Dispelling the Myths of Geothermal HVAC

A view of Apollo Nursing College, Chennai

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Geothermal HVAC utilizes one or more Geothermal Heat Pumps to pump heat to and/or from the ground or groundwater as:

- thermal energy to heat a structure or
- thermal energy sink to cool a structure.

In the United States, geothermal heat pumps were added to the definition of energy property under section 48(a) of the Internal Revenue Code on 3 October 2003, thus enabling the technology to claim tax incentives as a renewable energy device.

Heat Pumps are either:

1. water-to-water: a device producing chilled or heated water depending upon the requirement
2. water-to-air: a unitary device containing the condenser and blower to produce cool or warm air depending upon requirements.

The ground or groundwater component of the Geothermal HVAC solution is known as a "ground heat exchange" and they can be any of the following:

1. Lake/Pond Closed Loops: utilizing a series of pipes placed in bodies of water;
2. Open Loops: utilizing groundwater in an aquifer or body of water;
3. Vertical/Horizontal Closed Loops: utilizing a series of underground pipes bored into small wells or laid into trenches.

The high efficiency of Geothermal Heat pumps is derived from:

- The temperature below the ground or in water is either cooler or warmer than the ambient air temperature. In warm climates, the Geothermal Heat Pump transports the waste heat captured in the building and dissipates it into the cooler earth or water body.
- The cool or warm air is produced in the actual room or zone where it is needed.
- The HVAC system is modular and distributed. Individual units can be turned off when not needed. To paraphrase, the part-load can be 0 kW.

Since the development of this technology in the 1940's, there have been over 2 million such installations in the world. In the USA there are 80,000 new installations each year and 27,000 in Sweden. (*http://en.wikipedia.org/wiki/*

About the Authors

Grant Morrison has over 20 years experience in a broad range of operations and finance roles in the logistics, construction and finance industries across Australia, Asia and Europe. With a degree in Business from UTS, Australia, he has previously worked with Barclays Bank in the UK and ING, Australia.

Parwez Ahmed has 10 years of HVAC experience in India and is a mechanical engineer from RJIT. He is responsible for overseeing design and installation of both geothermal and water-source heat pump technology projects in India.

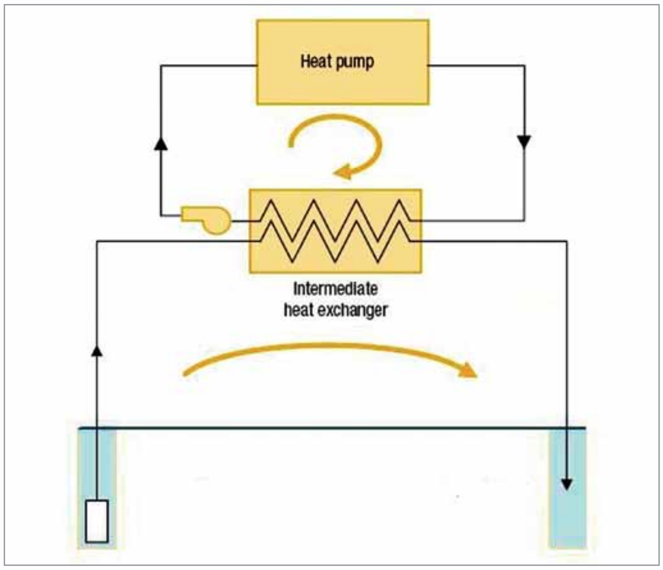

Figure 1: Schematic of open-loop system

Geothermal_heat_pump).

The US Environmental Protection Agency has called GSHPs the most energy-efficient, environmentally clean and cost-effective space conditioning system available. *(Environmental Protection Agency, 1993, Space Conditioning: The Next Frontier – Report 430-R-93-004. EPA)*.

According to the US Department of Energy – Energy Efficiency & Renewable Energy, "The biggest advantage of Geothermal Heat Pumps is that they use 25-50% less electricity than conventional heating or cooling systems. The underground piping often carries warranties of 25-50 years, and the heat pumps often last 20 years or more."

Despite the global popularity and recognition of the technology, there are less than five completed installations in India today.

The Apollo Nursing College Auditorium project is the first use of an open loop system in India and one of the few of this type of installation in the world.

Dispelling Myths Associated with the Technology

In promoting this technology in India, the authors have confronted a number of myths associated with the technology.

These myths include:

a. The technology is too expensive

b. The technology doesn't work in India

c. Geothermal HVAC requires geothermal energy to operate

The myths are believed or perpetuated by all HVAC industry stakeholders; ranging from end-users (customers) to HVAC/MEP consultants to architects and the government.

Dispelling Myth 1 – The technology is too expensive

To analyse the term "too expensive", one needs to break-down the costs of each component of the total HVAC solution during its life cycle.

There are two broad areas of life cycle analysis costs:

1. Equipment acquisition and installation costs including:
- High-side
- Low-side
- Ground heat exchange construction
- Ancillaries such as make-up water tanks, energy demand side (DG sets, substation)

2. Operation and maintenance costs including:
- Energy costs with DG set
- Water costs
- Spare parts and consumables

The authors agree that Geothermal Heat Pump technology may have a small upfront premium for equipment acquisition and installation costs comparable to premium conventional HVAC solutions with similar efficiency rating.

However, the premium for Geothermal Heat Pump technology may be reduced depending upon the type of "ground heat exchange". The following is a list of ground heat exchanges, from most expensive to least costly in the experience of the authors, per TR:

1. Vertical Closed Loop – requires borewell drilling
2. Horizontal Closed Loop – requires large land space and excavated trenches
3. Standing Column Well – can handle more TR than Vertical Closed Loop but requires borewell drilling
4. Lake/Pond Closed Loop – requires HDPE piping
5. Open Loop – requires a body of water on or under the property

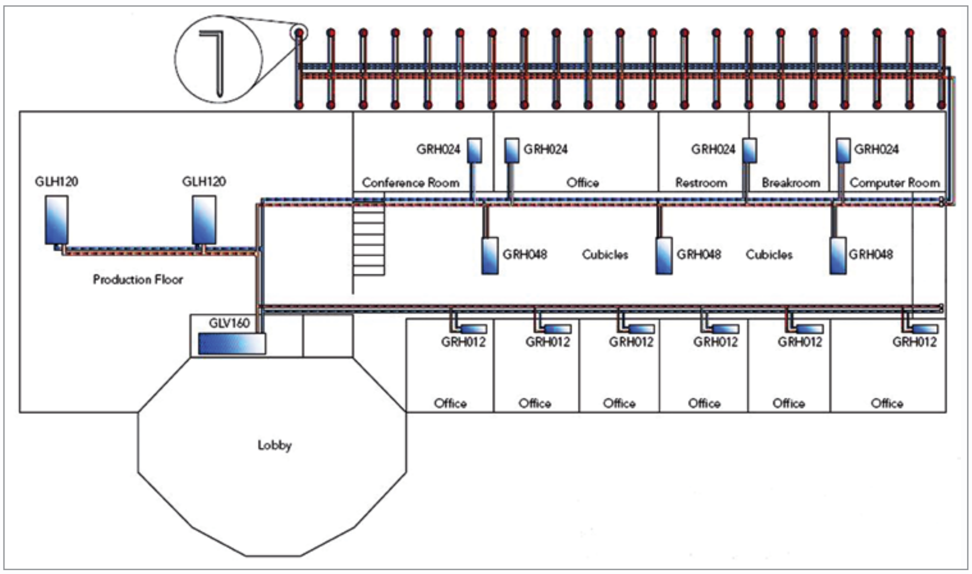

Figure 2: Schematic of decentralised distribution system

Figure 3: ClimateMaster GR060 vertical unit suspended from ceiling

In the experience of the authors, the life cycle costs of a Geothermal HVAC solution will always deliver a project pay-back lower than conventional HVAC solutions. This is because Geothermal Heat Pumps:

1. are a unitary device containing the condenser and blower within the one device.
2. do not require back-up units for contingency. Each unit provides thermal comfort for one room or as part of a zone. If one unit fails, all other units continue to operate.
3. are between 30-50% more efficient than conventional HVAC solutions; producing significant savings on energy consumption.
4. are entitled to 80% accelerated depreciation compared to conventional chillers/AHUs as per the Income Tax Act of India.
5. are entitled to normal Excise Duty waiver.
6. do not require make-up water and therefore they save operational costs of supplied water and capital costs of storage tanks.
7. have lower peak energy demand requirements and therefore save capital costs on sub-stations and DG sets and operating costs or fees.

The project pay-back will improve for new projects from 2010 onwards after the Government of India waived normal Excise Duties for Geothermal Heat Pumps in the 2010 Budget.

Dispelling Myth 2 – The technology does not work in India

All new technology faces resistance for acceptance. Geothermal Heat Pump technology is facing this technological resistance in India. The technology is new to India, although it has been successfully implemented in other parts of the world since the 1940's.

The reason why the myth perpetuates is because there is techno-phobia for new technology when it is misunderstood by the market or the market does not have skilled and experienced practitioners.

Furthermore, it is believed, that as Geothermal Heat Pumps are widely used in cold/cool climates such as North America and Europe, it is unsuited to hot/warm climates found in India. This is untrue. Geothermal Heat Pumps are used in hot/warm climate of Australia, the Middle East, Turkey and southern/west USA (Florida, California, Nevada, Texas, and Arizona etc).

India is a large country with many micro-climates and geological characteristics. A specific India-only climate or geology does not exist. Geothermal Heat Pump technology has been deployed in many of the planet's climates and geologies.

Where there is ground and/or water bodies (surface or subterranean), the technology will work. In addition, the technology can also be connected to a cooling tower at a lower cost than the construction of ground heat exchanges.

The authors have successfully implemented Geothermal HVAC solutions in India utilizing a range of ground heat exchange techniques.

Dispelling Myth 3 - Geothermal HVAC requires geothermal energy to operate

The terminology for the Geothermal Heat Pump can confuse those people who are unfamiliar with the technology. The "geothermal" component of the name is often confused with geothermal energy produced or extracted from the heat generated from the Earth's core.

Geothermal Heat Pumps require the same source of energy as conventional HVAC solutions – electricity. The electricity can be produced and sourced from a number of different supplies – renewable energy such as solar and hydro and carbon generated such as coal.

For Geothermal Heat Pumps, drilling to the Earth's core is not needed (and also impossible). The geothermal and renewable energy aspect of Geothermal Heat Pumps is via the use of water bodies and the ground to dissipate heat in hot/warm climate applications.

However, in the United States, Geothermal Heat Pumps are classified as energy equipment and therefore able to attract LEED credits for On-site Renewable Energy.

Project Example – Apollo Nursing College Auditorium, Chennai

General

The Geothermal Heat Pump HVAC application was designed to

Figure 4: Alfa Laval plate heat exchanger

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meet the following requirements.

- Thermal comfort of 24ºC
- Relative humidity under 60%
- Occupancy upto 200 people but flexibility to scale back on the conditioned space as per temporary partitioning requirements.

To meet the requirements, we:

- Selected five 5TR nominal capacity ClimateMaster Geothermal Heat Pumps from USA with a total actual capacity of 27TR
- Strategically distributed the units throughout the space to allow for partitioning
- Attached each Geothermal Heat Pump to a separate thermostat to maintain control and flexibility of the system

The US Department of Energy eQUEST Building Simulation program was used and our methodology included creating a 3D model of the auditorium and loading the model with:

- Heat load factor requirements of Apollo Hospitals
- Building characteristics
- BIN weather data for Chennai from ISHRAE
- Equipment performance library from ClimateMaster.

By creating an energy model via building simulation, we sized the unit as per the requirements; eradicating estimates and safety buffers. Indeed, ClimateMaster recommended that the solution was under-sized rather than over-sized. We decided to go with our selection, as this will save energy and help to combat humidity (which may build up if the units are cutting-out due to over-sizing).

Also, by having a distributed and modular technology, the Geothermal Heat Pumps are able to be placed throughout the conditioned space. This means that Apollo Hospitals can turn individual units off when the space is configured differently through temporary partitions. The units were placed in the false ceiling cavity, thus saving space. No separate AHUs are needed. The ground heat exchange unit was placed underground.

As per the schematic *Figure 1* there are a number of components to a Geothermal Heat Pump with an open loop ground heat exchange:

- Water-to-air Geothermal Heat Pumps from ClimateMas-

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Table 1: Life cycle cost analysis

Annual Energy requirement (kWh)	**Geothermal India**	**Conventional**	
Space Cooling (kWh)	17,800	40,150	
Heat Rejection (kWh)	-	2,910	
Ventilation Fans (kWh)	4,220	10,910	
Pumps & Auxiliary (kWh)	9,240	8,420	
hot Water (kWh)	-	-	
Total kWh	**31,260**	**62,390**	
Energy Rate per kWh	5.0	5.0	
AnnuaL Energy Upeneiture (Rs)	156,300	311,950	
TR	27	25	
Project Square Feet	5,124	5,124	
System kWh	0.40	0.85	
System EER	30	14	
Hours	2,920	2,920	
Acquisition & Installation (Rs)			
Ecuipment Cost / TR ex duties & shipping	69,420		
Cost of Equipment (Rs)	1,963,577	1,738,701	
Savings in Rs	**Geothermal India**	**Conventional**	**Cumulative Savings**
Totat Cost of Ownership Year 1 (Rs)	2,119,877	2,050,651	(69,2261)
Total Cost of Ownership Year 2 (Rs)	2,276,177	2,362,601	86,424
Total Cost of Ownership Year 3 (Rs)	2,432,477	2,674,551	242,074
Total Cost of Ownership Year 4 (Rs)	2,588,777	2,986,501	397,724
Totat Cost of Ownership Year 5 (Ps]	2,745,077	3,298,451	553,374
Total Cost of Ownership Year 6 (Rs)	2,901,377	3,610,401	709,024
Totat Cost of Ownership Year 7 (Rs)	3,057,677	3,922,351	86,4,674
Total Cost of Ownership Year 8 (Rs)	3,213,977	4,234,301	1,020,324
Total Cost of Ownership Year 9 (Ps)	3,370,277	4,546,251	1,175,974
Total Cost of Ownership Year 10 (Rs)	3,526,577	4,858,201	1,331,624
IRR		149.15%	
Payback Years		1.27	

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ter, USA containing Copeland scroll compressor and blower
- Individual thermostats connect to the DXM control board of each Geothermal Heat Pump
- Plate heat exchanger from Alfa Laval to allow the exchange of temperature between the ground loop and the condenser loop
- Grundfos circulation pump for the condenser loop
- Grundfos submersible pump for the open loop with the aquifer
- Grundfos control panels to control the pumps
- HDPE piping for the open loop – long lasting material which does not corrode or introduce impurities into the water.
- To lower the risk of ground water being at an unsustainable level for Geothermal HVAC, we have attached a cooling tower. This allows the customer to choose a variety of heat dissipation mechanisms; the choice between a Geothermal Heat Pump or Water Source Heat Pump application utilizing the same Heat Pumps.

Energy Performance

In our assessment and building simulation, we had predicted the Nursing College Auditorium project would consume on average 0.4kW/Ton; taking into account part loads and cut-out operation once the desired room temperature of 24°C was obtained.

To ensure the integrity of our HVAC system performance, we ensured a separate energy meter was attached to all components of the HVAC system – Geothermal Heat Pumps, circulation pump, submersible pump and controls. Additionally, Apollo Hospitals commissioned an independent consultant to record the specific measurements relating to the HVAC system.

After 23 days of data collection, the consultant recorded the following measurements:

- Average outside temperature = 30.6°C
- Average conditioned space temperature = 24.0°C
- Average relative humidity within the conditioned space = 41%
- Total HVAC system energy consumption including chilling/ blower/pumps = 0.89kW/Ton
- Chiller component of Geothermal Heat Pump = 0.51kW/Ton or EER = 24
- The Geothermal Heat Pump performed within 99.3% of the ARI certified testing conditions of the equipment Submittal Data for the corresponding site conditions (EAT and EWT).

Renewable Energy

There are two aspects to renewable energy for this project:

- Geothermal Component

Geothermal Heat Pumps are within the definition of energy property under section 48 (a) of the Internal Revenue Code of the US. It further says this equipment uses the ground or ground water as a thermal energy source or as a thermal energy sink to cool a structure. As such, it is a form of renewable energy.

In India, the Geothermal Heat Pump is recognized in a similar but not explicit context. The equipment attracts normal Excise Duty waivers; similar to government incentives provided for other renewable energy devices.

For the Nursing College Auditorium, our Geothermal Heat Pumps use the properties of the ground water but do not consume ground water. This is an important point of clarification. As per the schematic below, ground water is pumped up to a Plate Heat Exchanger before returning to the aquifer. As the ground water passes the Plate Heat Exchanger, the cooler temperature of the ground water is transferred to the building loop water. Note: only the temperature is transferred. This cooler water is then the EWT for the Geothermal Heat Pump. The LWT water which is warmer is then transferred via the Plate Heat Exchanger into the aquifer as a heat sink.

The EWT property of ground water is lower than EWT from a cooling tower and therefore, Geothermal Heat Pumps operate more efficiently than a chiller.

- Water Component

A cooling tower loses between 3-5% of its water needs through factors such evaporation and blow-off.

A Geothermal Heat Pump utilizes a closed building water loop (condenser pipes) and a closed or open loop for heat dissipation or extraction.

In this project, we utilized the properties of the ground water without consuming ground water via use of a Plate Heat Exchange intermediary. This project has 100% water conservation when used as a Geothermal HVAC system but has efficiency in excess of a water cooled chiller.

Life Cycle Cost

The life cycle cost analysis shown in *Table 1* was done by building an Energy Model using the US Department of Energy's eQUEST Building Simulation program with proprietary add-ins from ClimateMaster and weather BIN data from ISHRAE for Chennai.

Conclusion

By highlighting the myths associated with Geothermal HVAC, the authors have sought to confront and dispel each of these. The main benefits, however, are financial due to operational cost savings with lower energy consumption, and 100% conservation of water. Other benefits are 80% accelerated depreciation as per I.T. rules for energy efficiency devices and waiver of normal Excise Duties as per the 2010 budget. For those prequalifying for green building status, Geothermal Heat Pumps can obtain upto 41 LEED certification points. ❖