

Research on Reclaiming and Using the Urban Sewage Heat Energy in China

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Abstract: This paper studied methods of reclaiming and using the urban sewage heat energy, established the economic analysis model of the reutilization urban sewage heat energy based on the annual expenditures method, and presented the economic analysis of sewage source heat pump heating water system and other heating water system. It is shows that sewage source heat pump system with reclaiming the urban sewage heat energy has obvious effects of saving energy, economic and environment protection. It also points out that there is tremendous heat energy in the urban sewage, and the application prospect of the sewage source heat pump system are fine in China.

Keywords: Urban sewage, Heat energy, Sewage source heat pump, Economic analysis model, environment protection

1. INTRODUCTION

Urban Sewage is a kind of available low temperature resource, there are lots of good characteristics in it, such as it is warm in winter and cool in summer, small change of annual temperature's range, less influenced by weather, more quantity of heat energy etc. It is a kind of reutilization resource with no large-scale exploitation. For example, there is a sewage plant in Pekin, the temperature of secondary stage in winter may reach 13.5~16.5°C, which is about 20°C higher than the circumstance's averagely. The temperature of secondary stage may reach 22~25°C in summer, which is about 10°C lower than the circumstance's averagely. So there are lots of low level energy sources in the urban sewage, we may economize plenty of resources in proper way, and we may spend less expenditure on the disposal of the sewage, and we may find a effective way to save energy resources and to exploit new energy resources.

Technology of urban sewage source heat pump can realize the reutilization of the low level heat energy from urban sewage, recovered energy can be served for heating or cooling. There are some technical problems in need of being solved, there are no systemic and scientific studies and evaluation or applied systems, though the technology is primarily used in few developed countries or regions. It is in the start phase on the technology that with few real examples in China. This paper introduces the method of reutilization of heat energy from urban sewage, establishes economic analysis model which sewage source heat pump system compares with other system, carry out analysis from the point of saving energy, economy and protection of environment, in order to provide some practical foundation for

application of the technology of reutilization of heat energy from urban sewage.

2. METHODS OF REUTILIZATION OF HEAT ENERGY FROM URBAN SEWAGE USING SEWAGE SOURCE HEAT PUMP

Reutilization of heat energy from urban sewage is effective uses of heat energy from sewage water dealt or not dealt. There are two kinds of methods: directly method and indirectly method. Directly method is reclaiming heat energy from urban sewage using heat pump will be send to buildings; indirectly method is that the exchange of heat is finished by sewage via heat exchanger firstly, then reclaiming heat energy using heat pump will be send to buildings, such as the figure 1 and figure 2.

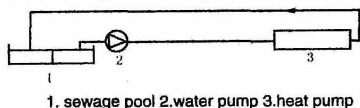


Figure 1: Directly method of reutilization heat energy from urban sewage

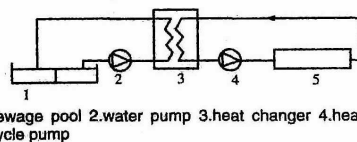


Figure 2: Indirectly method of reutilization of heat energy from municipal sewage

The heat increase of directly method is less, but its effect of saving energy is better than indirectly

method. The saving energy rate of directly method is 7% more than that of indirectly method in general. Otherwise, the system of indirectly method is more complicated, and the investment of equipment is high either.

3. ECONOMIC ANALYSIS MODEL

3.1 Index of annual expenditure

Annual expenditure index of the life-span is adopted to evaluate the economical feasibility of the reutilization heat energy from urban sewage using sewage source heat pump, annual expenditure method is to compare all projects' initial investment and operation expenditure, scattered the initial investment into each service life according to the value of time, then the project with the minimum value of the annual expenditure is the most welcome, it is the most economical project either. This kind of method shows the comparable character on economic of different systems. The calculated formula of the annual expenditure expressed as

$$AF = B \cdot CR + C \quad (1)$$

Where AF is annual expenditure, yuan

B is initial investment, including the expenditure of construction, equipments and installation of equipments, yuan

C is expenditure of annual operation, yuan

CR is Capital recycle system with equivalence

distributed
$$CR = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where i is rate of reclaiming, 10%

n is life-span, 20a

Equation(1) may calculate the annual expenditure AF_1 of heating and refrigeration systems with reutilization heat energy from urban sewage and AF_2 of heating and refrigeration systems with no utilization heat energy from urban sewage, then the difference is

$$\begin{aligned} \Delta AF &= AF_1 - AF_2 = B_1 CR + C_1 - B_2 CR + C_2 \\ &= B_1 \frac{i(1+i)^n}{(1+i)^n - 1} - B_2 \frac{i(1+i)^n}{(1+i)^n - 1} + C_1 - C_2 \end{aligned} \quad (2)$$

Where: B_1 is the initial investment of heating and refrigeration systems with reutilization heat energy from urban sewage, yuan; B_2 is the initial investment of common heating and refrigeration systems with no utilization of heat energy from urban sewage, yuan; C_1 is the annual expenditure of operation of heating and refrigeration systems with utilization of heat energy from urban sewage, yuan; C_2 is the annual expenditure of common operation of heating and refrigeration systems with no utilization of heat energy from urban sewage, yuan.

The difference between them may shows directly the economization of the annual expenditure when

the initial investment is scattered into each service life according to the value of time, if ΔAF is less than zero, it can show that heating and refrigeration systems with the reutilization heat energy from municipal sewage are economical than the common systems with no reutilization heat energy from urban sewage.

3.2 Initial investment and expenditure of annual operation

The initial investment mainly includes the expenditure of construction, equipment and installation of equipment etc. the initial investment is

$$B = CP \cdot Q \quad (3)$$

Where CP is the price of unit power of initial investment of every project, yuan/kW;

Q is the capacity of the system, kW

The expenditure of annual operation is

$$C = P \cdot G + P_e \cdot E \quad (4)$$

Where P is unit price of fuel

G is amount of consumed fuel, t

P_e is price of electricity, yuan/kWh

E is annual amount of consumed of electricity, kWh

4. CALCULATED RESULT AND ANALYSIS

A typical example is that the bath water of some swimming gymnasium in northeast of china, its annual amount of heat needed to heat the bath water is $\sum Q = 7.19 \times 10^9$ kJ, and the total power $W = 340.4$ kW

4.1 Annual expenditure of coal boiler system to heat water

The capacity of the coal boiler is 0.5t (350kW), the price of unit power is 400 yuan/kW, the efficiency of the coal boiler is 0.6, the price of coal is 350yuan/t, stands for the total of heat produced by coal $Q_c = 28073$ kJ/kg, then the annual expenditure of the coal boiler is

$$\begin{aligned} AF_c &= B_c \cdot CR_c + C_c \\ &= CP_c \cdot Q_c \frac{i(1+i)^n}{(1+i)^n - 1} + P_c \frac{\sum Q}{\eta \cdot Q_c} + P_e \cdot E_c \\ &= 165,000.00 \text{ yuan} \end{aligned}$$

4.2. Annual expenditure of gas boiler system to heat water

The price of unit power is 460 yuan/kW, the efficiency of the gas boiler is 0.75, the price of gas is 1.0 yuan/m³, stands for the total of heat produced by coal gas Q_g is 14654kJ/m³, then the annual expenditure of the gas boiler is

$$\begin{aligned} AF_e &= B_e \cdot CR_e + C_e \\ &= CP_e \cdot Q \frac{i(1+i)^n}{(1+i)^n - 1} + P_e \frac{\sum Q}{\eta_e \cdot Q_e} + P_e \cdot E_e \\ &= 16.01 \times 0.117 + 65.23 = 671,000.00 \text{ yuan} \end{aligned}$$

4.3. Annual expenditure of electric boiler system to heat water

The price of unit power is 350 yuan/kW, the efficiency of the electric boiler is 0.95, the price of electricity is 0.5yuan/kWh, then annual expenditure of electric boiler system to heat water is

$$\begin{aligned} AF &= B \cdot CR + C \\ &= CP \cdot Q \frac{i(1+i)^n}{(1+i)^n - 1} + P_e \frac{\sum Q}{\eta} \\ &= 12.25 \times 0.117 + 104.68 = 1,061,100.00 \text{ yuan} \end{aligned}$$

4.4. Annual expenditure of oil boiler system to heat water (diesel oil)

The price of unit power is 430 yuan/kW, the efficiency of the oil boiler is 0.9, stands for the total of heat produced by diesel oil Q_o is 14654kJm³, then annual expenditure of oil boiler system to heat water diesel oil is

$$\begin{aligned} AF_o &= B_o \cdot CR_o + C_o \\ &= CP_o \cdot Q \frac{i(1+i)^n}{(1+i)^n - 1} + P_o \frac{\sum Q}{\eta_o \cdot Q_o} + P_e \cdot E_o \\ &= 15.03 \times 0.117 + 52.89 = 546,400.00 \text{ yuan} \end{aligned}$$

4.5. Annual expenditure of sewage source heat pump system to heat water

The price of unit power is 1065 yuan/kW, the coefficient of performance of sewage source heat pump COP is 4.4, then the annual expenditure of sewage-source heat pump system with the utilization of heat energy of municipal sewage is

$$\begin{aligned} AF_{hp} &= B_{hp} \cdot CR_{hp} + C_{hp} \\ &= CP_{hp} \cdot Q \frac{i(1+i)^n}{(1+i)^n - 1} + P_e \frac{\sum Q}{COP} \\ &= 37.27 \times 0.117 + 22.6 = 269,600.00 \text{ yuan} \end{aligned}$$

It is shown in the table 1 that the initial expenditure of sewage-source heat pump system is the most and annual expenditure is the lowest among the oil boiler, gas boiler, electric boiler. That may prove the better economical performance of the sewage-source heat pump system with the utilization of urban sewage. The return periods of the investments are 0.67, 0.5, 0.3 year separately, the annual economization of the expenditure of operation is the system's benefit after the return periods of the investments. But the economical performance of the sewage-source heat pump system is not perfect since it is mainly influenced by structure of the energy source, compared with hot water system of the coal boiler, so we should analysis it with economics evaluation equation.

Table 1: Annual expenditures of every hot water system(10 thousand yuan)

Types of System	Sewage souse heat pump	Coal boiler	Oil boiler	Gas boiler	Electricity boiler
Initial investment	37.27	14	15.03	16.01	12.25
Operation expenditure	22.6	8.5	52.89	65.23	104.8
Annual Expenditure	26.96	10.14	54.64	67.10	106.1

We may get this equation (5), when the expenditure of sewage source heat hump system is as same as that of coal boiler system

$$B_c CR_c + P_c G = B_{wp} CR_{wp} + P_{wp} E \quad (5)$$

Critical equation below may be found when the above data is put into the equation (5)

$$-272 + 4.25 P_c - 4527 P_e = 0$$

Economic performance of the two systems are almost same, when the price of electricity is 0.5kWh and the price of coal is 596 yuan/t. and the price of coal is 350 yuan/t and the price of electricity is 0.5kWh, economic feasibility of the two systems are almost same when the price of coal is 596 yuan/t. If the price of coal goes up, the critical curve line moves up and economical sections of hot water system with the coal boiler becomes small; if the price of electricity goes up, the economical sections of the hot water system with sewage source heat-hump becomes small

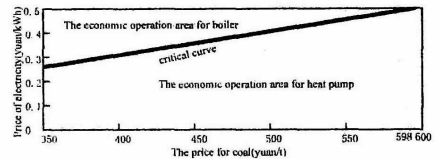


Figure3: The economic operation area for coal boiler and sewage source heat hump system

5. CONCLUSION

There is enormous energy store up in the municipal sewage water, which is a kind of clean and reutilization energy source. The spread and application of urban sewage resource heat pump system may change status of Chinese energy consumptive structure, decrease pollution of the atmosphere and protect the environment, economize energy for heating or cooling.

Establish systemic economic analysis model which sewage source heat pump system with heat energy recovery of municipal sewage compares with other system, the economic analysis model distribute

the initial expenditure to life-span, it makes that the economic analysis of the different systems have actual comparable feasibility. Economic returns of the different systems may be worked out straight and roundly, and those advantages are evidently. It is shown in the analysis that the economic feasibility of the sewage source heat hump system is better than that of oil boiler, coal boiler, gas boiler and electric boiler under the condition of same amount of heat provided.

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