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Scientific Research

HVAC vs Geothermal Heat Pump—Myth & Truth

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ABSTRACT

In India energy auditors in some cases have recommended ground water based heat pump in place of common HVAC system to achieve better efficiency. However the users were made to understand that heat pumps are not suitable for Indian climatic condition and it produces no better result than the conventional system. This article tries to find answer to this debate thru an impartial analysis with the available data. First the concept is tested thermodynamically to compare the derived COPs and next from the experimental data on specific energy consumption.

Keywords: Heat Pump; HVAC; COP

1. Introduction

Heating ventilation & air-conditioning system is the major energy consuming part in residential or commercial buildings. In countries like India, more than 50% of input energy is consumed by HVAC system of the building. Given the next page of a typical load distribution chart of one Government office building in India (**Figure 1(a)**). For this reason, an energy auditor first looks at HVAC system when he tries to find out some meaningful energy saving potential for his client. Off late, many auditors have started recommending geothermal heat pump in place of conventional vapour compression refrigeration system and claim much better performance of the former. On the other hand, the HVAC OEMs rubbish this claim and say that the proposition is much costlier and doesn't produce any better result. Now as energy auditor when one needs to comment on this subject, he must have clear understanding of the facts & figures.

2. Look at the Basic Thermodynamics

To start with let us look at the basic law of thermodynamics. The ideal refrigeration cycle can be called as reverse Carnot's cycle (**Figure 1(b)**) where the engine draws heat from the lower temp (sink) and deliver to higher temp (source). In the above figure, the machine requires W amount of work to absorb heat Q_2 at lower temp and transfer heat Q_1 to higher temp. Hence the efficiency, in conventional term co-efficient of performance, should be defined as:

$$\text{COP} = \frac{\text{heat removed}}{\text{work input}} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

So from the above equation it is clear that higher the T_1 lower the COP. Or in other words higher the ambient temp, lesser is the COP. In countries like India where summer temperature shoots up to 42˚C to 45˚C, the COP or EER (energy efficiency ratio) gets affected badly for conventional HVAC system. The concept of geothermal heat pump is that—heat is discarded not into the atmosphere but at 200 ft. deep underground sump where temp is much lower and constant (10˚C) throughout the year. Heat pump suppliers take this advantage of constant and lower sink temp to maximize their COP or EER.

Figures 2 and **3** are of Apollo group building at Chennai where conventional HVAC was retrofitted by geothermal heat pump [2]. Now if we look at the data carefully, the thermodynamic or Carnot COP of the above systems become

Conventional system (**Figure 2**) = 285.2/(321.8 − 285.2) = 7.792 (temp converted into Kelvin).

Retrofit system (**Figure 3**) = 284/ (313 − 284) = 9.793 (temp converted into Kelvin).

So mathematically it can be proven that the retrofit system gives much better energy performance. Now comparing the above two figures one can easily see that the retrofit system, if run exactly in identical conditions, produces air of much lower temp (lower by 5.2˚C) while consuming the same power [3]. So when the air temp is controlled by a thermostat to maintain it at 17.2˚C the compressor shall be on "load position" for much shorter period compared to the conventional system. This is the major area from where the savings comes. Having optimum temp difference helps to achieve heights possible suction prss at compressor inlet (or in other words compressor is made to work at lower differential prss) and thereby leading to less energy consumption.

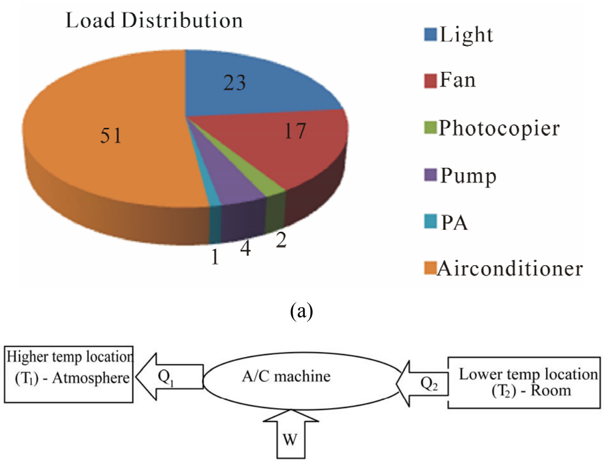

Figure 1. (a) Load distribution chart; (b) Schematic, reverse carnot cycle.

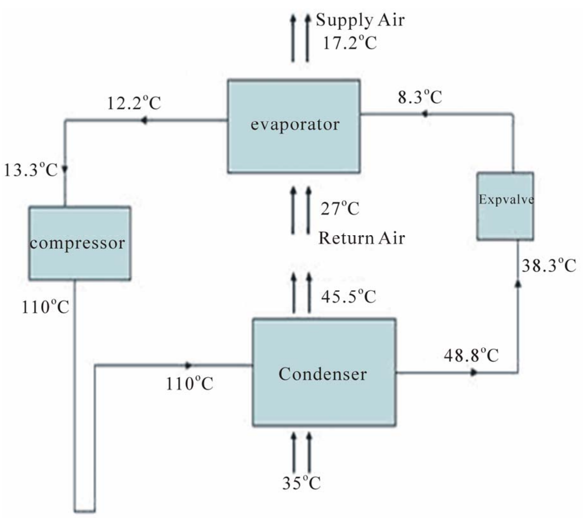

Figure 2. A conventional air conditioning system.

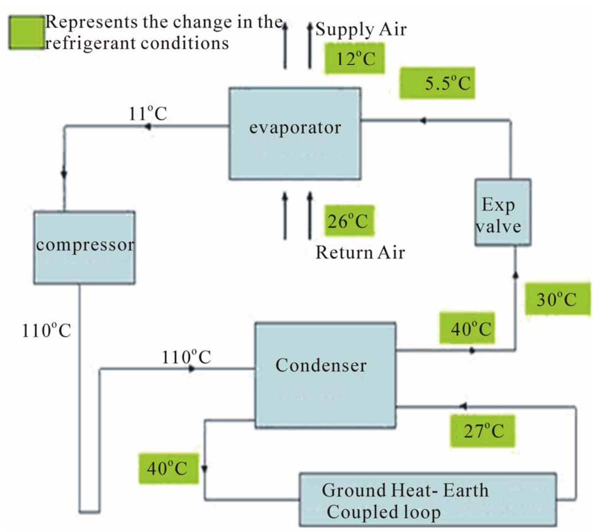

Figure 3. An earth coupled geoexchange system.

3. What Is the Basic Difference between the Two Systems?

From the above figures one may find that both the systems have much similarity in nature. The only difference is—in conventional HVAC, condenser cooling water is cooled by a cooling tower whereas for geothermal heat pump it is cooled in the underground geothermal loop. All other components are same for both the cases. Hence retrofit option for geothermal heat pump becomes easy and feasible. A study has been conducted by "Geothermal India" to compare the performance of both the systems at various ambient temps and results are given left (**Figure 4**).

From **Table 1** one may notice that EER of conventional system decreases with the rise in ambient temp whereas the EER of heat pump remains unaffected. Arguments were also given that geothermal cooling is successful only in cities with extreme climate like Delhi, Jaipur, Patna etc. To counter this argument studies and simulation were conducted for different cities across India and results **Table 2** were found quite encouraging [3]. Enfragy Solutions had conducted energy audit in more than 70 Government buildings having conventional HVAC system. The HVAC data of one such building **Table 3** is given the next page to show the energy distribution among various components of HVAC. The data suggests that even with best design and highly efficient components, chiller/compressor energy consumption remains critical for overall energy performance of HVAC system.

From **Table 3** it can be inferred that chiller unit/com-

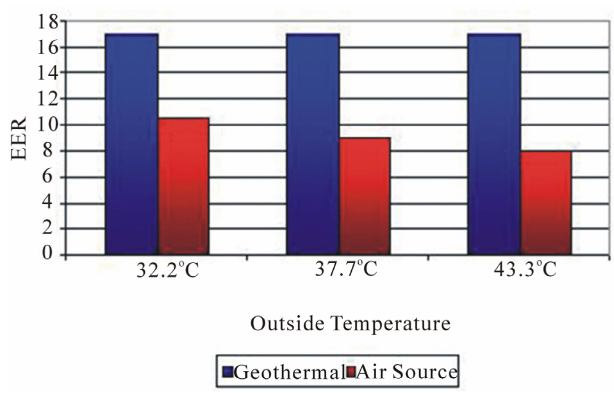

Figure 4. EER comparison.

Table 1. EER Comparison.

EER Comparison: Geothermal vs. Air Source Cooling			
Outside Temp (˚C)	32.2	37.7	43.3
Geothermal EER	17	17	17
Air Source EER	10.5	9	8

Table 2. India benchmark of HVAC system 200,000 sq ft air conditioned commercial area. Geothermal heat pump rated at 0.6 kW + ground heat exchange. Chiller rated at 0.6 kW + Cooling tower. System: Space cooling + Pumps & auxiliaries + Ventilation fans.

City	Chiller (kW/ton)	Geothermal (kW/ton)	Chiller-EER	Geothermal-EER
Ahmedabad	1.15	0.48	10.46	25.01
Bangalore	1.12	0.45	10.72	26.81
Chennai	1.27	0.51	9.48	23.69
Hyderabad	1.23	0.53	9.75	22.58
Jaipur	1.11	0.43	10.85	27.61
Kolkata	1.25	0.49	10.57	24.65
Mumbai	1.16	0.46	10.34	25.85
Nagpur	1.16	0.48	10.39	25.13
NCR	1.17	0.47	10.28	25.73
Pune	1.13	0.44	10.65	27.13

Table 3. Break-up of total SEC.

HVAC Components Consuming Energy	Specific Energy Consumption (kW/ton)	
	Before Audit	After Audit Recommendation
Chiller Unit (with Compressor)	0.98	0.65
Air, Distribution System	0.33	0.18
Water Pump	0.39	0.15
Cooling Tower	0.19	0.08
Total	1.89	1.06

pressor consumes more than 50% of input energy in the HVAC system hence it plays a major role in controlling the overall energy consumption. Another important point in this regard to be remembered that chiller's SEC is not uniform but varies with the load condition. At full load it gives the designed value of SEC, but shows higher SEC at part load conditions **Table 4** [4].

Therefore controlling the energy consumption of chiller/compressor is the key for reducing total energy consumption. We saw that when the conventional system is retrofitted with geothermal heat pump there are changes in temperature profile which results in lesser loading of compressor *i.e.* compressor is on "load position" for shorter period and on "unload position" for longer period. Since unload power of compressor is just 1/4 of load power, retrofitting option saves substantial amount of energy. From the **Table 4** it is also clear that impact of geothermal heat pump shall be more for systems operating with part load for considerable period of time.

Another important observation can be shared here. In all most all the sites where Enfragy conducted energy audit, the RH (Relative Humidity) of the conditioned air was found 60% to 69%. The data collected from Geothermal India suggests that even in city like Chennai, which is highly humid throughout the year, they are able to maintain 50% - 54% RH of the conditioned air. Since RH plays a crucial role on the comfort level, heat pump shows better results in humid areas. Experiment suggests that air with 50% RH and 24˚C gives same comfort level as of air with 65% RH and 22˚C. Hence lower RH generates saving of 2˚C out of cooling requirement.

Table 4. Power consumption—kW/ton (centrifugal chillers) at different % of loading. % Loading.

ECWT	100%	87.50%	75%	62.50%	50%	37.50%	25%
90 DEG F	0.625	0.633	0.635	0.652	0.686	0.750	0.950
86 DEG F	0.605	0.597	0.601	0.618	0.652	0.714	0.835
82 DEG F	0.571	0.565	0.571	0.588	0.621	0.681	0.803
78 DEG F	0.539	0.536	0.544	0.561	0.593	0.652	0.775
74 DEG F	0.511	0.510	0.519	0.536	0.566	0.623	0.748
70 DEG F	0.484	0.485	0.494	0.510	0.539	0.595	0.724
66 DEG F	0.459	0.462	0.470	0.484	0.512	0.567	0.700

Other relevant observation Enfragy Audit team gathered is that most of the installed HVAC systems are not truly reversible in nature. During winter, when hot air is required in place of cold air, the same is achieved by simply turning on electric heater or in other words "heat convectors". All modern geothermal heat pumps are reversible in nature that means during heating cycle it extracts the underground heat and pump it inside the building to make the air hot. This "reversibility" makes the heat pump a better choice over conventional HVAC system.

4. Conclusions

Table 2 shows that geothermal cooling can be effective in all kind of climate zones. The heat pump can become more economical for the hotel industries as it generates hot water without any additional input energy. The only initial investment for this purpose is the installation of one de-superheater. The waste heat generated by ground source heat pump is used to heat the water. Heat pump is also beneficial to those clients who have acute shortage of raw water. Lot of water is wasted in cooling tower as drift and blow down loss. Hence for normal operation of cooling tower, substantial amount of make-up water is needed on daily basis. However this requirement can be eliminated by retrofitting geothermal cooling system.

Other than LEED rating, BEE star rating is also very popular in India for green building certification. Improving kW/ton figure through heat pump enhances the chance of getting green building certification and carbon credit. It is to be noted that ECBC (Energy Conservation

Building Code) is expected to get incorporated in National Building Code very soon making the statutory EPI (Energy Performance Index; kWh/sqm/year) of all commercial buildings more stringent. Heat pump shall definitely play a major role towards the compliance of ECBC. For all green field building projects, the architects/civil engineers need to take proposal for both conventional HVAC and Geothermal heat pump and do the complete life cycle cost analysis based on the guaranteed EER/ COP. Our internal audit reports suggest that Geothermal heat pump option gives higher ROI, better IRR and lower payback period.

In India the apex energy efficiency body BEE should take initiative to formulate and publish the standards and norms of geothermal heat pump and bring it under national energy star leveling programme. Under such circumstances only heat pump shall become popular among the users and energy auditors.

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