RURAL ENERGY PROGRAM

# Geothermal Heat Pump Feasibility Study, Preliminary Design and Technology Transfer

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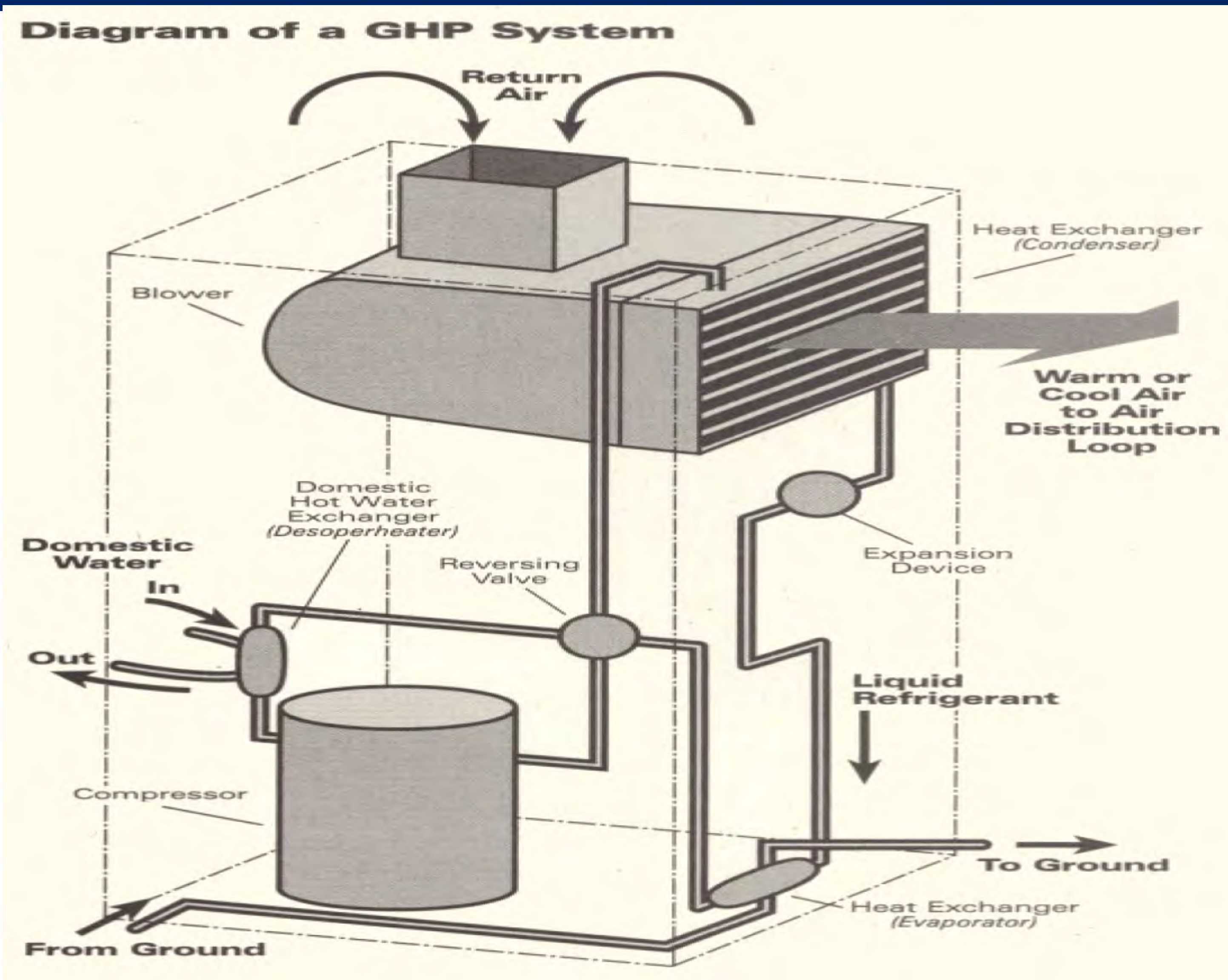

# Geothermal Heat Pump Feasibility Study, Preliminary Design and Technology Transfer

**John D. Geyer**
**Certified Geothermal Designer, No. 0076**

**John Geyer & Associates, Inc.**
**Vancouver, WA, USA**

**September, 2008**
Tbilisi, Georgia

# EXECUTIVE SUMMARY

In September, 2008, Winrock Georgia brought John Geyer, a trainer and designer of geothermal heat pump systems, to Tbilisi to design ground-coupled heat exchangers and to write specifications for heating and cooling equipment at two privately funded demonstration projects. Site surveys, feasibility analyses and interviews with local drillers and builders were made. Local building methods and materials were reviewed. Heat Loads were developed and converted into facility designs with hard copy outputs and "next-step" guidance provided for each demonstration project. Project developers and their architects and mechanical engineers received in-depth orientation to geothermal design principles and parameters. Locally developed heat loads were verified against geothermal software calculations for same.

Winrock's internal goals included technical briefings to Georgian energy officials for the purpose of adding geothermal heat pumps to Strategic Energy Planning and resource options. Two such briefings were presented to a dozen attendees. Groundwork and procedures for ongoing geothermal education and market development were presented.

All elements in the scope of subcontract work were accomplished without incident. Technical reference materials and industry contacts and catalogs were delivered to Winrock. The Tbilisi office now has a small library and ability to lead or support ongoing local planning and policies for use of geothermal heat pumps in Georgia.

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# CONTRACT SUMMARY

Between September 13 and 23, 2008, John D. Geyer of John Geyer & Associates, Inc. of Vancouver, Washington, USA was attached to Winrock Georgia in Tbilisi to provide technical services and general training regarding Geothermal Heat Pumps. Geyer's credentials are attached as Appendix A.

Feasibility assessments and conceptual designs (Appendices B and C) of geothermal heating and cooling systems were made for two new construction projects to be built locally with private funding as geothermal demonstration models. One is a personal residence of 2,800 square meters and the other is a 7,800 square meter, multiple-use, commercial building in Tbilisi's urban core. The residence's size qualifies it as proxy for other types of public and commercial buildings. No other forms of geothermal energy were evaluated.

Concurrently, Geyer met with Georgian academics, architects, mechanical engineers, water well and geotechnical drillers and project developers with technical and language support by Winrock staff and project hosts. Building construction standards and climatic data were assessed. Construction materials, prevailing work methods and equipment needed for ground-coupled heat exchanger creation ("geothermal loops") were evaluated for availability, suitability and cost. Local heating-ventilation-air conditioning ("HVAC") venders and the construction materials' market were visited. Deep ground temperatures were measured via natural springs at four Tbilisi locations. Temperatures varied from 14.5$^{o}$ to 17$^{o}$C. A Georgian manufacturer of suitable underground piping was located and detailed material specifications and construction guidelines were provided to the demonstration project host who will build the systems. Hard-copy and electronic files of design work were provided to hosts and to Winrock.

One three hour briefing (Appendix D) was presented to a dozen Georgia officials and educators (Appendix E) about rural and urban market development with examples from the United States and Canada. Brief overview of global manufacturing standards and technology usage was included, as were industry development strategies potentially usable in Georgia.

Winrock Georgia received a "starter library" of technical materials, software, website references for general and specific information, and examples of agricultural applications of geothermal technology (Appendix H). Guidelines for feasibility assessment are included.

# PROJECT SUMMARY

The private developers of the two demonstration projects are Tbilisi business people and project developers. A residential project already in construction and a retail / office / residential, mixed-use project in early development are both candidates for geothermal cooling and heating. Both will be a first-of-kind in Georgia. The developers are contemplating to make geothermal systems hallmarks of all their future projects, starting with row-house residential dwellings.

The developer's readiness to fund and lead geothermal construction and Winrock's ability to find and fund technical feasibility studies for energy efficient designs helped sparked this collaborative effort. Institutional goals include evaluating geothermal heating and cooling's potential in Georgian energy policies and mapping steps toward readying industry to provide goods and services. The developers goals are threefold: (1) economical, affordable and reliable space conditioning for a private residence and a mixed-use building; (2) determination of geothermal's compatibility with Georgian construction methods; and (3) assessment of geothermal design and construction as a business opportunity.

Site, structural and plan evaluations were performed by Geyer. Structural design drawings and final plans were incomplete so heat loss (heating load) and gain (cooling load) estimates for each structure were made on Excel spreadsheets (Appendix E). Seasonal climate and occupancy adjustments were applied to establish monthly and annual energy needs. Heat Load results were compared in detail with calculations by local mechanical engineers using Soviet-era methods. Vertical and horizontal, ground-coupled heat exchangers were modeled and evaluated with Geo Loop Design Studio software by Gaia Geothermal (Premier Edition, 5.3.3).

The residential building site is on a rocky promontory without deep or organic soils. Such characteristics preclude use of horizontal loops, despite land surface availability. Talks with "old-school" Georgian water well drillers and Turkish geotechnical drillers found experience and equipment to be generally unavailable and work schedules and prices to be prohibitive. Since the private residence includes a large, year-round swimming pool. Decisions were made to use this water as the heat sink and source instead of expensive ground loops with construction risks. This adaptation demonstrates the flexibility of geothermal design's "*Work with whatever (conditions) you have*" philosophy. The pool will supply heating and cooling and domestic hot water via high efficiency, water-water heat pumps.

The commercial building is a nine-story structure with four levels of underground parking. The building "footprint" covers all available land; hence, there is no place for vertical ground loops. Approximately 65 concrete pilings extend 12 to 15 meters below the lowest parking level to bedrock. Placement of ground loop piping inside each meter-wide piling was examined closely. Maximum service by such loops was only 27% of cooling load in real time. At this scale, further analysis of piling mass and thermal performance found internal temperature ranges over time to be too large for sustained use. Denied use of ground loops and "energy pilings", determination of groundwater availability for an "open loop" heat exchanger is the next step. Detailed questions and assessment steps have been provided to the developers.

Apart from one favorable and one pending design proposal, the developers received detailed instruction in geothermal planning and design principles. Appropriate equipment is designated and progress is made toward specifying equipment sources and construction methods. Survey of regional drillers and drilling equipment has begun. The critical influence of building insulation is showcased and thermal factors of Georgian masonry products used in Block and Frame construction are noted. In thermal terms, these low density blocks are inferior materials.

The briefing to university, academy, Parliamentary and non-governmental organization ("NGO") energy experts included review of economic costs and benefits of various energy generation and efficiency measures. Georgia's "best value" for rural heating is development of warm water district heating systems for villages and towns ($35^{o}$ to $80^{oC}$ natural geothermal waters). Drilling to 1,000 meters is possible with local equipment and, once a warm well and distribution piping exist, long term benefits are extremely cost effective. Georgia's next highest priority energy investment is construction of more thermally-efficient buildings. After that, widespread use of ground-coupled heat exchangers and water-source heat pumps (i.e., geothermal systems) *could* become the least costly and most widely available energy resource for heating and cooling for buildings of all sizes. Each of these energy strategies is more affordable, more "do-able", more incremental, more local and faster to develop than is construction of new generation and transmission infrastructure. None require significant exploration expense, lead time, research & development or "demonstration projects" to establish that they work. Pioneering projects will require guidance to direct and train unskilled and inexperienced workers.

# GEOTHERMAL HEAT PUMPS AND HOW THEY WORK

## HOW DO THEY HEAT AND COOL?

Refrigerators and air conditioners both contain heat pumps. In a refrigerator, heat is removed from the food storage area and discharged to kitchen air. Air conditioners work the same way – they move heat from inside the building interior and discharge it to outside air. Conventional or "air-source" heat pumps differ from those in refrigerators and air conditioners because they are reversible – that is, they can concentrate heat from outside air and move it indoors to provide warmth, as well as move heat out of the building to provide cooling. To do this, air source heat pumps and central air conditioners need a large outside unit to exchange heat with outdoor air.

Like air-source heat pumps, geothermal heat pumps work by moving heat, rather than by converting chemical energy to thermal energy like a furnace. Integrated systems of indoor air or water loops, refrigeration loops inside the heat pump, and water-filled, ground-coupled heat exchanger "loops" capture, concentrate and relocate heat per needs of conditioned indoor spaces.

## HOW ARE THEY MADE?

The geothermal heat pump is packaged inside a single cabinet, roughly the size of a small to large kitchen refrigerator. This contains the compressor, loop-to-refrigerant heat exchanger, fan or pump, external power connections and controls. These may be configured for horizontal or upright installation. They can occupy open space, crawlspace under floors, attics over ceilings or stand against walls as console units. Everything is located indoors; there is nothing outside and above ground.

In geothermal heating and cooling systems, the heat pump is connected to the building by a distribution system – most commonly air ducts in North America and hydronic (i.e. hot water) piping to radiators or floors in Europe. The heat pump is also connected to the earth through a series of buried plastic pipes called a "loop" or ground-coupled heat exchanger. The system trades heat with the earth via water flowing through the loop, meaning that no noisy or unsightly outdoor unit is needed.

## HOW DO THEY WORK?

Geothermal heat pumps are more efficient than air source heat pumps because earth temperatures are more uniform throughout the year than are air temperatures. Also, heat transfer effectiveness of water exceeds that of air. Mid-latitude ground temperatures of 10 to 25°C are well suited to use as heat sources or sinks (i.e., as places to acquire or waste heat).

All heat pumps use a vapor compression cycle within the machine to transfer heat from one form and location to another. Common refrigerants are R-22 (out-dated), R-134A and R-410A. In heating mode, the cycle starts as the cold, liquid refrigerant within the heat pump passes through a heat exchanger (the evaporator) and absorbs heat from the low temperature source (i.e., fluid circulated in the ground loop). The refrigerant evaporates into a gas as heat is absorbed. The gaseous refrigerant then passes through a compressor where it is pressurized, raising its temperature to over 90°C. Hot gas then circulates through a refrigerant-to-air heat exchanger (read: fan coil) where excess heat is transferred to air and sent through ducts or into a hot water storage tank. When the refrigerant loses its heat, it condenses back into a liquid. The liquid refrigerant passes through an expansion valve and the process begins again.

In cooling mode, a three-way reversing valve inside the heat pump changes flow direction of the gas so the machine runs backward. Although heat pumps are complex internally, relative to combustion or electric resistance heating devices, they are marvels of compact design for reliability and thermal efficiency. Some include features such as additional heat exchangers for domestic water heating and microprocessor-based automatic controls and protection devices.

To further improve efficiency, many heat pump manufacturers use variable speed, electronically-controlled motors on air duct fan systems. Depending on unit size, manufacturers may opt for reciprocating, inertia, rotary or scroll compressors – all of which are hermetically sealed and mounted in the indoor cabinet. Overall, scroll compressors are favored for durability and efficiency at all operating speeds. Some advanced heat pumps feature two-speed or variable speed operation while others offer dual compressors to vary output and to match loads.

Residential-sized heat pump systems can include “desuperheaters” that heat domestic water when the system operates in either cooling or heating mode. The desuperheater is a small auxiliary heat exchanger at the compressor outlet. It strips excess heat (“superheat”) from the compressed gas into a water line that circulates water to the home’s domestic water storage tank. In summer, when the air conditioning runs frequently, a desuperheater may provide all the hot water needed by a household. It can usually provide 4 to 7 liters of hot water per kilowatt of cooling capacity in each hour that it operates. A desuperheater provides less hot water during the winter and none in the spring or fall when the system is not operating.

Because the heat pump is so much more efficient than other means of water heating, some makers offer "triple function", "full condensing" or "full demand" systems that use a separate heat exchanger to meet all household hot water needs. These units provide hot water as quickly and as cost effectively as any competing system.

## HOW IS PERFORMANCE MEASURED?

Performance of geothermal heat pumps in the United States (the largest and fastest growing market) can be determined from American Refrigeration Institute (ARI) ratings of certified products. Rated products are always marked "ARI Certified". Extended-range (of entering water temperature), water-to-air heat pumps with closed loop heat exchangers are normally rated under ARI Standard 330-93. Water source heat pumps for Boiler/Chiller use are ARI 320-93, while groundwater or open-loop units are "ARI 325-93." ARI provides peak performance information as an Energy Efficiency Ratio (EER; an expression of Btu/watt-hour) for cooling and a Coefficient of Performance (COP) for heating. Both are ratios of effective energy output relative to electrical energy input. Canada has a parallel, compatible rating system.

In this writer's opinion, the best single American reference for technical data and design principles is the American Society of Heating, Refrigeration and Air Conditioning Engineers ("ASHRAE) design manual for Ground-Source Heat Pumps in Commercial and Institutional Buildings. Authors are Kavanaugh and Rafferty, 1997. Chapters 6 and 7 provide unequalled treatment of groundwater (i.e. well) and surface water (i.e., lake or pond) systems as may be used in Georgia where excavation or drilling machines are not available or affordable.

Geothermal heat pumps typically deliver COPs of 3.0 to 4.5 for forced air systems (pump power not included) and 3.5 to 5.2 for water-to-water pumps at Entering Water Temperature near 13$^{o}$C. Overall system efficiencies typically average 2.8 to 4.2. Cooling efficiency of geothermal units starts at EER of 13 and extend as high as 27 with average of 16 to 18. Marketing claims of higher EERs may be artifacts of creative marketing wherein low compressor speeds are matched with high fan speeds to elevate rating numbers. European research seeks to push these upward but Laws of Physics prevail.

Since 1992, the U.S. federal government has stated that geothermal heat pumps are the most energy efficient, most environmentally friendly, and most cost-effective space conditioning systems commercially available. This determination was first made by the Environmental Protection Agency and then by the Department of Energy. Combined studies find that average systems available in North America are at least 48% more efficient that the best gas furnaces on a source fuel basis (i.e., accounting for all losses in the fuel cycle, including electricity generation and transmission) and 75% better than oil furnaces. The best geothermal systems outperform the most efficient gas technology, gas heat pumps, by an average of 36% in heating mode and 43% when cooling.

Customer choice may be ultimate measure of “Does geothermal work? And “How well?’ The market’s answer in all 50 United States, across Europe and, increasingly in Asia, is that they do work in all climates with heating and cooling needs of confined spaces. Sustained, 20% annual growth for more than a decade in North America market confirms that geothermal systems outperform and out-save money and emissions compared to any other heating and cooling methods. Markets are driven by customer demand but still total less than 2% of annual U.S. mechanical installations.

# DISCUSSION

Cursory review of Georgia's energy environment finds trained and capable people, abundant hydropower resources with installed but under-utilized capacity, and a generally complete transmission grid. It also finds national security risk in dependence on expensive fuel imports for both generation and end-use. At the same time, there appears to be a void on the demand side of energy management and planning. Principles of conservation, energy efficiency, sustainability and renewability (beyond hydropower's intrinsic qualities) and appreciation that a "kilowatt-saved" has more economic and societal value than a "kilowatt-generated" remain in Georgia's future.

Georgia's situation is superior to many nations and regions in that its energy planning is sophisticated, comprehensive and current. A 250-page, strategic energy plan by Southeast Europe Consultants in December, 2007 appears to be the most thorough review. As good as this survey of supply-side energy options is, it stops short of industry-standard, *Integrated* Resource Planning by concentrating on only one side of energy supply and management options. Planning methodologies and scope of renewable technologies evaluated in this report are each of mid-1980s vintage in the U.S. electric industry. Expansion of this study to include high efficiency, end-use technologies (such as geothermal heat pumps and building construction standards) in "Least Cost Analysis" will open easy-to-implement savings and quality-of-life options across Georgia. Development of such an addendum to this report is recommended.

Geothermal Heat Pumps were invented in the 1940's and 1950's and reached commercially available in the 1970s. Nothing in this technology's theory or manufacturing is unproven or requires further Research or Development. North American equipment pricing is mature and competitive. Operation takes one kilowatt of electric energy from the grid to power compressors, pumps and fans inside a unitary heat pump (wherein everything is inside one "box"). Three to four additional kilowatts (thermal) of energy are thereby collected from the earth, concentrated by the machine, and delivered into conditioned space. This "hybrid" of Supply- and Demand-side energy creation and delivery is relatively unique among HVAC equipment and remains unknown to traditional energy managers, even within the US, Canada and Europe. With over 1.5 million house-sized units installed and 10% to 15% added each year, GHPs represent only about 1 to 2% of the North American market. That is to say, this most advanced market is more mature than Georgia's but remains very young. Many lessons can be borrowed and built on as geothermal heating and cooling is introduced into Georgia.

There is no question as to whether this low-temperature form of geothermal energy is available or works in the Caucasus. It is and it does; all that varies with climate is the number of hours each year that the system runs. More Degree Days mean more run time and more savings. Global access to equipment, tools and training assures that a self-sustaining industry can be created through technical training, market access (i.e., distribution and sales) and consumer education (read: "public education"; consumer status will follow). Geothermal is the message that people want to hear: "*It is economic, it is efficient, and it is environmentally good.*" As such, geothermal is a demand-driven market. Once building owners and operators know what it does and that it is available and within reach, they want it. Endorsement by experts ("*It is real and it works and it is good for the country.*") and leadership by example (e.g., saving with geothermal in government buildings and schools) are enough to start and sustain a demand-based market.

In four years, Canada has developed a 150 member industry that does 10% of U.S. business volume. At whatever rate and to whatever level it aspires, Georgia can accomplish much of the same, especially in the context of post-war reconstruction.

Leading American adopters of geothermal technology include the military (housing and offices at about 50 domestic bases), public schools (about 1,400 to date with 200 new each year) and State-run buildings (prisons, hospitals, government offices). Three-quarter million private residences enjoy its benefits. George W. Bush's Crawford, Texas "ranch house" is 100% geothermal. Vice President Dick Cheny's Washington D.C. home (U.S. Naval Observatory building) is partially heated and cooled by geothermal. Mr. Al Gore's 20-room home in Nashville, Tennessee is also 100% geothermally heated. If these three men can agree on the best heating system available and use it themselves, there HAS to be something good to be said for it.

The belief that energy efficiency is too expensive to be affordable has no place in thoughtful leadership. If not affordable by individuals, then public buildings that serve them can provide more comfort for less cost if benefits of quality construction are leveraged and compounded by use of highly efficiency heating systems. U.S. experience and this mission find that both residential and commercial construction costs of geothermal systems are comparable to standard equipment of good quality. Operating cost of each is about half with geothermal. Life Cycle Costs in large buildings are often one-fourth of conventional systems over 20 to 25 years. In this study, only the residential design is detailed enough to make economic estimates but recovery of added geothermal expense will occur in fewer than three years.

# RECOMMENDATIONS

In 2008, Georgia's opportunities to add geothermal heating and cooling to traditional methods are as favorable as circumstances are regrettable. Much new building construction needs to be done. Design and installation in new construction is easier and more cost effective than retrofitting existing buildings. This is especially so within urban areas.

To develop parameters, policies and infrastructure for geothermal construction and use, the following steps are encouraged. None are unique; all are time-tested ways to create or transform energy markets. Major costs are deferred until as late in the process and as close to "real" project construction as possible.

1. Identify or form a self-chartered group to study energy efficiency and alternative and renewable energy technologies. (Worry later about how to classify this type of geothermal energy.) Attendees of the Rural Energy Program's September 19, 2008 briefing are logical candidates to start this.

2. Expand and refine information and assumptions in the Georgia Energy Strategy report (Southeast Europe Consultants, 2007). Add Geothermal Heat Pumps to the list of Renewables and develop current technical and economic data to compare cost and megawatt potentials. I suggest treating geothermal heat from the earth as Supply-side renewable resource.

3. Create a network of experienced geothermal experts outside the country to support the Geothermal Study Group, answering questions and channeling information quickly and continuously. Gather answers from American and European industries. Focus on asking questions of importance to Georgia and let others provide technical answers for local use.

4. Register at least one Study Group member in the U.S.'s Geothermal Heat Pump Consortium (geoexchange.org). Pull information from GHPC's large website to form a local Georgian reference library.

5. Register at least one Study Group member in the International Ground Source Heat Pump Association (igshpa.okstate.edu) and incorporate this information into the Georgian reference library. When possible send one or two people to IGSHPA's annual Technical Conference and

Trade Show (2008 meeting: October 1 and 2, Nashville, Tennessee). Acquire CD's with technical presentations made at the conference (sold by IGSHPA to registrants).

6. Define specific goals for information gathering and pre-plan activities when desired information is obtained. Move from "study" to "action" as quickly as possible.

Follow the two studied demonstration projects (private residence and multi-use commercial building) through construction and seek new private or public parties to install systems for their own use that may also become case studies and additional demonstration facilities.

Enlist home- and building-owner cooperation in documenting start-up and operating histories, as well as operating costs, for at least one full year (all seasons' weather). Create one location in which to keep records and designate someone to receive and respond to inquiries.

7. Identify local and regional manufacturers of geothermal products, including distributors and vendors. Build a public library of competitive sources. Post information on a Georgian website, including links to industry elsewhere.

8. Identify candidate sites for geothermal construction that belong to or are funded or operated by organizations participating in the Geothermal Study Group. Lobby for "YES!".

9. Under guidance, monitor and learn from each step of pioneering work: feasibility analysis, preliminary/concept design, final design, equipment "shopping" and purchase, import, loop installation, equipment installation, start-up and commissioning, operation and economics.

10. With understanding of Georgian geothermal priorities, and with pioneering sites to learn from, establish a technical training school for tradesmen, educators and public officials. Promote and teach geothermal courses at least 4 times a year (quarterly). Develop local training skills following the 11-part IGSHPA curricula for installers. Use part or all, according to interest.

11. With local projects and "experts" to point to, work to establish local and national policies that bring energy efficiency and environmentally "clean" heating and cooling technology to Georgia. Make geothermal heat pumps and geothermal hot water district heating the cornerstones of new development. Integrate results with national and regional Kyoto Protocol compliance goals.

12. Involve Georgian media (television, newspaper) in geothermal progress so that the public learns of it. Questions will follow, so informal geothermal courses should accompany formal energy classes at universities, institutes and other schools.

13. Formalize the early study group into a Georgian Geothermal Association. Affiliate with the International Geothermal Association and the Geothermal Resources Council (Davis, CA., USA). Make Georgia's geothermal growth part of the world experience and import all that others have learned.

14. Talk about geothermal heating and cooling in new venues. Once people learn of it, most desire to hear and learn more. Advocacy leads to interest and acceptance; silence kills progress.

15. And, FINALLY: In both, informal discussions and formal procedures, make the foremost question not "*Why Geothermal*?" but "*Why **NOT** geothermal*?" Then, build active discussion around debate of the answer.

# APPENDICES

A. Technical Briefing Outline

B. Technical Briefing Attendees

C. Residence Demonstration Project Overview

D. Commercial Building Demonstration Project Overview

E. Ground Loop Design Summary (sample)

F. Sample Training curriculum

G. Renewable Energy World Magazine article on Geothermal Heat Pumps

H. Credentials & Qualifications – J. Geyer

**APPENDIX A**:

19 September, 2008 Rural Energy Program
Technical Briefing Outline

My name is John Geyer:

I am: - Not an Engineer. I am:

- utility planner
- 30 years in alternative and renewable electric generation
- 15 years in geo heat pumps

1. Geothermal Heat Pumps (Ghp) Are:
2. Ended-range, closed-loop, ground-coupled, water source heat pumps
3. Ghp is a standard, vapor-compression, refrigeration systems using r-22 or r-410a
4. GHP heats, cools and heats domestic water to 40C
5. Heating COP is 4 to 5. Cooling EER is 15 to 24.
6. Closed loops of HDPE plastic pipe are buried in the ground at 2 meters (200 centimeters) or drilled vertically to 50 to 100 meters.
7. Electricity from the grid runs compressor, water pump to ground, and water pump to building. Uses 1 kW electric to collect, concentrate and deliver 4 kW from the ground. 1kW electric delivers 4 or 5 kW thermal.
8. 3 kW of used heat have no generation or transmission by wire and are renewable and free.
9. 16 Tetri of electricity (1 kWh) delivers 4 kW thermal. This means the cost of each kW thermal is only 4 tetri.
10. GHPs save money for the building and Greenhouse Gas emissions for the planet.
11. Monthly electricity costs drop 40 to 60%. A GEL 200 bill becomes about GEL 80. It is not ¼ because the ghp system runs more minutes each hour than electric resistance heat.
12. Air conditioning costs the same as heating.
13. Maintenance costs drop 80 to 90 percent (like a kitchen refrigerator).
14. Only ¼ as much grid power is used compared to all-electric heating or cooling. Existing generation does 4 X as much work
15. GHP can be water-to-water or water-to-air.
16. GHP works anywhere there is available land, digging machines for soil or rock, and correct materials and equipment can be procured.
17. Earth temperature from 11 to 18C becomes 35 degree water or 30 degree air.
18. To install a GHP system, you need an excavator or water-well drill. The bigger the drill, the faster and less expensive to make vertical loops. The hole is filled with Bentonite Clay and water. It becomes the texture of thick yogurt.
19. When holes are dug or drilled, pipe is put in and covered with dirt or some other material.
20. Piping is joined like plastic pipe for natural gas but is different plastic formula. Yellow gas pipe cracks after repeated heating and cooling.

21. Lakes, ponds or rivers can run GHPs. Coiled pipes are in the water or clean water can go inside heat pumps.
22. Once installed, GHP machines last 20 to 30 years. The ground loops are used forever.
23. Ghps are not new and they need no research. They begin in 1950 and have been used in homes since 1970.
24. 1.2 million house-side GHP systems are working in the US and about 100,000 are in Canada.
25. US will install 120,000 house-sided GHP systems this year for over $1 billion (retail). Customer demand drives 20% market growth. We have only small government help with costs (no incentives or tax breaks) but schools and the federal government and schools are our #1 and #2 GHP users.
26. Residential GHP costs twice as much to install as cheap, inefficient systems as usually installed by builders, and half as much to operate. Commercial and public building systems in new construction cost -10% to +20% of normal heating and air conditioning equipment.
27. Two demonstration units in Tbilisi will be installed with private money within this year. One is a large commercial building and the other is a home. Operating costs and information can be shared with this group and others with reason to know.

Questions and Answers

# **APPENDIX B:** GEOTHERMAL BRIEFING ATENDEES, 19 SEPTEMBER 2008**,** RURAL ENEGERY PROGRAM, TBILISI, GEORGIA

Presentation by: John Geyer
John Geyer & Associates, Inc.

Participants:

Mr. Baadur Chkhaidze – Energy Expert, Professor at Tbilisi Technical University

Mr. Timur Mikiashvili – Energy Expert, Professor at Tbilisi Technical University

Ms. Nelly Verulava – Energy Expert; Academy of Energy (National building efficiency leader)

Ms. Karine Melikidze – Energy Expert; Professor at Tbilisi Technical University (Building Efficiency Policy Advisor)

Mr. Giorgi Gigineishvili – Assistant Professor, Tbilisi Technical University

Mr. Vladimir Surguladze, Chief Expert, Ministry of Energy

Ms. Liana Garibashvili – Energy Efficiency Center, Georgia

Mr. Murman Margvelashvili - World Experience for Georgia

Mr. Otar Khuopenia – Gross Energy

Mr. Horst U. Meinecke – Chief of Party, Rural Energy Program

3 staff – Winrock Georgia

# <u>APPENDIX C:</u> Private Residence Demonstration Project Overview

TBILISI, GEORGIA

John Geyer Sept, 2008

- What is “success” in cooling and heating this house?
  - Economical, comfortable, reliable
  - Special system for a special house
  - Example for other geo systems that may form a business

- What do we have to work with?
  - Accurate measurement of heat gain (cool) & heat loss (heat)
  - Hydronic (hot water) equipment for floors and fan coils
  - Tools and workers to install both hot water systems
  - Id and source for water-to-water heat pumps
  - No ducts for forced air
  - No soil on the property; surface rock everywhere (no digging)
  - No suitable drill or experienced driller in the country
  - Large, year-round swimming pool w/ gas heater
  - Construction budget

- What don’t we know?
  - Ground water availability
  - Ground temperature (thought to be between 14 and 18 c)
  - Cost of ground loops

What has highest probability of success to support high-efficiency, water-to-water heat pumps?

1. Use of swimming pool instead of loops to run heat pumps
    a. Big enough (change ½ degree c, per day)
    b. Already budgeted
    c. Temperature controlled with gas heater
    d. Accepts all air conditioning waste heat
    e. No new ground; no new tools; no new workers

2. Same radiant floor, fan coils and domestic water heating

How would the pool system work?

- 9 x 12 x 1.5 meter pool holds 150,000 liters or 45,000 gallons
- House maximum load is 50 kw (heating) and 42kw (cooling)
- Peak operation changes pool temp 1c in 12 hours (operating 1/3 of each hour); most hours/days would be only about half of this
- All a/c waste heat (7 or 8 months) becomes pool heat and saves partial gas fuel – this is only part of total pool heat
- House heat is replaced daily by sun (daytime cover "off) or by gas pool heater, according to pool thermostat
- Heat pumps with copper-nickle heat exchangers can handle pool chemicals; option is a small plate heat exchanger between the pool and the heat pump (pool water should never enter the heat pump)
- Indoor loops to floors and fan coils would draw water from one 300 to 500 liter storage tank, as for normal hydronic systems
- Domestic water heating (to higher temperature than floor or fan coil water) would be with dedicated, small water-to-water heat pump and storage tanks near kitchen, bed rooms and spa
- House would operate as if with ground loop at lower capital cost, more construction certainty and nearly-equal savings

# <u>APPENDIX C:</u> Commercial Building Demonstration Project Overview, TBILISI, GEORGIA John Geyer Sept, 2008

- What is "success" in cooling & heating this 7,400 meter building?
  - Demonstration project for geothermal heating and cooling in Georgia
  - Compatibility with normal construction practices
  - Compatibility with normal controls and comfort
  - O&m cost savings
  - Special system for special building: marketing topic
- What do we have to work with?
  - Lot line, urban construction; no surface parking
  - Mixed use – retail, office and residential
  - 66 foundation pilings, each 12 to 15 meters x 1 meter
  - Unknown ground water availability
  - Urban infrastructure and storm drains
  - Preliminary design/size, schedule and budget
  - Conventional indoor distribution system
  - Preliminary maximum heat load and w/w heat pumps :
    - Peak load: 620 kw cooling / 504 kw heating;
    - Peak demand: 109 kw cooling / 228 kw heating
    - Total capacity: 835 kw cooling / 422 kw heating
    - Loop flow: 2006 l/min cooling / 1627 l/min heating
    - System cop: 5.7 cooling / 2.2 heating
  - Inexpensive loops inside foundation pilings
  - Local source of hdpe piping (verify specs and cost)
- What don't we know? (or, what are design risks?)
  - Availability of ground water
  - Actual performance of loops inside foundation pilings
  - Actual building design
- What does "lack of success" (in design) look like?
  - Ground loop failure (fails to reheat/cool water)
  - Construction approval problems
  - Foundation problems
  - Excessive costs to build
  - Hard to get equipment or no maintenance parts/help
  - Failure to provide comfort to tenants
  - Incompatibility with standard local control system
  - Excessive operating costs or maintenance
  - Need to modify after construction and start-up

- What are the big unanswered questions?
    - How much of the building can piling loops serve?
    - What savings can be relialized with geothermal system?
    - Can large capacity water wells be drilled on this site?
    - What does high discharge into storm drains cost?
    - Can local construction workers install correctly?
    - What can be done if ground loops fail?
- What are loop design options?
    - Closed loops are limited to inside pilings; no other space
        - Maximum pipe density is 100 meters per piling
        - 66 pilings = about 60 tons or 210 kw capacity (~25%)
    - "open-loop" pump & dump wells with 35,000 liter tank
- What has highest probability of success?
    - Open-loop for 25% to 50% of the building (owners' area)
    - Piling loops lack capacity and durability over time
    - Piling loops may or may not be acceptible to authorities
    - High efficiency heat pumps can be served economically by normal boiler and chiller
- What data is needed for improved design?
    - Test well to determine water location and quantity
    - Injection well study to estimate pump power and quantity
    - Final building size
    - Commercial gas and electricity tariffs
    - Local experience with plate & frame heat exchangers
- What looks like preferred design at preliminary stage?
    - Open-loop pumping up to 250 liters/minute of groundwater into a 35,000 liter tank with overflow pumped back into one or two injection wells. Piping runs through building to water-water heat pumps.
    - Abandon piling loop option as capacity is to small and thermal risk is too high to justify use.
- What remains to be done in next-stage design?
    - Verify building heat loads
    - Design zones/areas for geothermal service; calculate size
    - Verify water well depth, production, drilling method
    - Design injection well and pump per drilling log data
    - Design interior distribution of water heating and cooling per local standards and construction methods
    - Calculate heat balance and tank size for open loop system
        - Allow rainwater collection and, possibly, storm drain use into tank supply design

- Calculate boiler/chiller size and system cost for water source heat pumps for entire building
- Review findings, costs and issues to select geothermal system or expand boiler/chiller to the entire building
- Commit to water-source heat pumps for maximum efficiency and savings
  - Recognize that savings are in technology efficiency, not how feed water is heated or cooled
  - Whether or not geothermal water is possible, efficiency and savings remain possible
  - Small chillers and boilers can maintain low tank temperatures at a fraction of fan coil cost
  - Heat pumps cool and heat so a small chiller replaces large air conditioners

# **APPENDIX E:** GROUND LOOP DESIGN SUMMARY (SAMPLE)

United States
Environmental Protection
Agency

Air and Radiation
(6202J)

EPA 430-K-97-007
September 1997

EPA

# A Short Primer and Environmental Guidance for

## Contents


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## Introduction

According to a United States General Accounting Office report entitled *Geothermal Energy: Outlook Limited for Some Uses but Promising for Geothermal Heat Pumps* (June 1994), "geothermal heat pumps[1] are the **most** energy-efficient means of heating and cooling buildings in most areas of the United States." In addition, in a 1993 EPA report, *Space Conditioning: The Next Frontier*, a comparison of energy efficient technology for residential dwellings was performed. In this study, geothermal heat pumps were identified as one of the most energy efficient technologies available. Use of GHP systems in place of traditional systems will result in significant reductions in emissions of greenhouse gases such as carbon dioxide, as well as reductions in emissions of sulfur oxides and nitrogen oxides, major causes of acid rain. Accordingly, the Energy Policy Act of 1992 contains provisions to encourage the use of geothermal systems as alternative energy sources.

This document briefly highlights some of the major issues associated with the installation and operation of geothermal heat pumps (GHPs). The document provides general information on GHPs, including:

- a description of the three most common types of GHP systems;
- the potential environmental risks of GHPS systems;
- an overview of best management practices for GHP systems; and
- sources of further information about GHPs, which are listed in an annotated bibliography.

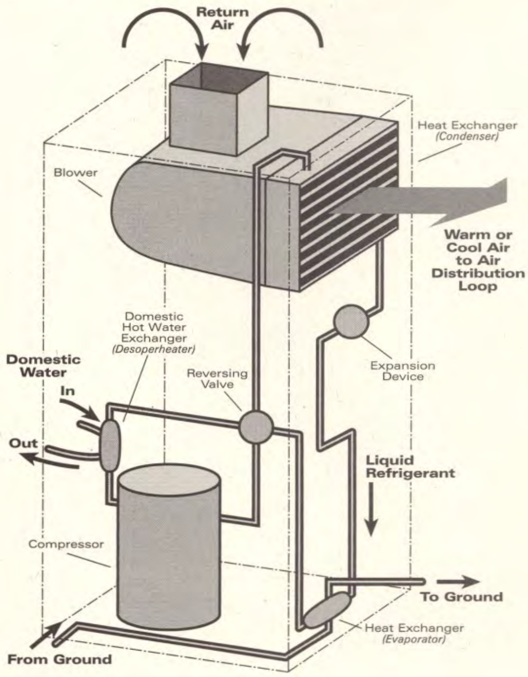
## What Is A Geothermal Heat Pump?

Geothermal heat pumps (GHPs) take advantage of the natural heat stored underground to provide space conditioning — heating, cooling, and humidity control. GHPs also may provide water heating, either to supplement or replace conventional water heaters. GHPs work by moving heat, rather than by converting chemical energy to heat (as in a furnace). Using the same technology as does a refrigerator, a heat pump can move heat taken from the ground and apply it to a building. The process can also be reversed and the subsurface can be used as a sink for a building's excess heat to provide air conditioning.

Modern geothermal heating and cooling systems are composed of three subsystems or primary parts: an earth connection for transferring heat between the earth and a fluid contained in a series of pipes, a pump to move heat between the fluid in the earth connection and the building, and a distribution subsystem for delivering heating or cooling to the building. The geothermal system may also have a desuperheater to supplement the building's water heater, or a full-demand water heater to meet all of the building's hot water needs. Exhibit 1 depicts the general structure of a GHP system.

Due to the relative stability of ground temperature, geothermal systems are inherently more efficient than air source heat pumps that rely on outside air as a heat source or heat sink. Geothermal heat pumps provide the highest efficiencies both in summer cooling and winter heating, as well as water heating. More than 95 percent of all geothermal heating and cooling customers are completely satisfied with their systems.[2]

Exhibit 1: **Diagram of a GHP System**




[1] *Geothermal heat pump systems are often referred to as geothermal, earth-coupled, water coupled, groundwater, ground-coupled, closed-loop, coiled, Slinky™, GeoExchange℠, open, and water-source heat pump systems.*

[2] *Geothermal Heat Pump Consortium,* Geothermal Heating and Cooling: A Wise Investment, *October 1995.*

## What Are The Types Of GHP Systems?

GHP systems can be divided into two broad categories: closed-loop and open-loop systems. Closed-loop GHP systems rely on the contained circulation of fluids through an underground loop of pipes, which acts as a heat exchanger by transporting heat to or from the ground. The main variations on the closed-loop system include horizontal and vertical closed-loop systems, and vary according to the configuration of the pipe, the type of antifreeze solution used, and the amount of heating and cooling required. Unlike closed-loop systems, open-loop systems do not confine fluid to a loop of pipes; rather, they use a pumping well to move water through the heat pump and then discharge the water. Open-loop systems are almost always installed vertically, and vary according to the use and method of disposing the groundwater used to provide heating or cooling.

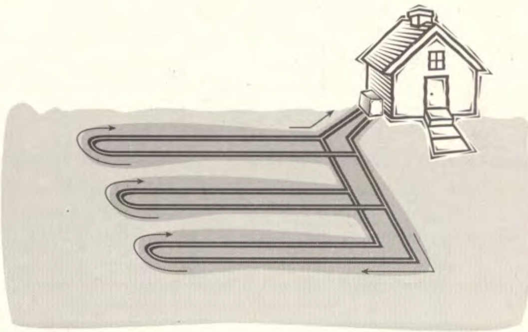
The selection of the type of system (closed-loop or open-loop) depends on many factors. These include availability of groundwater, soil type, energy requirements, size of lot, and the judgment of the local contractor. For example, rocky soil may prevent trenching for installing a horizontal closed-loop system, in which case, the contractor could use boreholes to install a vertical loop system. If the lot contains a pond or lake, or a well with a sufficient supply of groundwater, a vertical open-loop system may be a wise choice. A small lot, on the other hand, may allow only a vertical closed-loop system.

The three most common GHP system configurations, (1) horizontal closed-loop, (2) vertical closed-loop, and (3) vertical open-loop, are described below.

### Horizontal Closed-Loop GHP

***Description.*** As explained above, closed-loop GHP systems rely on the contained circulation of fluids through an underground loop of pipes, which acts as a heat exchanger by transporting heat to or from the ground. Horizontal loops are most often installed in narrow trenches about five feet deep and from a few hundred feet to several thousand feet long. The trench is located sufficiently far away from the house so that any freezing surrounding the pipe does not affect the foundation. The heat exchange fluid used in such systems is water, although in cold climates antifreeze is often added to the water to enable the system to function at temperatures below 32 degrees F.

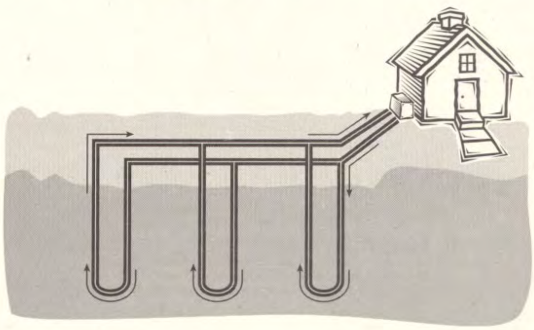
Exhibit 2: **Diagram of a Horizontal Closed-Loop GHP System**



### Vertical Closed-Loop GHP

***Description.*** Vertical loops are most often installed in boreholes drilled into the ground. The pipes in which the heat exchange fluid circulates are typically installed to depths up to 400 feet. The horizontal spacing between boreholes is typically between 10 and 25 feet. The distance between boreholes is selected to optimize system efficiency and the long and short term ability of the ground to retain or give off heat. The heat exchange fluid used in such systems is water, although in many cases antifreeze is added to the water to protect the fluid from freezing conditions and extend the operating range of the system.

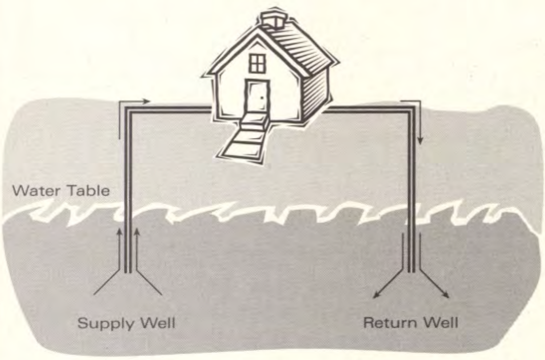
Exhibit 3: **Diagram of a Vertical Closed-Loop GHP System**



### Vertical Open-Loop GHP

*Description.* Open-loop GHP systems, also known as groundwater heat pump systems, typically depend upon groundwater to supply or accept heat. Open-loop systems do not confine fluid to a loop of pipes; rather, they use a pumping well to move water through the heat pump and then discharge the water. Although surface water could possibly be used, most open-loop systems rely on groundwater. The used water is either discharged to surface waters, discharged to a buried drain field, or reinjected into the aquifer. The water supply well must yield enough water to transport the required amount of heat.

Exhibit 4: **Diagram of a Vertical Open-Loop GHP System**




## Comparison to Water Wells

The installation of vertical GHP systems (closed-loop and open-loop) is similar to the installation of water wells in that both involve drilling a borehole through soil and rock. Vertical open-loop GHP systems are more similar to water wells because boreholes for both systems must reach ground water to be functional. Vertical closed-loop systems do not rely on the use of ground water. Consequently, procedures governing the installation practices for water wells are generally more appropriate for vertical open-loop GHP systems. For vertical closed-loop GHP systems, grouting and other groundwater protection practices may be different than those for water-producing wells. Unlike water wells, casing is not needed for closed-loop systems and should not be used unless it is required to prevent the borehole from collapsing during installation.

The similarities between installation of GHP loops and installation of water wells — coupled with the general lack of GHP-specific regulations — means that GHP installation often will be governed by existing regulations that apply to water wells and other activities involving the pumping and discharging of water, such as the National Pollutant Discharge Elimination System (NPDES) requirements or the Underground Injection Control (UIC) regulations. Exhibit 5 displays which existing regulatory regime applies to various GHP systems, as defined by their source and sink of water.

Exhibit 5: **Current Regulations Applicable to Open-Loop GHP Systems**

| | | Source of Water | |
|---|---|---|---|
| | | **Surface** | **Subsurface** |
| **Sink of Water** | **Surface** | NPDES[3] | NPDES |
| | **Subsurface** | Rarely Seen[4] | UIC Regs[5] |

[3] *National Pollutant Discharge Elimination System. Under authority of the Clean Water Act, discharges to surface water bodies may require permits. For more information on NPDES, contact your appropriate State official. A list of State contacts can be found on-line at* **http://www.uidaho.edu/ghpc/** *or in EPA's* Manual on Environmental Issues Related to Geothermal Heat Pump Systems *available at 1-888-STAR-YES (1-888-782-7937).*

[4] *It is very unlikely that a GHP would utilize a surface source of water that is subsequently disposed to the subsurface.*

[5] *Underground Injection Control regulations govern the subsurface discharge to wells of water or wastes. For more information on UIC, contact your appropriate State official. A list of State contacts can be found on-line at* **http://www.uidaho.edu/ghpc/** *or in EPA's* Manual on Environmental Issues Related to Geothermal Heat Pump Systems *available at 1-888-STAR-YES (1-888-782-7937).*

## How Do GHPs Affect The Environment?

Increased utilization of GHP systems has the potential to achieve great environmental gains. Because they utilize existing energy stored in the soil and groundwater rather than energy produced by burning fuels, GHPs drastically reduce emissions of greenhouse gases and other pollutants, such as sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_X$), precursors to acid rain. What's more, such environmental benefits can be achieved with minimal environmental risk. This section discusses the overall environmental impacts of GHP systems.

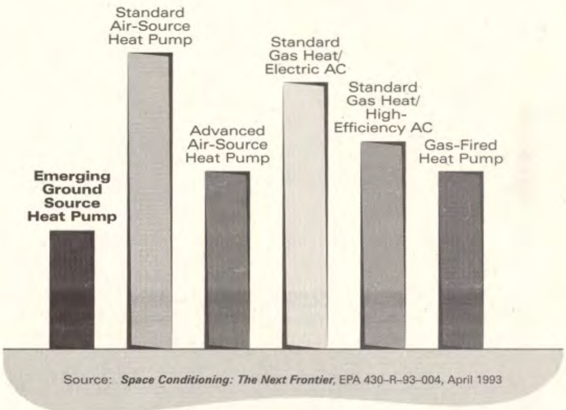
### Reduced Air Pollution

As mentioned above, a GAO report stated that "geothermal heat pumps are the **most** energy-efficient means of heating and cooling buildings in most areas of the United States." Use of GHP systems in place of traditional systems will result in significant reductions in emissions of greenhouse gases such as carbon dioxide, as well as reductions in emissions of sulfur oxides and nitrogen oxides, major causes of acid rain. EPA also has concluded that well-designed and properly installed high efficiency geothermal heat pump systems produce less environmental harm than any other alternative space conditioning technology currently available, stating that geothermal systems are the most efficient technology available, with the lowest $CO_2$ emissions, for minimum greenhouse warming impact. Overall, EPA found emerging geothermal heating and cooling systems to have the lowest environmental cost of all technologies analyzed, including air-source heat pumps and natural gas furnaces.

If 400,000 annual geothermal installations are achieved each year by 2001, U.S. greenhouse gas emissions will be reduced by over 1 million metric tons of carbon each year. This reduction in emissions is equivalent to taking over a half million cars off the road, or planting over a million acres of trees. After that time, a self-sustaining geothermal industry will cause annual carbon emissions in the U.S. to decrease by an additional 450,000 tons every year. That translates into a total annual carbon emissions reduction of at least 5 million metric tons by the year 2010.[6]

In addition, most geothermal heat pumps use R-22, the same refrigerant that is used in virtually all residential air conditioners and heat pumps. GHPs typically require only about one half of the amount of refrigerant as the same sized air conditioner, thereby reducing the environmental damage to the ozone layer in the unlikely event of a leak. Further, most GHP systems seal the refrigerant at the factory rather than require it to be installed on-site, resulting in reduced risk of a leak compared to a standard heat pump or air conditioner.

Exhibit 6: **Relative Comparison of Pollution Emissions for Various HVAC Equipment**
[based on data for Atlanta, GA]




Source: *Space Conditioning: The Next Frontier*, EPA 430–R–93–004, April 1993

### Potential Environmental Concerns

Because GHP systems are, by design, installed in contact with the soil and/or groundwater, there exists the potential for subsurface contamination. As shown in Exhibit 7 below, the potential concerns vary with the type of GHP system in question:

Exhibit 7: **How Groundwater Contamination Can Occur**

| Type of Contamination | Horizontal Closed-Loop | Vertical Closed-Loop | Vertical Open-Loop |
|---|---|---|---|
| **Antifreeze leaks** | Yes | Yes | No |
| **Surface to subsurface contamination** | No | Yes | Yes |
| **Inter-aquifer flow** | No | Yes | Yes |
| **Groundwater supply impairment** | No | No | Yes |

[6] *Geothermal Heat Pump Consortium, "Geothermal Heating and Cooling Systems: Fascinating Facts," October 1995.*

Despite these potential problems, GHP systems have been designed to ensure that if best management practices are applied during the installation, operation, and decommissioning stages, there is little, if any, danger of serious environmental risk.

**Antifreeze leaks.** The potential environmental impact resulting from a leak in the outside GHP loop is primarily dependent on the toxicity and volume of antifreeze released into the environment. Depending on the fluid used, concern need not be high. Many GHP systems use very little antifreeze if any, and some organic antifreezes biodegrade in a matter of days. The primary human health risk associated with antifreezes is inhalation by workers during system installation. If the cautions and procedures found on the antifreeze MSD sheets are followed, however, this should not be a concern.

**Surface to subsurface contamination/Inter-aquifer flow.** Improperly constructed boreholes for vertical closed-loop systems and open-loop systems could serve as channels of contamination from the surface to the subsurface, or from one aquifer to another. However, proper sealing of the borehole will all but eliminate the possibility of contamination. Boreholes should be grouted from top to bottom when more than one aquifer is penetrated, and partially when the only threat is of surface contamination reaching a single aquifer.

**Groundwater supply impairment.** Excessive water withdrawals for an open-loop system from an aquifer may reduce local groundwater supplies. However, if local professionals are contacted to assess groundwater withdrawal and recharge potential during the design and construction phases, this should not be a problem.

The following three sections discuss each of these environmental issues in turn and demonstrate how several layers of protection have been built into GHP system design to ensure that the actual risk of environmental contamination is minimal.

## How Can Environmental Concerns Be Addressed?

Most of the environmental concerns identified in the previous section of this document can be addressed with relative ease if proper care is taken in GHP system design, installation, and operation. The mitigating factors associated with each environmental concern are introduced below. More detailed information can be found in EPA's *Guidebook on Environmental Issues Related to Geothermal Heat Pump Systems*.

### Antifreeze Leaks

The risk posed by a leak of antifreeze is mitigated by a number of factors and installation practices:

**Installer Should Use a Benign Antifreeze.** Typically, the varieties of antifreezes used in GHP systems are relatively benign alcohol or salt based substances that are used in small amounts, and most are biodegradable. Common antifreeze compounds include calcium chloride, potassium acetate, potassium carbonate, sodium chloride, ethanol, methanol, ethylene glycol and propylene glycol. More information on the characteristics, properties and relative risks of antifreezes in GHP systems can be found in *Semi-Quantitative Evaluation of Consequences of Antifreeze Spills from Geothermal Heat Pumps*, available from EPA's Atmospheric Pollution Prevention Division distribution center in Washington, D.C. 1-888-STAR-YES (1-888-782-7937); and also in *Assessment of Antifreeze Solutions for Ground-Source Heat Pump Systems*, available from the Geothermal Heat Pump Consortium in Washington, D.C. (202) 508-5500.

**Antifreeze is unlikely to be released to the environment.** The chance of a leak from properly installed and operating GHPS is small to none. If, however, a leak did occur, the amount of antifreeze lost would be minimal. For example, a typical 5 ton GHP system contains approximately 15 gallons of antifreeze diluted in about 60 gallons of water. If even a small amount of fluid leaked from the system, the circulation pump would begin to cavitate due to the resulting pressure drop in the loop, and the system would shut down. This minimizes the amount of fluid released to the environment, and immediately alerts the owner to the problem.

**Piping in GHP systems is strong.** Industry standard piping is HDPE. GHPs built with HDPE piping are using one of the strongest, most durable piping materials available. Sections of this piping are joined together by heat fusion, a process that renders the joints even stronger than the surrounding pipe. The strength of this pipe is illustrated by the fact that it is commonly used to transport natural gas hundreds of miles at much higher pressures than those present in a GHP system.

**Piping is pressure tested.** The contactor should pressure test the piping in all GHPs before placement to ensure its strength and suitability for conditions likely to be encountered underground.

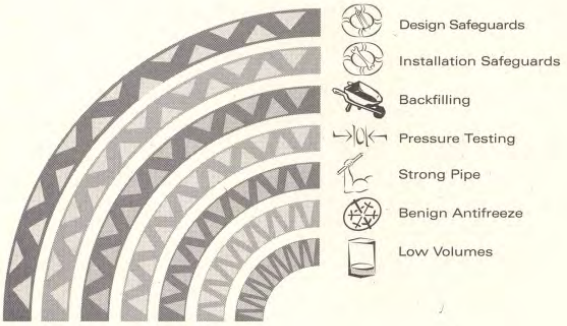
**Backfilling is done very carefully.** GHP installers should be careful to properly backfill around the piping loop. Backfill should be tested to ensure that it is inert, and grouts with low permeability (no more than $10^{-7}$ inch/sec) should be used. In addition, the backfill should be inspected to ensure that it is free of sharp rocks or other objects that could potentially puncture or otherwise damage the piping.

**Design safeguards exist.** International Ground Source Heat Pump Association (IGSHPA) programs and other training programs teach how to design systems with complete environmental assurance.

**Installation and operation safeguards exist.** Contractor training and certification programs, piping manufacturer installation and testing procedures, and IGSHPA standards assure that systems are installed and operated with complete environmental assurance.

Exhibit 8 demonstrates visually how the underground portions of a GHP (i.e., those components in actual contact with the environment) are designed and installed to minimize the potential for environmental contamination from antifreeze.

Exhibit 8: **GHPs Are Designed to Minimize Leakage Risk.** Each Layer Represents an Additional Reduction of the Risk of Antifreeze Leakage.




### Surface to Subsurface Contamination

There are a number of Best Management Practices (BMPs) that help to minimize the chance of surface contamination reaching the subsurface. The following BMPs are applied to all types of vertical GHP systems.

**Disturbed soil is seeded.** Seeding disturbed soil during construction and installation ensures that runoff that could potentially infiltrate the borehole is minimized.

**Surface drainage is diverted.** Diverting surface drainage away from the well and maintaining the area surrounding the well in clean condition will reduce surface contaminant infiltration during construction.

**Boreholes are grouted.** Partially or fully grouting the borehole will prevent surface contaminant infiltration during operation.

**Boreholes are drilled only by qualified professionals.** Ensuring that proper procedures are followed for drilling and grouting boreholes will reduce the risk of surface contaminant infiltration.

**Loops are properly located.** Locating the GHP system loop away from potential contamination sources like landfills, lagoons, underground storage tanks, and septic systems, in an area with good surface drainage, will minimize the opportunity for surface contamination to enter the groundwater from along the borehole.

### Inter-aquifer Flow

There are differing views on the preferred Best Management Practices (BMPs) that can help minimize the chance of inter-aquifer flow. The goal of all methods is to adequately seal off polluted water formations and prevent contamination of the overlying or underlying waterbearing zones. The following are some of the current BMP views that can be applied to all types of vertical GHP systems.

**Entire length of the borehole is grouted.** One perspective is that full length grouting of the borehole using approved materials and standards is best for preventing inter-aquifer flow.

**Grouting above and below affected aquifers.** Another perspective is that grouting at least 10 feet above and below the affected aquifers is sufficient to prevent inter-aquifer flow.

### Groundwater Supply Impairment

There are a number of Best Management Practices (BMPs) that can help minimize the chance of groundwater supply impairment. These BMPs are applicable to open-loop GHP systems.

**Aquifers are assessed prior to system installation.** Assessing the yield of the aquifer and projected use volumes before system installation to ensure the adequacy of the water supply will help to avoid aquifer drawdown.

**Drainage is environmentally benign and seasonally adaptable.** Ensuring that drainage for surface disposal does not cause soil erosion, and that the disposal method is compatible with the volume to be discharged and able to handle extreme weather conditions (i.e., freezing), will ensure that the system can be utilized indefinitely.

**Return wells are assessed and properly designed.** Ensuring that well capacity is sufficient to accept the maximum discharge from a system will help to avoid discharge problems.

**Thermal plumes are minimized.** Assessing the potential of subsurface disposal to introduce a thermal plume will help to avoid adverse thermal impacts to other wells.

## Where Can I Go For More Information?

There are a number of sources from which additional information regarding GHPs may be obtained. Because State laws and regulations are constantly evolving, you should contact appropriate officials in your State. Contact the National Ground Water Association (NGWA) at 1-800-551-7379 or the National Rural Electric Cooperative Association (NRECA) at 1-800-245-9440 for a list of State officials that oversee implementation of relevant laws and regulations in each State.

In addition, there are a number of helpful industry and government contacts who are willing and able to answer any questions you may have regarding GHPs. These include the International Ground Source Heat Pump Association (IGSHPA) at 1-800-626-4747, and the Geothermal Heat Pump Consortium (GHPC) at 202-508-5500, or on-line at **http://www.ghpc.org.** The University of Idaho has collected information on state regulations and this can be found on-line at **http://www.uidaho.edu/ghpc/**. In addition, printed information on GHPs may also be obtained from the U.S. Environmental Protection Agency's ENERGY STAR Hotline at 1-888-STAR-YES (1-888-782-7937).

One document addresses the various environmental aspects of GHPs in more detail. It is titled Guidebook on Environmental Issues Related to Geothermal Heat Pump Systems. This document highlights the environmental issues associated with GHPs from installation through decommissioning, and discusses the regulatory options and best management practices for addressing those issues. The document is intended for regulators and GHP professionals. Additional information is available from EPA on-line at **http://www.epa.gov/appdstar/hvac/geothermal.html**.

## Overview of GHP-Related Documents

There are a number of very good documents that explain how GHPs are designed and how they work, as well as the best management practices for each type of GHP at each phase in their life cycle. These include:

Caneta Research Inc. *Commercial/Institutional Ground-Source Heat Pump — Engineering Manual.* ASHRAE, 1995.

Electric Power Research Institute. *State and Federal Vertical Borehole Grouting Regulations.* EPRI RP 3881-01, July 1996.

International Ground Source Heat Pump Association. *Closed-Loop/Ground Source Heat Pump Systems — Installation Guide.* Oklahoma State University, 1988. 236 pp.

International Ground Source Heat Pump Association. *Ground Source Systems Design and Installation Standards.* Oklahoma State University, [n.d.]. 9 pp.

International Ground Source Heat Pump Association. *Grouting Procedures for Ground-Source Heat Pump Systems.* Oklahoma State University, 1991. 45 pp.

International Ground Source Heat Pump Association. *Soil and Rock Classification for the Design of Ground-Coupled Heat Pump Systems.* Oklahoma State University, 1988. 55 pp.

Missouri Department of Natural Resources' Division of Geology and Land Survey. *Miscellaneous Publications No. 50, Missouri Private Water Well, Heat Pump System, Pump Installation and Monitoring Well Construction Rules.* Division of Geology and Land Survey, Department of Natural Resources, March 1995.

National Ground Water Association. *Guidelines for the Construction of Vertical Boreholes for Closed Loop Heat Pump Systems.* NGWA, July, 1997.

Pennsylvania Department of Environmental Protection; Bureau of Water Quality Management; Division of Assessment and Standards; Groundwater Quality Section. *Ground Source Heat Pump Manual.* [n.p.], Revised January, 1996. Publication Number: 3610-BK-DEP1562
Bureau of Water Quality Management
Department of Environmental Protection
P.O. Box 8465
Harrisburg, PA 17105-8465
(717) 783-3638 (Central Office)
**http://www.dep.state.pa.us/dep/DEPUTATE/Watermgt/WC/WC_WQAS/GENERAL/SOURCE/gshpttoc.htm**

US Environmental Protection Agency (USEPA). *Guidebook on Environmental Issues Related to Geothermal Heat Pump Systems.* 1997.

US Environmental Protection Agency (USEPA). *Space Conditioning: The Next Frontier.* EPA 430-R-93-004, April 1993.

US General Accounting Office (USGAO). *Geothermal Energy: Outlook Limited for Some Uses but Promising for Geothermal Heat Pumps.* RECD-94-84, June 1994.

☆U.S. GOVERNMENT PRINTING OFFICE: 1997 -514-003/60606

APPENDIX F
SAMPLE TRAINING CURRICULUM

**JG & A, Inc.**
ENERGY MARKETING AND TECHNOLOGY CONSULTANTS

# Introduction to Geothermal Heat Pumps

aka: Ground-Coupled, Water Source Heat Pumps
aka: "GeoExchange"

## Introduction to Geothermal Heat Pumps

- ✓ Four Basic Components
- ✓ How they Work - Heating and Cooling
- ✓ Brief History
- ✓ Geothermal v. Air Source Heat Pumps
- ✓ Efficiency Potential
- ✓ Northwest Market Potential

## Geothermal Loop Systems

- ✓ Vertical -- Parallel
- ✓ Vertical -- Series
- ✓ Horizontal
- ✓ Slinky -- Compact and Extended
- ✓ Open Loop
- ✓ Pond Loop -- Summer and Winter
- ✓ Direct Exchange, aka "DX"
- ✓ Standing Column
- ✓ Domestic Water
- ✓ Hydronic -- Single and Multiple Zones

## Polyethylene Pipe (High Density)

- ✓ Standards - IGSHPA, ASTM, ASHRAE
- ✓ Polyethylene v. PVC or Polybutylene Pipe
- ✓ Fusion -- Socket, Butt, Sidewall
- ✓ Loop Emplacement -- Vertical, Horizontal
- ✓ Headers and Fittings
- ✓ Polyethylene Warrantees

## Thermal Conductivity

- ✓ Importance to System Cost and Reliability
- ✓ Conductivity of Materials -- Rock, Soil, Clay, Sediments
- ✓ Enhancement -- Grout, Clips, Design

## Grout and Groundwater Protection

- ✓ Grout Characteristics
- ✓ Environmental Protection
- ✓ Grout Properties - Plus and Minus
- ✓ Grout Placement -- Tremie Pipe and Pump
- ✓ Settling of Bentonite Grout in Annulus
- ✓ Cement Surface Seals
- ✓ Abandonment of Loops

## Antifreeze

- ✓ Basic Types and Qualities
- ✓ Health and Safety Hazards
- ✓ Environmental Hazards

## Commissioning and Start Up

- ✓ User Education
- ✓ Tagging
- ✓ Service Requirements and Life Expectancy

P.O. Box 821085
(360) 882-5050
5910 N.E. 82nd Avenue
jgeyer@jgainc.com
Vancouver, WA 98662
FAX (360) 882-5051

## APPENDIX G: Article: Excerpted and Copied in total Renewable Energy World.com Sept. 9, 2008

Introductory comment:

This article is appended in total as a comprehensive, research-based discussion of the breadth of heat pump appliances. Some are geothermal (i.e., some are ground-coupled or use ground or surface water), others are not. Commercial application and active industry focus are subordinated herein to discussion of the full range of mechanical systems addressed in European union research and development grants between 2004 and 2009. Technical content is consistently accurate although failure to differentiate among more or less viable, durable or cost effective machines leaves readers to assess ultimate utility or operating efficiency among device-types. North american units favor water-water or water-air indoor units with ground-coupled, closed-loop heat exchangers while european sites tend to suffer less land area and access to excavation or drilling equipment for ground loop installation. This favors air source.

**J. Geyer**

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September 9, 2008 Renewable Energy World Magazine

Geothermal Heat Pumps

There are over two million ground source heat pumps used for heating or cooling around the world, yet opinion remains divided on their renewable credentials. While some hail them as a low-input means of using freely available heat, some renewables purists reject them because they require electrical input. Much depends on the overall efficiency, as explained in this outline of how heat pumps function and some of their main applications.

William Thomson, the first Lord Kelvin, described the theoretical
basis for the heat pump in 1852. As a noted freethinker, he would probably be amused that it is now a potentially significant tool in the fight to lower CO2 emissions. His key theoretical advance was to overturn the notion that heat could only flow ‘downhill' from the hot to the cold. A heat pump collects low-grade heat and can deliver it at a higher temperature, but needs some imported energy to do so.

Lord Kelvin certainly did foresee its first application in buildings for cooling, and millions of air conditioners, chillers and refrigerators (i.e. heat pumps) are manufactured and installed every year. Indeed, the increased demand for the comfort that they can bring, particularly in very hot climates, is one of the main drivers of the rapid increase in energy use in buildings of all types over the past 50 years.

However, heat pumps can also do exactly what the name says — pump heat! To apply them as heating devices (rather than the now almost ubiquitous cooling devices) low-grade heat is collected from the atmosphere (air), bodies of water (such as lakes or rivers) or from the ground. Using a refrigerant circuit, this heat is upgraded by an electrically-driven compressor and can then be delivered at a useful temperature for
heating. For cooling, this process is simply reversed; low-temperature heat is collected from inside a building, upgraded and rejected to the atmosphere, water or ground.

It is difficult to assemble authoritative statistics for the number of heat pumps used for domestic heating. At the five-yearly World Geothermal Congress in 2005, a review concluded that there are in excess of 1.3
million. Writing in Renewable Energy World magazine earlier this year, Eric Martinot of the Worldwatch Institute quoted a figure of more than two million ground source heat pumps used for heating or cooling in over thirty countries.

The key to ensuring that a heat pump is a worthwhile installation — in terms of overall efficiency and related carbon emissions — is the Coefficient of Performance (COP). This is the ratio of the units of heat (kWh th) the equipment delivers for every unit of electricity (kWh e) consumed. A well-designed, properly-sized system using modern components should deliver a COP of 2.5-4.5. Clearly, the efficiency of the generation to provide the electricity is important to the overall worth of the system. If the electricity comes from a conventional power station operating at about 35% efficiency and the heat pump has a COP of 3.5, then the heat pump will be 1.4 times more energy-efficient overall than a gas-fired boiler. If the electricity comes from a more efficient combined-cycle power station, say operating at 45% efficiency and the heat pump has a COP of 4,then the system will be more than twice as efficient as the boiler. Of course, if the electricity were to come directly from a wind or solar renewable energy source, then the heat pump represents an excellent way to generate heat without any associated carbon emissions.

There are a variety of different types of heat pumps. They can be categorized by function (heating, cooling, domestic hot water, ventilation, drying, heat recovery etc); by heat source (ground, water, air, exhaust air, etc); by working fluids (both for the heat collection and distribution — brine/water, water/water, air/water, air/air, etc.) and by unit, construction, location, drive power and more.

For buildings, and heating and hot water applications, the main heat input is likely to be air, water or ground. In some parts of the world, particularly North America, the heat is most likely to be delivered as air through ductwork, either warmer in the heating season, or cooler when this is required. Reversible units are thus quite common for areas with both heating and cooling needs at different times of the year. In Europe, by contrast, the output is most likely to be delivered using water either through a radiator or under-floor system.

Almost all of the heat pumps used in buildings will use the wider environment as their energy ‘source'. While air is the most widely available source, a significant difficulty arises in that heat pumps work best when there are lower temperature differences; on cold days when demand for heating is highest a heat pump will then either be working inefficiently, or not delivering sufficient heat to meet the demand. In moderate climates with well insulated buildings they may be able to meet the heating needs, otherwise a secondary heat source will have to be used as well.

Water heat pumps have a big advantage in that water has a much higher heat-carrying capacity than air, better heat-transfer characteristics and can be moved around easily and efficiently. However, relatively few buildings have a conveniently located, appropriate source of water to use.

As a result, interest in geothermal heat pumps (or ground source heat pumps) has burgeoned. Typically, these are closed loop systems, and usually use the ground surrounding or underneath a building. By installing a suitably sized loop of pipework in the ground, water can be circulated to collect the renewable energy stored in the earth and deliver it to a water-source heat pump.

While very simple in concept, these systems can be rather more complex in their design. The loop temperatures are engineered to ensure the movement of heat by conduction through the ground. The systems need to be thought of as coupled, comprising the building, the heat pump and the ground loops, which need to be carefully matched to ensure a long-lasting, reliable system.

There are numerous different possible configurations for a heat pump. For example, heat pump has input air at 7ºC and output water at 50ºC. Below is an overview of the main types of electrically-driven, vapour compression heat pumps typically used in single and multiple family homes, and in industrial, commercial and community buildings.

Water/water and brine/water

These are frequently used for heating operation (usually ground source) as well as cooling, heat recovery and hot water production. Water/water systems are used with an available water source such as a lake or borehole, while brine/water systems will be closed loop, ground-coupled installations. While in early systems ‘brine' may originally have literally been brine (saltwater), the term is now used to refer to any water circuit with antifreeze in it.

They are generally compact units suitable for indoor use. Typically, they will have a hermetic compressor chosen for extremely quiet operation, and modern heat pumps will include some acoustic shielding and vibration isolation as well. A steel, flat-plate heat exchanger is usually used for the evaporator and condenser, though shell and tube or coaxial ones can also be used. A chlorine-free refrigerant should be chosen. A controller will usually be integrated or externally mounted, and displays are usually kept as simple as possible

For simple installation, the heating system circulation pump, and/or the source side circulation pump will be integrated into the heat pump casing, and for extra compactness, the hot water tank is sometimes built in as well.

Direct expansion/water heat pump

These do not have a heat exchanger on the source side. Instead, a loop of pipe puts the refrigerant in direct contact with the ground or water body. The compressor circulates the refrigerant directly, eliminating the heat transfer losses. It is particularly important that the refrigerant loops are totally sealed and corrosion resistant.

Direct expansion/direct condensation

These systems are similar, but the distribution of heat is achieved directly using the refrigerant, usually in a radiant floor heating system. The condenser, like the evaporator, is composed of seamless, plastic-sheathed copper tubing, and the latent condensation energy is released at a constant temperature.

Air/water heat pump — split units

These use air as their heat source and usually operate in bivalent heating systems. They are particularly well suited for retrofit and renovation as they need less structural work. The indoor unit will contain the main components and be protected from frost. Typically a fully hermetic compressor will be used, and a stainless steel flat plate heat exchanger for the condenser. The outdoor unit will then be connected through refrigeration lines; with the elimination of air ducts it is possible to get fans to run very quietly.

Air/water heat pump— compact units, indoors

In this case the outside air is the heat source— units typically operate in bivalent heating systems. They are compact, and frequently used in indoor installations. They use a hermetic compressor and often a copper-tube, aluminium-finned evaporator. The refrigeration cycle should be fully insulated to prevent thermal losses and condensation.

Air/water heat pumps — compact units, outdoors

These compact units can be installed in any open location. All components of the refrigeration cycle are integrated into the unit, so no air ducts are required, though the housing unit needs to provide protection against the weather. The connection to the heating system will consist of two insulated pipes for supply and return, and will be installed underground, along with the pump power supply and control cable.

Domestic hot water/heat pumps — air source, compact units

These are supplied as fully-integrated compact units, normally as exhaust air heat pumps with a hot water storage tank. All components are integrated into the unit. These will often have fairly sophisticated electronic controls to ensure simple and effective operation of all the main controls that may be needed, such as Legionella treatment, the use of off-peak power and so on.

Domestic hot water heat pumps — air source, split units

With these units, external hot water tanks are used, and a built in feed pump circulates water from the heat pump to the hot water tank. This allows tanks of any model or capacity to be used with these systems.

Other types of heat pumps include ground or water heat pumps with domestic hot water, split units, air/air heat pumps for ventilation, various designs of exhaust air heat pumps, and some for heating and cooling.

Conclusion

Geothermal heat pumps are an often-overlooked member of the set of renewable energy tools available for reducing CO2 emissions. To some, the fact that they need an electrical input counts against them significantly; indeed, if poorly sized, with a low COP and using power from an inefficient generation source, they might actually be a poor choice of technology resulting in an increase in CO2 emissions (compared with burning the fuel directly for heat).

However, systems with good COP, appropriately sized, and particularly those using renewable electricity to provide the electrical power, can make a big contribution to higher efficiency. This is particularly true for many urban buildings; some planning authorities require a percentage of a building's energy to come from renewable sources as a condition of granting planning permission. Since many urban sites, particularly compact ones, may have little wind resource and only a small or shaded area to try to collect solar energy, a geothermal heat pump may be the only option for on-site renewable energy generation.

This article is based on material in the book Geothermal Heat Pumps — a Guide for Planning and Installing by Karl Ochsner with an introduction by Robin Curtis. The book is published by Earthscan.
http://www.earthscan.co.uk/?tabid=415

http://www.renewableenergyworld.com/rea/news/reworld/story?id=53531

**<u>APPENDIX H</u>**: J. GEYER CREDENTIALS & QUALIFICATIONS

*1. JOHN D. GEYER*

**JOHN GEYER & ASSOCIATES, INC.**
P.O. Box 821085 Vancouver, WA 98682
Voice: 360.882.5050 Fax: 360 882 50501
jgeyer@jgainc.com

John Geyer is an electric-industry marketing consultant, based in Vancouver, WA. Involved with renewable and efficient energy technologies since the oil embargo in 1973, John has been closely tied to utility industry changes since 1987 (i.e. deregulation and wholesale marketing). After 13 years of alternative energy work for U.S.D.A., Forest Service and nine more for Department of Energy's Bonneville Power Administration, he has been a leader in geothermal heat pump market development since 1992. He is a founder and principal of Sound Geothermal and Northwest Geothermal corporations and designer of the Western Regional Training Center in Davis, CA. Mr. Geyer was factory representative for HDPE geothermal products for Chevron-Phillips Chemical Company's *Performance Pipe* and nine-state territory sales manager for other geothermal products and services from 1997 through 2003. While not currently aligned with any single heat pump manufacturer, he provides turnkey soil conductivity testing and system design support to architects and engineers. He also wholesales HDPE and geo-specialty products not otherwise available to contractors.

B.S. , Forestry Oregon State University, 1969

M.S., Management – Marylhurst College, 1988

GeoExchange Credentials:

International Ground Source Heat Pump Association - *member* No. 14266-596.

International Ground Source Heat Pump Association - *Certified Installer, No. 13100/400*

International Ground Source Heat Pump Association - *Certified Trainer, No. 1071/1196*

Association of Energy Engineers - *Certified Geothermal Designer*, No. 0076

Geothermal Heat Pump Consortium - C*harter Member* (1994)

Chevron/Phillips Performance Pipe - F*actory Representative & Trainer* , '97-'03

Geo Bore Technologies, Inc - *Distributor, 1999-2006*

Geo Pro Grout, Geothermal Supply Co. - *Territory Sales Manager* (1996-2000)

Geo Resource Technologies, Inc. – *Soil Conductivity Test Technician*