THE UTILIZATION OF GSHP IN THE YANGTZE RIVER AREA

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ABSTRACT

The elements and classification of ground source heat pumps (GSHP) are expounded and its prospects in the Yangtze River Area of China were also indicated in the paper. The energy consumption of a model building in the area was simulated with eQUEST tool. Furthermore, the monthly and annual HVAC electric consumption of air source heat pumps (ASHP) and GSHP are contrasted and analyzed, and it is concluded that the GSHP is more efficient than conventional ASHP in the Yangtze River Area.

KEYWORDS

GSHP, Yangtze River Area, simulation, energy efficient, environment

INTRODUCTION

The Yangtze River Area of China is in hot-summer and cold-winter area, it includes several large and medium-sized cities such as Chengdu、Chongqing、Changsha、Wuhan、Nanjing、Shanghai and so on. It is an economically developed and densely populated area. Its climate is characterized by hot summer and cold、wet winter, and the number of days that need heating and cooling exceed 200. The huge amount of energy consumption in this region has been increasingly forcing government to emphasize energy efficient. A high efficient renewable energy technology for space heating and cooling in the area is hot needed. Geothermy is renewable, and it is estimated that the geothermal resources in the world is 1. 45 $\times 10^{26}$ J in total which is equal to 4. 95 $\times 10^{15}$t standard coal(Gao 1995). The ground is used as a heat source or sink in GSHP systems, and thermal pollution could be reduced. GSHP is a highly efficient renewable energy technology, at the same time it is consistent with the requirements of China's sustainable development strategy.

ELEMENTS AND CLASSIFICATION OF GSHP

A ground-source heat pump (GSHP) system utilizes the earth、ground water or surface water as the heat source or sink for providing heating and cooling. As its temperature is generally much closer to room conditions than the ambient air temperatures over the whole year, it could provide higher evaporating temperature in heating mode and lower condensing temperature in cooling mode than ASHP. From a thermodynamic point of view, GSHP is potentially more efficient than convention ASHP. With numerical calculation、experimentation and other methods, Swardt (2001) 、Derder (1997) 、Kavanangh (1992) compared ASHP with GSHP, and they concluded that GSHP has evident predominance in aspects of heating capacity、 heating COP and greenhouse gasses emission.

GSHP systems are categorized by ASHRAE (1995) based on the heat sources or sinks used. These categories are:

- Ground-water heat pump (GWHP) systems
- Surface water heat pump (SWHP) systems
- Ground-coupled heat pump (GCHP) systems

PROMOTION PROSPECTS OF GSHP IN THE YANGTZE RIVER AREA

The Geographical position of the Yangtze River Area is shown in Figure 1.

Climate conditions

The Yangtze River Area of China is in hot-summer and cold-winter area. The average temperature is 2～7 ℃ in the coldest month in winter, and it is the coldest area which locate in the same latitude in the world. For the requirements of improving the thermal comfort, it is forecasted that there will be 5 billion m^2 building area that need heating. The cooling and heating load is close, so the capability of the ground deposited energy could be adequately used in the area.

Geography conditions

It rains abundantly in the Yangtze River Area, and it has plenty of ground water sources with a high ground water level. All of above conditions provide opportunity for GWHP and SWHP. Shallow soil in most area of the Yangtze River basin is wet mollisol, and it belongs to quaternary period illuvial horizon, so heat conduction between soil and underground heat exchangers could be well.

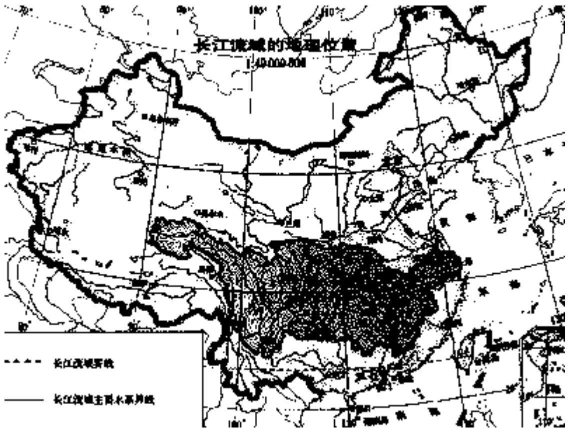

Figure 1Geographical position of the Yangtze River Area (black color area)

Energy conditions

Compared with abundant water source, the coal、oil and natural gas source is very short in the Yangtze River Area. The average coal self-support rate of Hunan, Hubei, Jiangxi, Jiangsu and Shanghai is only 40% in the year 2000, and it is predicted that the rate will be 28% in 2010 and 19% in 2020(Zhao et al.2000). So lots of coal is transported from north and North West China and this causes busy traffic、high delivery expenses and low dependability. With the rising oil price, the oil boiler and fire-directed absorption chiller become uneconomical. Besides, lots of greenhouse gasses and contamination will be produced when coal and oil are burned.

CONTRAST THE ENERGY USED BY ASHP AND GSHP WITH EQUEST TOOL

Computer-based simulation is accepted by many studies as a tool for evaluating building energy (James 2000, Al-Homoud 2001). There are many different types of computer-based simulation tools that are available for performing whole-building simulation, such as DOE-2、EnergyPlus and DeST. eQuest is a quick energy simulation tool developed by Doe-2.2 which is the most widely used simulation tools for office and commercial buildings, and it is approbated worldwidely.

The author chooses the four typical cities of the Yangtze River Area: Chengdu 、 Chongqing 、 Changsha and Shanghai, and contrast the energy used by the widely used ASHP in the area presently with GSHP (here, it means GCHP) in the model building.

Description of the model building

The model building envelope was designed according to (Long 2005); it is a six-storey office building with the floor height of 3m and every storey is 420m^2. The total area of the structure is about 2520 m^2 and the building faces north-south. The building shape factor is 0.265. There are 6 glass windows in south wall and north wall, and 3 glass windows are in east wall and west wall. The average window-wall ratio is 0.279. The insulation layers are used in exterior wall and roof, and the specific forms and parameters of each building envelope are showed in Table 1.

Personnel density、lighting load、office equipment and running schedule of each zoon are ascertained by referring《Public building energy efficiency design standards 2005》.The specific parameters are showed in Table2.

To establish a concise model, thermal zones are only divided to perimeter and core spaces; the air-condition systems of ASHP and GSHP are packaged single zone heat pumps.

Table 1 Forms and parameters of building envelope

Envelope	**Layers**	**U-value (W/m^2.°C)**
Exterior wall	10mm Face Brick + 10mm Cement mortar + 25mmEPS+240mm Clay solid brick + 20mm Cement mortar	1.0
Roof	15mm Cement mortar + 40mm fine-stone concrete + 30mmXPS+20mm Cement mortar + 120mm ferroconcrete	0.8
Window、door	3mm monolayer common glass	3

Table 2: Indoor load and running schedule

Space name	Persons (m^2/p)	Lighting (W/m^2)	Equipment (W/m^2)	Schedule	Temperature setpoint (°C)	Fresh air (m^3/h·p)
Office (General)	4	11	20	8:00-17:00	26/20	30
Office (Private)	8	18	13	8:00-17:00	26/20	30

Corridor	50	5	0	8:00-17:00	26/20	30
Lobby	20	11	5	8:00-17:00	26/20	30
Conference room	2.5	11	5	8:00-17:00	26/20	30
Restrooms	20	11	5	8:00-17:00	26/20	30

The analyses of modeling result

Compared GSHP with ASHP, the monthly HVAC energy efficient rates of the four cities are shown in Figure 2-5. The whole April is in transition season , and the HVAC energy consumption of October and November is few, so the three months are not taken into account. From the four figures, we could find that: the HVAC energy efficient rates in cooling season are higher than in heating season, especially in July and August; GSHP even uses more energy than ASHP in the later period of heating season in Chengdu、Chongqing、Shanghai.

Air temperature of July and August is the highest in a year, however, because of underground soil's thermal hysteresis, underground temperature is still low, and so, contrasting to other months of cooling season, the COP of GSHP is much higher than ASHP's in July and August. In the later period of heating season, GSHP has extracted heat from underground soil several months, the soil temperature becomes lower and lower. So, evaporating temperature of GSHP also becomes lower, and this leads to GSHP's lower COP. However, in the later period of heating season, the air temperature has rebounded, the work environment of ASHP is not poor any more. So, the ASHP could be more efficient than GSHP in the later period of heating season.

The annual electric consumption of the model building in which the ASHP and GSHP are used is shown figure 6; and the figure 7 shows the HVAC electric consumption of the two systems. Seen from the two figures, it is distinct that the annual electric consumption and HVAC electric consumption of GSHP are less than that consumed by ASHP. Compared GSHP with ASHP, figure 8 shows the HVAC energy efficient rate.

The HVAC energy efficient rate is 19.5%, 27.0%, 32.5% and 27.0% for the four cities respectively. It is indicated that 19.5% for Chengdu is the smallest, and 32.5% for Changsha's is the biggest. One of the reasons is that Changsha's climate is unsuitable for running ASHP but in Chengdu the weather is rather mild ("the air temperature in January and July of Chengdu are 6.2°C and 25.8°C; for Changsha are 4.7°C and 29.3°C" (Anon.). The other reason is that the thermophysical properties and thermal environment of underground soil are almost same in the two cities. Climate and geography conditions such as underground soil thermophysical properties 、 surface water and groundwater temperature and weather could profoundly influence the running effect of GSHP. The relation between running characters of GSHP and the climate and geography conditions should be further studied.

It is estimated by EPA that although the initial cost of GSHP is higher, in long-term interests, the average running cost is 30 %～40 % lower than conventional ASHP(Shou 2001). The result of the simulation in this paper is consistent with the conclusions. So more GSHP should be used in the Yangtze River Area for energy saving.

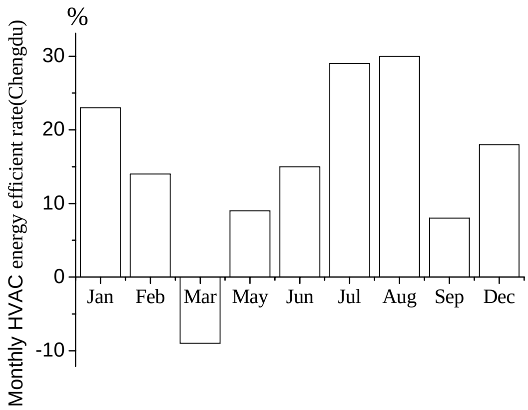

Figure 2 Monthly HVAC energy efficient rate of Chengdu

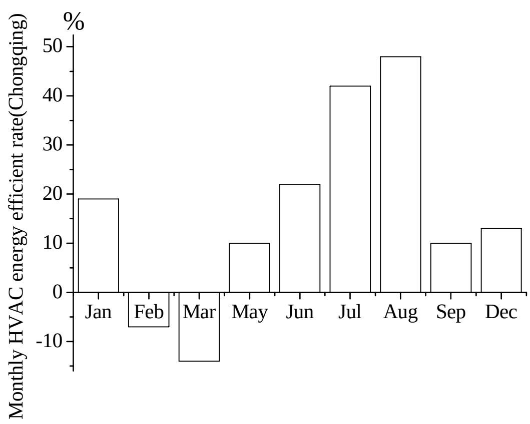

Figure 3 Monthly HVAC energy efficient rate of Chongqing

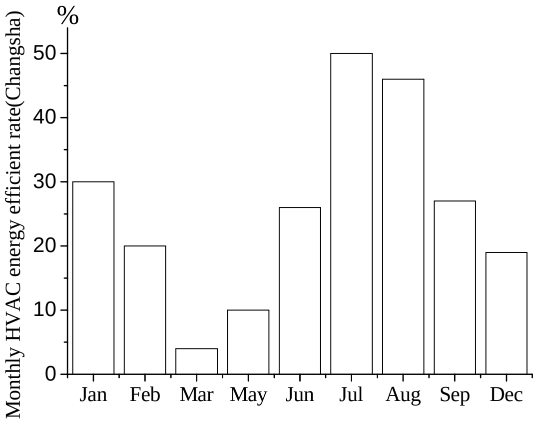

Figure 4 Monthly HVAC energy efficient rate of Changsha

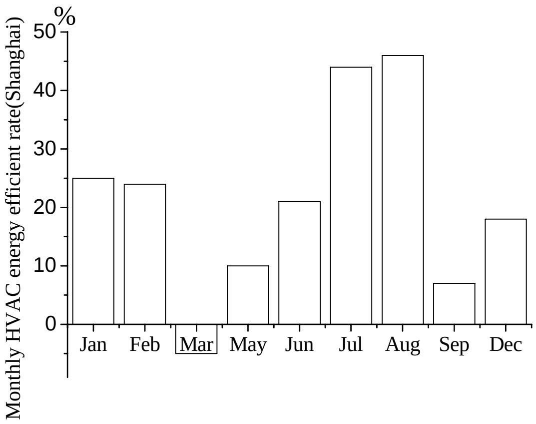

Figure 5 Monthly HVAC energy efficient rate of Shanghai

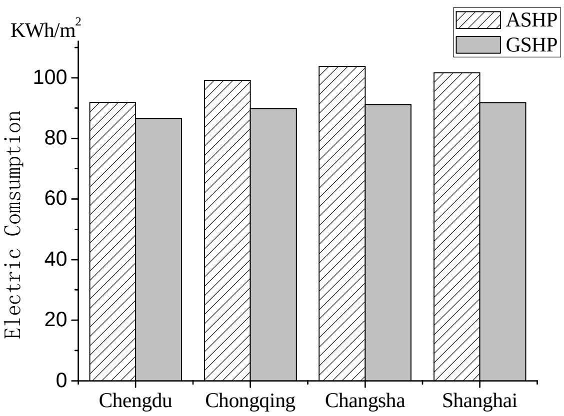

Figure 6 Electric consumption

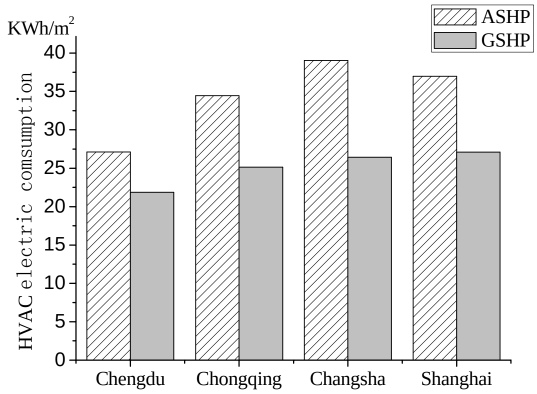

Figure 7 HVAC electric consumption

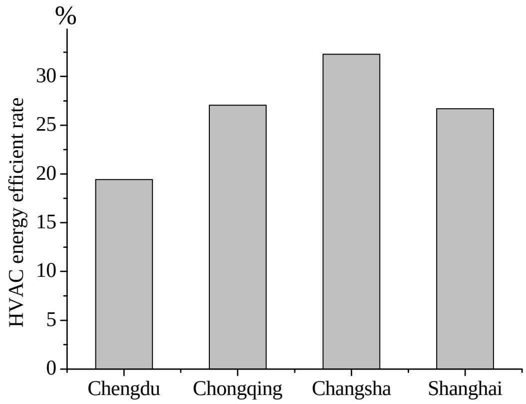

Figure 8 HVAC energy efficient rate

CONCLUSION

The GSHP is generally recognized to be one of the most outstanding technologies for heating and cooling in both residential and commercial buildings. GSHP is more efficient and environment protectively and more suitable than other ways for the Yangtze River basin. At present, the trade standards and criterions of design 、 installation 、 operating 、 maintenance and other aspects of GSHP have not been formed in China, so lots of efforts should be made to promote it.

REFERENCES

Anonymity http:// www.weather.com.cn/

DE SWARDT. 2001. “A performance comparison between an air source and a ground source reversible heat pump,” International Journal of Energy Research. 2001(10):899-910.

DERDER S. 1997. “Municipality water reticulation ground-coupled reversible heat pump system as alternative to an air source system,” American Society of Mechanical Engineer, 97(12):402-1215.

Gao Zukun. 1995. “Ground/water heat pump system for heating purpose，” Heating Ventilating & Air Chonditioning. 95（4）: 9-12.

Kavanangh. 1992. “Simulation of ground-coupled heat pumps with an analytical solution,” International Solar Energy Conference ’92, Vol 1, pp: 395-400.

Long Enshen, Wang Yong, Ma Xiaofei. 2005. “Identifications: the RVRs are approximate in different cities with the same energy efficient measures,” Building and Environment. 2005 (4): 465-471

MS Al-Homoud. 2001. “Computer-aided building energy analysis techniques,” Building and Environment. 2001(4):421–433.

Public building energy efficiency design standards 2005. Beijing: China Architecture & Building Press

WP James.2000. Computerized Building Energy Simulation Handbook. New York: Marcel Dekker

Shou Qingyun. “An efficient air-conditioning system: GSHP,” Energy Conservation. 2001(1):41-43

Zhao Yongsheng, Xia Caiqing, Li Lingti. “Discussion of energy development strategy in Yangtze River Area,” Energy Of China. 2000（5）：22-24