastructure limitations
5. GHP installation infrastructure limitations

Tier 3—

6. Lack of new technologies and techniques to improve GHP system cost/performance

The multiple tiers are included to indicate that barriers 2 through 5 had essentially the same level of support among survey participants, whereas barrier 1 was perceived as being of greater importance and barrier 6 of lesser importance than 2 through 5.

7. Actions that Could Accelerate Market Adoption of GHPs in the United States

When GHP industry experts were asked to identify and prioritize the barriers, almost every participant suggested solutions at the same time. The author assimilated these suggestions into 13 possible actions, and then asked the group of industry experts to prioritize them. The subset of suggestions receiving strong support is listed below in order of priority (1 being the highest priority):

Tier 1—

1. Assemble independent, statistically valid, hard data on the costs and benefits of GHPs. In other words, mine the installed base of GHP systems to assemble independent, statistically valid, hard data on installed costs and energy, demand, and maintenance savings versus baseline systems in existing GHP installations in major market segments (schools, federal, residential, etc.) by climate. The work must characterize not only the benefits to consumers, but also the benefits such as reduced peak demand and improved annual load factor that would accrue to RECs, utilities, or other third parties that might install GHP infrastructure for consumers in the future (see actions 3 and 4 below).

2. Independently assess the national benefits of aggressive GHP deployment. Conduct an independent assessment of the national benefits (energy, demand, cost, carbon, jobs) achievable from a maximum deployment strategy for GHPs, including comparisons to other supply- and demand-side options, on the basis of when benefits could be achieved, national investment required, and probability of success.

Tier 2—

3. Streamline and deploy nationwide REC programs to provide GHP infrastructure. Streamline and deploy USDA/RUS's new authority to finance RECs to provide GHP infrastructure to buildings (the outside-the-building infrastructure providing access to the geothermal energy source and heat sink) just as they provide electricity supply infrastructure, and recover the costs through a tariff on the utility bill.

4. Develop and deploy programs to provide universal access to GHP infrastructure. Develop, promote to regulators and utilities, streamline, and deploy programs for investor-owned and municipal utilities to provide GHP infrastructure to buildings just as they provide electricity supply (or natural gas or water and wastewater) infrastructure, and recover the costs through a tariff on the utility bill. In localities where utilities are not interested in this opportunity, enable others in the marketplace to do so.

5. Develop the data, analysis, and tools to enable lowest life-cycle-cost GHP infrastructure. Develop the data, analysis, and tools to enable engineering and business planning professionals to serve clients such as RECs, other utilities, not-for-profit special

entities, developers, building owner associations, energy service companies, owners of large numbers of buildings, single building owners, or others desiring to provide the public or themselves with GHP infrastructure in the most economical manner:

- Develop the engineering data, analysis, and tools to enable selection, design, specification, and construction of the lowest life-cycle-cost GHP infrastructure option as a function of varying conditions that may be encountered (drilling and trenching conditions, surface water availability, etc.) at the application's site and scale (building, neighborhood or community) ; and
- Develop the business planning data, analysis, and tools to enable selection of the ownership and financing deal structure that implements the lowest life-cycle-cost GHP infrastructure in the most economical manner for the GHP infrastructure owner and the owner's GHP customers, as a function of varying financial conditions that may be encountered (federal, state, and local tax incentives and treatment of depreciation; federal, state, and local financial incentives; emissions reduction credit ownership; whether rules and regulations allow any of the serving utilities to provide GHP infrastructure, utility interest in doing so) at the application's site and scale (building, neighborhood or community) .

Tier 3─

6. <u>Expand geographic areas where high-quality GHP design infrastructure exists</u>. This can be accomplished by improving training materials and training more architects, commercial HVAC designers, and true residential system designers.

7. <u>Expand geographic areas where high-quality GHP installation infrastructure exists</u>. This can be accomplished by improving training materials and training more drillers, loop installers, residential HVAC contractors, and commercial mechanical contractors and design/build contractors.

The relationships between the barriers and the actions to address them are summarized in Table 2, and a discussion of those relationships follows.

Interestingly, although the only Tier 1 barrier is first cost, the participating GHP experts rank most highly actions such as assembling independent, statistically valid, hard data from the installed base of GHP systems, and conducting an independent assessment of the national benefits of GHPs. Neither of these Tier 1 actions directly addresses first cost, but the sense of the group appears to be that a higher volume of GHP projects begets improved affordability, and that without hard data and documented benefits, policymakers, regulators, and consumers would be unlikely to advocate for and commit to actions, such as those in Tier 2, which would serve to build volume.

The GHP expert group appears to strongly support the notion that the outside-the-building portion of the GHP system, such as the ground heat exchanger, will outlive the building and many generations of heat pumps and is, in essence, a form of utility infrastructure. They believe that utilities in general (electric, natural gas, water and wastewater) should be allowed to use long-term financing to install, own, and operate GHP infrastructure with cost recovery through a tariff on the utility bill, and other entities should be allowed to do the same, since the utilities in some localities may not be interested.

Action 3 focuses on streamlining and deploying REC programs nationwide to provide GHP infrastructure to residential and commercial customers, since Congress has already granted the authorities and action can begin immediately.[85] So far one REC[86] has taken a loan under this new program and one other REC has filed an application. Apparently the GHP loop tariff would be $15 to $30 per month for most homes, less than the energy cost savings. The remaining indoor part of the GHP system that the customer still buys costs about the same as conventional alternative systems today, and could cost less in high-volume production.

Table 2. Barriers to Expanded Adoption of GHPs and Actions to Address Them

	Barriers					
	Tier 1— 1. High first cost of GHP systems to consumers.	Tier 2— 2. Lack of consumer knowledge and/or trust in GHP system benefits.	Tier 2— 3. Lack of policymaker and regulator knowledge and/or trust in GHP system benefits.	Tier 2— 4. GHP design and business planning infrastructure limitations.	Tier 2— 5. GHP installation infrastructure limitations.	Tier 3— 6. Lack of new technologies and techniques to improve GHP system cost/performance.
Actions						
Tier 1—						
1. Assemble independent, statistically valid, hard data on the costs and benefits of GHPs.		x	x	x		
2. Independently assess the national benefits of aggressive GHP deployment.		x	x	x		
Tier 2—						
3. Streamline and deploy nationwide REC programs to provide GHP infrastructure.	x	x	x	x	x	x
4. Develop and deploy programs to provide universal access to GHP infrastructure.	x	x	x	x	x	x
5. Develop the data, analysis, and tools enabling lowest-LCC GHP infrastructure.	x	x	x	x		
Tier 3—						
6. Expand geographic areas where high quality GHP design infrastructure exists.	x	x	x	x		
7. Expand geographic areas where high quality GHP installation infrastructure exists.	x	x	x		x	

Since most customers are not served by RECs, Action 4 involves using the REC programs as models and customizing and promoting them to other utilities and their regulators or municipal administrators, and to others in the marketplace such as not-for-profit special entities, developers, building owner associations, and energy service companies (ESCOs) who may be willing to provide access to GHP infrastructure while eliminating the first-cost premium of GHP systems.

Action 5 is an enabling action ─ without it Actions 3 and 4 cannot be accomplished. No matter who takes down the financing and picks up the tab for the GHP infrastructure ─ RECs, IOUs, MUNIs, not-for-profit special entities, developers, building owner associations, ESCOs, building owners ─ there is a fundamental need for engineering professionals to determine the lowest life-cycle-cost GHP infrastructure to install, and for business planning professionals to determine the most advantageous ownership and financing deal structure. These professionals must be armed with the data, analysis, and tools that enable them to expeditiously look at all the options and recommend the best to their clients.

Action 6 is essential for seamlessly integrating buildings with GHP infrastructure. There is an important distinction to be made between engineering the GHP infrastructure (Action 5) and engineering the rest of the GHP system (Action 6). Up to now the building owners have been shouldering the financial burden for both, hence the owner's engineer (or HVAC contractor in the case of a home) has been designing both. In the future, the building owner having to finance the entire GHP system may be a last resort, rather than the norm.

One could envision a modest number of specialized professionals designing the GHP infrastructure for the entire nation, with utilities and others listed previously as their clients. It may be far more likely that specialists like these could become expert at examining all the options — including the Earth, surface water, recycled gray water, sewage treatment plant effluent, retention basin storm water, harvested rainwater, and water from a subsurface aquifer — at community or neighborhood or even building scale, than could a local building owner's HVAC designer or homeowner's HVAC contractor.

Nonetheless, significant effort will have to be spent expanding geographic areas where affordable community-based design infrastructure exists, and expanding capacity in areas already having such infrastructure, by improving training materials and training more architects, commercial HVAC designers, and true residential system designers. In the short run these people would continue to be responsible for the entire GHP system, indoors and out, and in many localities this may never change. The training efforts can be targeted to areas where demand for GHP design services exceeds supply, whether this demand is driven by markets behaving traditionally or by GHP infrastructure being put in at scale.

Action 7 is essential for implementing GHP infrastructure in a timely fashion once it is designed. It has taken almost 30 years to create the current patchwork of GHP drillers and loop installers, which supports only about 60,000 GHP unit installations annually nationwide. Success with Actions 3, 4 and 5 could radically increase the demand for installation services, especially in areas where third parties finance the GHP infrastructure. Significant effort will have to be expended to expand the installation capacity in the geographic areas where needed. This would involve improving training materials and training more drillers, loop installers, residential HVAC contractors, and commercial mechanical contractors and design/build contractors.

Note that there are no actions exclusively aimed at addressing Barrier 6, "inadequate pipeline of technologies and techniques to reduce cost and improve GHP system performance." However, Action 5 will entail research (to create the validated models enabling design and performance prediction of the various GHP infrastructure options, for example) so that credible feasibility studies and life-cycle-cost analyses can be performed and construction-ready designs and specifications generated. Furthermore, if Actions 3 and 4 are successful in expanding project activity, all segments of the GHP industry will have the opportunity to invest in improving the technologies and techniques that underlie their products and services, and federal research programs would have the opportunity to accelerate progress with leverage from this private-sector investment.

8. Conclusions

Every building in America sits on the ground, and the ground is generally cooler than outdoor air in summer and warmer in winter. GHPs use the only renewable energy resource that is available at every building's point of use, on-demand, that cannot be depleted (assuming proper design), and is potentially affordable in all 50 states. GHPs may be among the most affordable renewable energy resources, especially considering the investments in electrical transmission that will be necessary to deliver many of the best wind, solar, and geothermal power generation resources to market.

The United States was the world leader in GHP technology and market development from the 1980s to the early 2000s, but today GHP shipments in Europe are believed to be 135,000 to 190,000 units annually compared to 60,000 in the United States. Rapid market growth is also reported in Asia, especially China and South Korea, owing to supportive government policies, including GHPs being highlighted at the 2008 Beijing Olympic Games. The Canadians are also reporting strong growth in recent years, with grant programs in place at the federal level and other levels in some cases. In terms of the installed base of GHPs, the United States still has the largest absolute number, but on a per capita basis many European countries are ahead.

Today's domestic GHP industry is better positioned for rapid growth than ever before. Not only has the industry grown with the help of past federal and utility programs, but it has proven that it can stabilize and grow on its own again when such programs disappear. Compared to the early days, the diverse segments of the industry are better able to work with each other as a cohesive whole. The United States has the world's largest installed base of GHP systems, which can be mined for statistically valid hard data on costs and benefits, as well as best practices.

The most important trade allies to the GHP industry, electric utilities, today are better able to focus on peak load reduction and improved load factor than they were in the past when restructuring was looming. The industry's support organizations ─ IGSHPA, GHPC, ASHRAE, NGWA ─ are mature and robust.

If the domestic GHP markets were to expand rapidly most of the segments of the industry would be able to expand accordingly without creating bottlenecks. However, the GHP system design and installation infrastructure would require special attention. Currently these infrastructures only exist in some localities, and elsewhere customers lack access to the technology.

Considering residential and commercial building markets, both new construction and retrofits, it is estimated that GHPs have the potential to reduce non-renewable primary energy consumption in buildings by 3.4 to 3.9 quads annually by the year 2030. Since buildings currently consume about 40 quads of non-renewable primary energy annually, and are projected to consume 49.5 quads in 2030, GHPs have the potential to offset about 35 to 40 percent of the projected growth in building energy consumption between now and 2030.

Today in the commercial markets, GHPs are primarily limited to institutional customers (federal, state, and local governments, K-12 schools, etc.) that take the life-cycle view. In residential markets, GHPs are limited to a small subset of newly constructed homes where the homeowner builds to occupy, and to home retrofits where the owner plans to occupy the premises long enough to justify the investment. In all of these cases the building owner must have the financial wherewithal to use their own credit to finance the system.

The primary GHP market failure is the expectation that building owners should finance the "GHP infrastructure," or outside-the-building portion of the GHP system, such as the ground heat exchanger. GHP infrastructure will outlive the building and many generations of heat pumps, and is akin to utility infrastructure (poles and wires, underground natural gas piping). This begs the question – why do we expect building owners to finance GHP infrastructure on their own credit, but not other utility infrastructure? The outside portion of the GHP system is generally half or more of the overall GHP system cost, and if this cost is excluded, GHP systems are about the same price as competitive alternatives and could cost less in volume production.

Congress has already granted the authority for USDA/RUS to provide long-term loans, with terms of up to 35 years, at the cost of government funds to RECs nationwide to mount programs to provide GHP infrastructure to residential and commercial customers, and action can begin immediately.[87] So far one REC[88] has taken a loan under this new program and one other REC has filed an application. Apparently the GHP loop tariff would be $15 to $30 per month for most homes, less than the energy cost savings. The remaining indoor part of the GHP system that the customer still buys costs about the same as conventional alternative systems today, and could cost less in high-volume production.

The key barriers to rapid growth of the GHP industry, in order of priority (1 being the most important barrier), are the following.

1. High first cost of GHP systems to consumers
2. Lack of consumer knowledge and/or confidence in GHP system benefits
3. Lack of policymaker and regulator knowledge of and/or confidence in GHP system benefits
4. Limitations of GHP design and business planning infrastructure
5. Limitations of GHP installation infrastructure
6. Lack of new technologies and techniques to improve GHP system cost and performance.

The following actions would address the barriers and facilitate rapid growth of the GHP industry:

1. Assemble independent, statistically valid, hard data on the costs and benefits of GHPs
2. Independently assess the national benefits of aggressive GHP deployment
3. Streamline and deploy nationwide REC programs to provide GHP infrastructure
4. Develop and deploy programs to provide universal access to GHP infrastructure
5. Develop the data, analysis, and tools to enable lowest life-cycle-cost GHP infrastructure
6. Expand geographic areas where high-quality GHP design infrastructure exists
7. Expand geographic areas where high-quality GHP installation infrastructure exists.

A serious policy mistake very damaging to federal agency use of GHPs occurred in 2005 when the Energy Policy Act defined renewable energy that counted toward agency renewable goals as power generation only, excluding thermal forms of renewable energy such as GHPs. Future policies should ensure that GHP systems are not excluded from renewable portfolio standards and goals and related environmental initiatives.

9. Recommendations

More effective stewardship of our resources contributes to the security, environmental sustainability, and economic well-being of the nation. GHPs have received little attention at the national policy level as an important component of a strategy to achieve these goals. Policymakers have apparently overlooked the part of the solution that is everywhere in the ground we stand on.

A recent study suggested that through maximum deployment of energy efficiency and renewable energy, it was feasible to be on a carbon reduction path by 2030 that would lead to 2050 levels 60 to 80 percent lower than 2005 levels.[89] This is the scale of carbon reductions that climate experts say is necessary to avoid catastrophic climate change. Another recent study suggested that, as a step in the right direction, the federal government should set a goal for the U.S. buildings sector to use no more primary energy in 2030 than it did in 2008.[90] Based on previous analyses by others, updated and summarized in this report, it is estimated that 35 to 40 percent of this latter goal could be achieved through aggressive deployment of GHPs.

Given the need to rein in our nation’s energy consumption and carbon emissions, while at the same time stimulating our economy out of its most serious downturn since the Great Depression, the author recommends that federal policymakers seriously consider aggressively deploying GHPs nationwide, with programs commencing as soon as possible.

If this recommendation is pursued, the author further recommends that the following actions be seriously considered as part of the overall implementation strategy:

1. Assemble independent, statistically valid, hard data on the costs and benefits of GHPs

2. Independently assess the national benefits of aggressive GHP deployment
3. Streamline and deploy nationwide REC programs to provide GHP infrastructure
4. Develop and deploy programs to provide universal access to GHP infrastructure
5. Develop the data, analysis, and tools to enable lowest-LCC GHP infrastructure
6. Expand geographic areas where high-quality GHP design infrastructure exists
7. Expand geographic areas where high-quality GHP installation infrastructure exists

In addition, future policies should ensure that GHP systems are not excluded from renewable portfolio standards and goals and related environmental initiatives.

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