The analysis of Ground Source Heat Pump systems cost in small scale supplies situation

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Abstract

Ground is a kind of energy storage, and the energy contained by the ground can maintain normal ground surroundings' or groundwater's temperatures varying between 5℃ and 30℃ with the depths and latitudes. Due to the heat balance between the solar radiation and the mantle thermal conduction through the atmospheric transmission, the underground earth become a heat source at constant temperature. This feature can be utilized to construct a type of systems that can exchange heat from the earth to the evaporators with a heat pump and a couple of bores.

So far, GSHP (ground source heat pump) systems have increased to 8624MW(56% of global) in the U.S. Because it can operate at higher efficiency and less CO2 ejection compared with the conventional fossil power heat equipment; Moreover, compared with solar panels, wind turbines and tides hydroelectricity, GSHP can work without the limits of seasons and weathers.

This poster is focused on the analysis of GSHP cost advantages with contents like below: For the first, build the relations between the outputs of heat quantity and the size of bores; For the next, compare the GSHP operate cost with traditional commercial power cost; Furthermore, estimate the efficiency of GSPH systems.

GSHP conduction principle

GSHP system conducts heat with a couple of bores under ground which use water or air as medium. It can operates in two modes. In the cooling mode, the pump rejects the hotter water to the ground earth from the evaporator in the room with one of the bores, and draws up the cooler water from under ground with the other bore, so it can make a cooling process(figure1 left). On the contrary, in the heating mode, the pump draws the hotter water from the ground earth to the evaporator in the room, and rejects the cold water to the under ground, so it can make a heating process. (figure1 right).

Though GHSP system still works with power pump, but the heat energy it can transfer are always higher than it exhaust. By the far, the highest efficiencies of this kind of systems can achieve 300% to 600%, it means that spend 1Kw•h powers can save 3Kw•h power exhaust at least.

Figure1: GSHP operating modes

Sector(Quad)	Technical Potential	Market Potential
Commercial	0.6	0.05
Residential	3.1	0.1
Total	3.7	0.15

Table1: National Primary Energy Savings Potential of GSHP

Depth requirement with heat supply

The Length of GSHP bores is the main factors of the energy supply. And the equations about the energy outputs is:

Cooling process $$L_c = \frac{1000Q_C}{q_h}\left(\frac{COP_c+1}{COP_c}\right) \quad (1)$$

Heating process $$L_h = \frac{1000Q_h}{q_h}\left(\frac{COP_h-1}{COP_h}\right) \quad (2)$$

COP is the coefficient of performance

$$COP = \frac{P_{load}}{(P_{load}-P_{loop})/a} = \frac{Q_{load}}{(Q_{load}-Q_{loop})/a} \quad (3)$$

In this equation, P_{load} is the power that pump can give into the surroundings; P_{loop} is the power consumed by the pump when system transits heat from ground. And 'a' is the pump efficient. For the ideal condition COP can be modified as

$$COP = \frac{T_h(^oC)}{T_h - T_L(^oC)} \quad (4)$$

And q_h is the heat load which is determined by the conditions of the pump, for a common compression pump, the compress power 'We' can be 15kJ/kg.

$$q_h = COP/We \quad (5)$$

For matlab experiment, the minimum COP can be used to measure the cost. So follow the design brochure, the room temperature can be set as 5℃ inlet and 18℃ outlet for winter, 40 ℃ inlet and 25℃ outlet for summer. The COP_h=1.39 and (

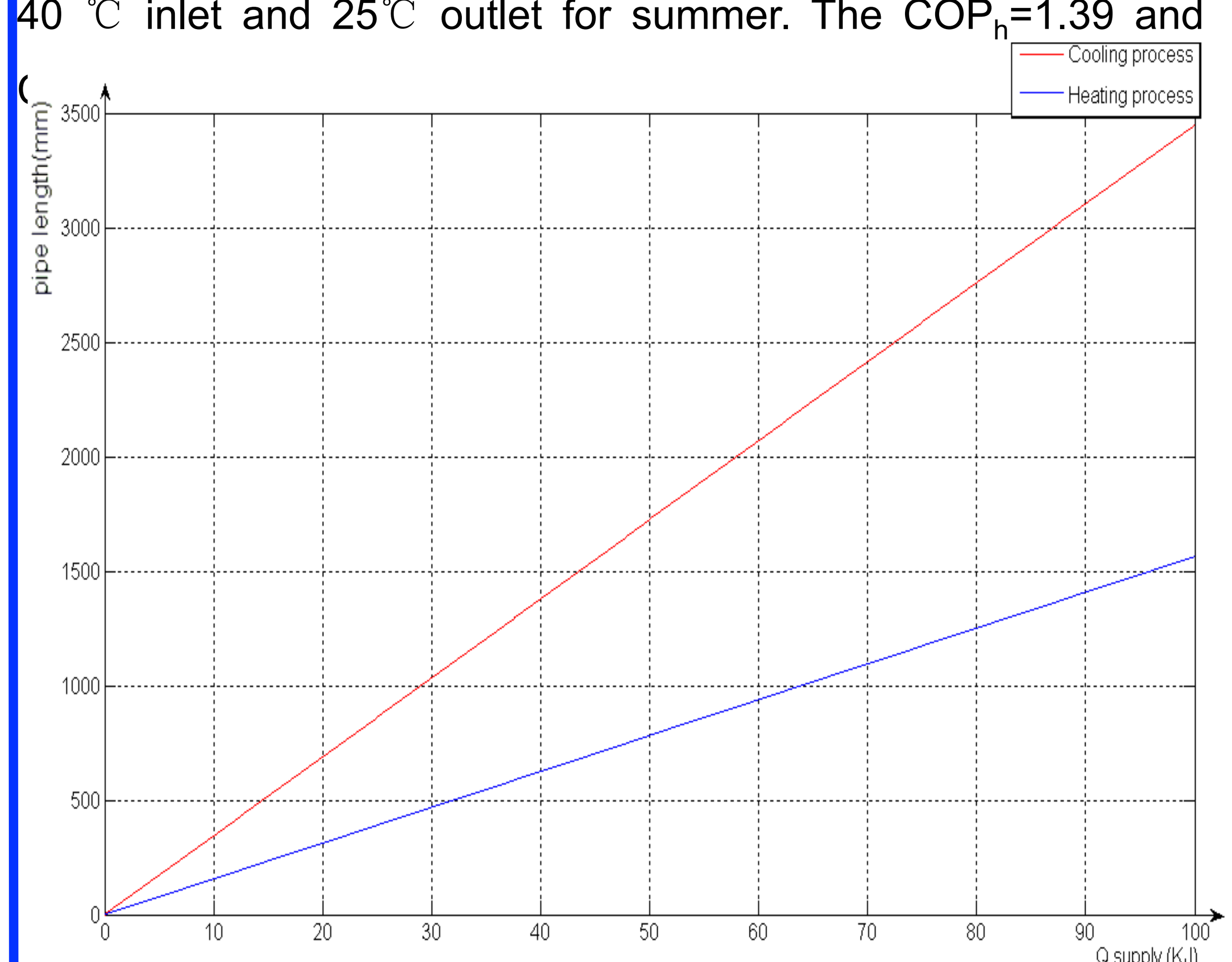

figure2: length requirements of the heat and cool process

Because the cost of pipes will follow the length , so the price of pipes can also follow this two figures. From the linear curves, the bores of the cooling process need extend more size than the heating process if heat transfer value is fixed. This is very important that Lc can determine the system installation scale.

GSHP energy operate cost

For a fixed space, the equation of the energy and the air temperature change is

$$Q = \rho VCp\,(To-Ti) \quad (6)$$

From equation (1)-(3), the cost of GSHP can be as below:

$$pr = preQloop + \frac{1000\lambda}{q_h}Q_C\left(\frac{COP_c+1}{COP_c}\right) \quad (7)$$

$$pr = preQ_{loop} + \frac{1000\lambda}{q_h}Q_C\left(\frac{COP_h-1}{COP_h}\right) \quad (8)$$

Both of this two equations combine two factors, the item PreQloop is the pump operating cost, the other one is the system extra necessary cost of installation for the first time. Considers equation (4) and (5) ,

$$\Pr = \Pr_e\left(\frac{COP_C-a}{COP_C}\right)Q_C + \frac{1000\lambda We}{COP_c^2}Q_C(COP_c+1) \quad (9)$$

$$\Pr = \Pr_e\left(\frac{COP_h-a}{COP_h}\right)Q_C + \frac{1000\lambda We}{COP_h^2}Q_C(COP_h-1) \quad (10)$$

Equation (9) and (10) reflect the relation during the investment cost of system, the energy requirements, and the pump coefficient. In the equations, p_{re} is power balance from electrical company, such as CT state Pre=19cent/KW • H. And from the figure1 ,the design can just use equation (9) to estimate the operation up limits. The 3D relation as below:

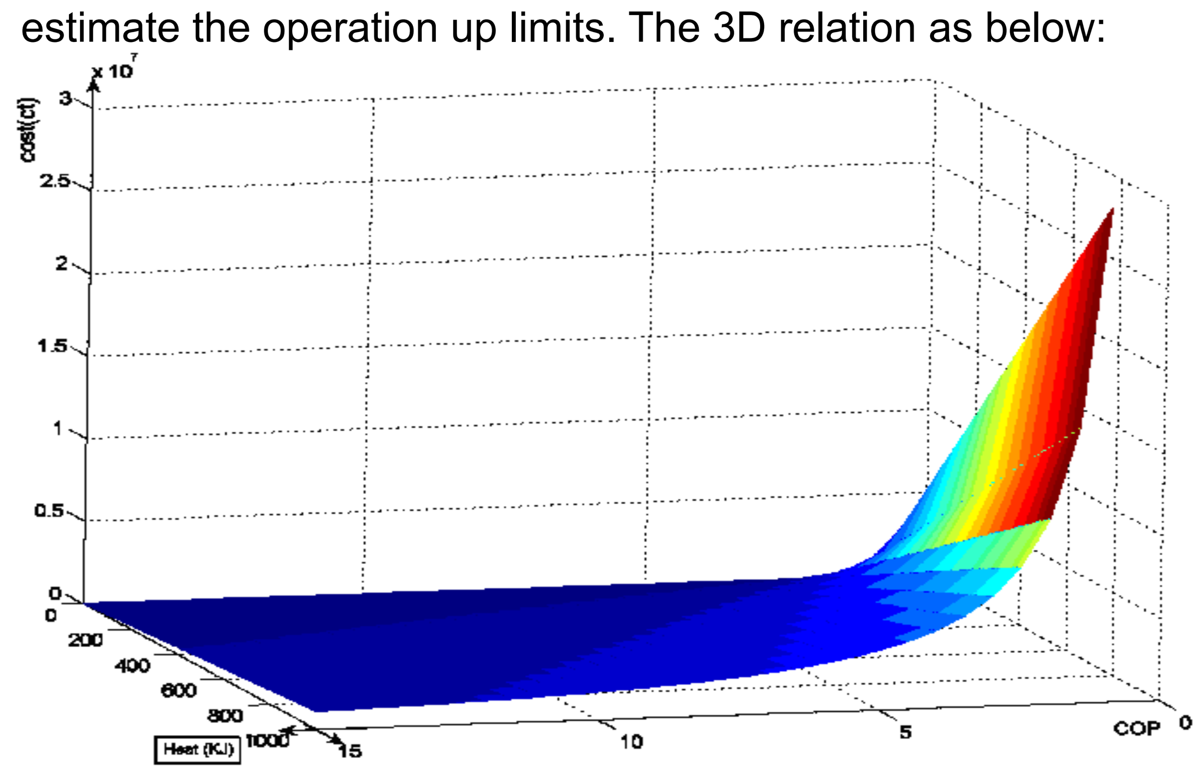

figure3: system installed cost about cop and Heat

This surface shows that the value of COP can effect the cost obviously, if the COP value less than 5, the cost of GSHP will increase quickly. While the energy can let cost go up with a very low rates. So the pump COP feature can mainly determine the efficiency and the cost of the GSHP.

For measuring the energy can be erned from the system, equation(3) can be modified as:

$$Q_{load} = \frac{COP_c}{COPc-a}Q_{loop} \quad (11)$$

So finally, the cost equation is

$$P_h = pr(Q_{load}-Q_{loop}) = \frac{a}{COPc-a}Q_{loop}P_e \quad (12)$$

From the equation (12), the price saved is given ,also it reflect the extra energy value can be harvested in system. And this energy profits can be measured by power balance.

Conclusion

From this detection, many points can be concluded as below:

(A) We use equation research prove that GSHP indeed can benefit the costumer in balance, though it is still paid some money for pump power and installation.

(B) We find the efficiency and profits can be gotten mainly depend on the performance of pump (COP).

(C) We find GSHP system operate power is determined by the pump not bore depth. And the energy can be supplied is fixed with the bore size.

(D) As the report shows, If we can confirm the GSHP system run with a series of good facilities, it will be a good method to build a sustainable life.

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