168 Journal of Air-Conditioning and Refrigeration Volume 6 August(1998)/pp. 168~176

# Study on Energy Saving Properties by using City-Water as a Heat Source for Dwellings

Yong-Hyun Chung*, Minoro Mizuno*, Yoshiyuki Simoda**, Jong-Soo Kum*** and Kwang-Hwan Choi***

**Key Words** : City-water, Unused Energy, Sensible waste heat, Multiple heat pump system

**Abstract**

A simulation study was conducted to use city-water which is thermally regulated by unused energy as a heat source for urban dwellings. This study utilized multiple heat pump system using the city-water as a heat source and suggested a method of reducing the heat load of hot water supply. The simulation was done to calculate the energy savings at a dwelling for a year. The relation between the controlled temperature of city-water and electric energy in all seasons was also investigated. Furthermore, it has been found that the controlled water system can lead to considerable energy savings and decrease environmental load such as sensible waste heat which otherwise would form heat islands.

## 1. Introduction

The increase in environmental loads has resulted in the need to develop new forms of energy production for a sustainable use for the society. Recently, the viability of using unused energy has been considered. In major cities in Japan, District Heating and Cooling (D. H. C) system utilizing unused energy has been constructed only in a limited boundary. For the optimum use of unused energy, it is necessary to have a network having pipelines and heat exchanger to connect unused energy source to the urban demands. On the other hand, the construction cost of the network is too high. It is a common knowledge that the user who needs heat and water cannot afford to build the network. To solve the cost problem in the heat netwok, the city-water pipeline which carries water having greater specific heat capacity than air is suggested in order to overcome the mismatch of the heat source and the demand.[1]

* Department of Environmental Engineering, Osaka University
** Cooperative Research Center for Advanced Science and Technology, Osaka University
*** Department of Refrigeration and Air-Conditioning Engineering, Pukyong National University

This study focuses on a dwelling side using the city-water as a heat source. By making the comparison of conventional heat pump with the system which has a multiple function heat pump using air and water as a heat source, evaluation of the energy savings and reduction of the sensible waste heat, which caused heat island phenomenon, were made.

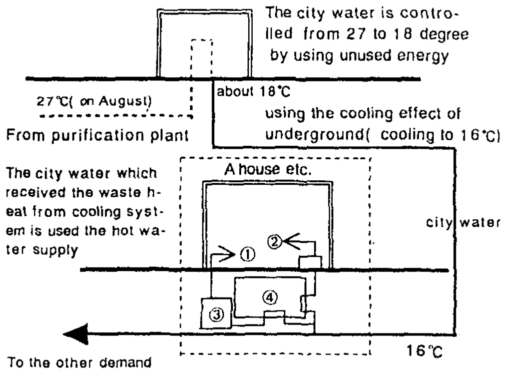
## 2. The outline of model system

### 2.1 On the temperature

The model system uses the controlled city-water at various temperatures by using unused energy. The city-water maintained at 16℃ close to underground temperature means that it minimizes heat loss and does not change the water quality. It is used in this study as a heat source of the model system in urban dwellings. Figure 1 shows the outline of the model system.

### 2.2 On the system

There is a difficulty in varying different




① for hot water supply
② for water supply
③ hot water storage tank
④ a multiple function heat pump

**Fig.1** The outline of model system(cooling mode)

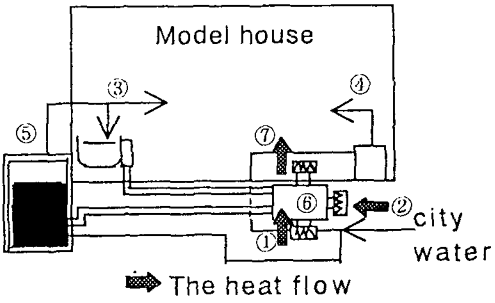
levels of temperature by the conventional heat pump with a refrigerant. However, the multiple function heat pump uses a complex refrigerant to a chieve different purposes such as getting hot water, cooling and heating. In this study, the multiple function heat pump system utilizes water as a heat souice. It is composed of several units such as hot water storage unit, hot water supplier, outdoor unit, etc. It can recover the waste heat from cooling mode and waste bath water by changing the refrigerant flow. To calculate the amount of energy savings, the COP according to the temperature of each heat source was calculated by using the data of the multiple function heat pump given in the catalogue.[2]

### 2.3 Control modes of the system

The control modes of the multiple function heat pump using city-water as a heat source are studied as follows.

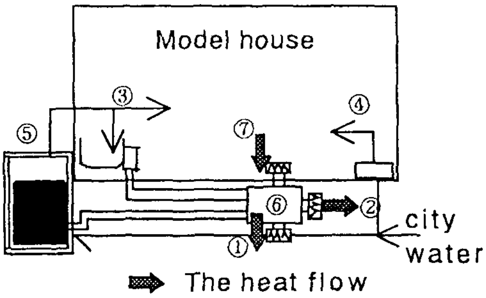
(1) The heating mode

The two types of heat source used in the system are air and city-water. Their performance can be evaluated with the knowledge of coeffient of performance(COP). The model system selects the better heat source between air and water by comparing the COP of the system. There are some limitations of using city-water as a heat source. If the city-water is utilized as a heat source to supply hot water, it must be reheated. This means that there are no merits on the energy savings. The city-water which has no relation with the change of temperature can be utilized only for a heat source(refer to Table 2). When the amount of city-water is not enough for heat source of the system, air can be utilized as a heat source. The reduction of heat load for making hot water by raising the city-water temperature to 16℃ is expected. The hea-




① get heat from water ② get heat from air
③ for hot water supply ④ for water supply
⑤ hot water storage tank
⑥ a multiple function heat pump
⑦ space heating

**Fig.2** The heating mode




① waste heat to water ② waste heat to air
③ for hot water supply ④ for water supply
⑤ hot water storage tank
⑥ a multiple function heat pump
⑦ space cooling

**Fig.3** The cooling mode

ting mode of the system is shown in Fig. 2.

(2) The cooling mode

In contrast to the heating mode of the system. the city-water which needs heating can be used as a heat source on the cooling mode. The other portion of the city-water is not used as a heat source. On the cooling mode, a reduction of heat load for hot water supply is expected by recovering the waste heat from a multiple function heat pump. Figure 3 shows the cooling mode of the system.

(3) The recovery of heat from bath water

The recovery of heat from bath wather is helpful to reduce the heat load for making hot water supply. It is possible to recover the heat from bath water by changing the refrigerant flow in the multiple function heat pump. The collection of heat from bath water has been conducted by comparing the temperature of outside air with that of the bath water which has better performance at the same time.

### 2.4 Establishment of a model system

To simulate a house having different pa-

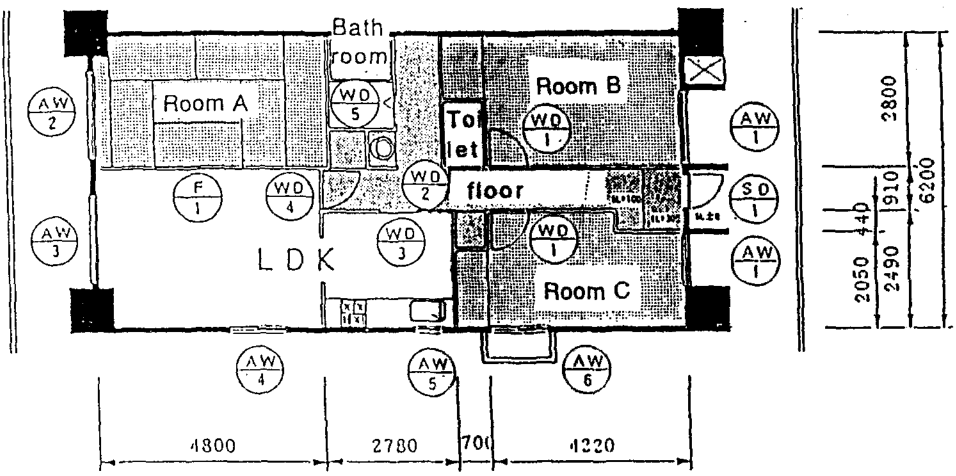



**Fig.4** Model house

tterns of water and heat demands at the given period of the time, a model house is established as the given below.

(1) The model house

Figure 4 shows a model house capable of accommodating 4 persons. This house has the total area of $77.5m^2$ and heating and cooling area of $61.29m^2$.

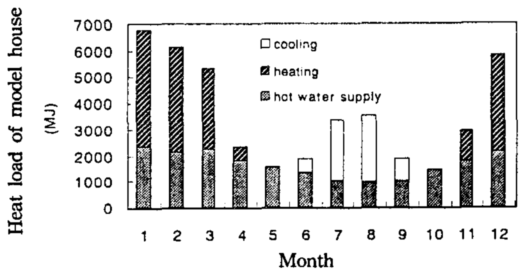



**Fig.5** The monthly heat load on the various heat demands of model house

(2) The heat load

The SMASH program[3] for calculation of heat load on dwelling was developed by Institute of Building Energy Conservation(I.B.E.C). The data on weather conditions in Osaka was used to calculate the heat load of the model house. As shown in Fig. 5, the monthly heat load was calculated for the different kinds of heat demand.

(3) The pattern and the quantity of using city-water[4,5]

It is assumed that the quantity and pattern of city-water usage, given in Table 1, have the same trends throughout the year. The consumptions and temperatures of water for various usage during different seasons are shown in Table 2. The city-water tempera-

**Table 1** The pattern and the quantity of used city water

| | The amount of city water according to time pattern | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Usage | 1~5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Toilet | | | 20 | 30 | | | | | 5 | | | | | | 10 | 15 | 15 | 5 | | |
| Face Washing | | 15 | 45 | 10 | | | | | | | | | 5 | | | | 5 | 5 | 10 | 5 |
| Bath | | | | | | | | | | | | | | | | 100 | | | | |
| Shower/Bath | | | | | | | | | | | | | | | | 25 | 25 | 25 | 25 | |
| Laundry | | | | 60 | 40 | | | | | | | | | | | | | | | |
| Dish Washing | | | | 20 | | | | | | | 20 | | | 20 | 40 | | | | | |

The number means the percentage of the water used per daily water demand and the blank space equals 0%

**Table 2** Water consumption and it's temperature for various uses at different seasons

| | Water consumption( ℓ /d) | | | Using temperature(℃) | |
|---|---|---|---|---|---|
| Usage | Heating season | Intermediate | Cooling season | Heating season | Except Heating season |
| Toilet | 146 | 154 | 165 | Natural temperature | Natural temperature |
| Face Washing | 65 | 61 | 56 | 40~42 | Natural temperature |
| Bath | 180 | 180 | 180 | 42~45 | 42~45 |
| Shower/Bath | 102 | 112 | 127 | 43 | 43 |
| Laundry | 152 | 214 | 300 | 35 | 35 |
| Dish Washing | 144 | 144 | 144 | 30 | 30 |

Table 3 The comparative cases of model system

| Case | Heat source | | Control of city water temperature | Heat pump |
|---|---|---|---|---|
| | Air | City water | | |
| A | use | use | to 16℃ | Multipule function heat pump |
| B | use | use | no | Multipule function heat pump |
| C | use | no use | no | Multipule function heat pump |
| D (conventional model) | use | no use | no | Conventional heat pump, Gas heater for hot water supply |

ture is used at the outlet point of the purification plant of Osaka City, located in Osaka Prefecture. The monthly temperature variations of air and city-water are shown in Fig. 6.

### 2.5 The comparative cases of the model system

Four cases of the model system are suggested in Table 3 and the evaluation of each system is made. For case A, the city-water at a constant temperature is used as a heat source of heating and cooling is the base case in this study. Case B uses the natural temperature of the city-water as a heat source. Case C having multiple heat pump system uses only air as a heat source for heating. Compared with the other cases, Case D uses only air as a heat source for heating. and cooling, and the gas for making hot water.

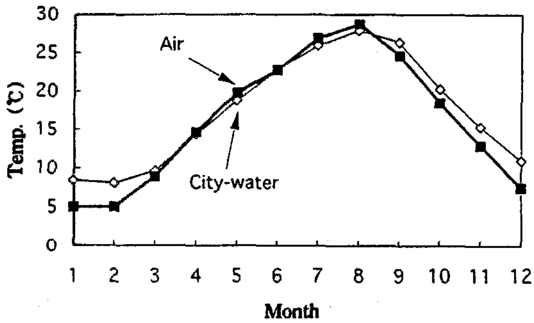



Fig.6 The monthly temperature of heat source in Osaka city

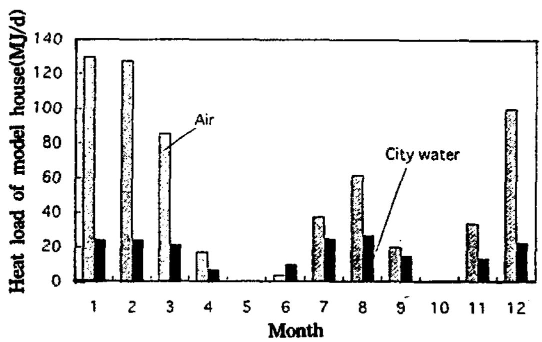



Fig.7 The amount of treated for each heat source in case A

## 3. Results and Discussions

### 3.1 Concerning with heating and cooling

Figure 7 shows the amount of heat gained when using the air and the city-water as heat sources in case A. This exhibits a tendency that the heat obtained by using the city-water is limited by the amount of city-water available per day. Since it is designed to choose high efficiency heat source while running, the

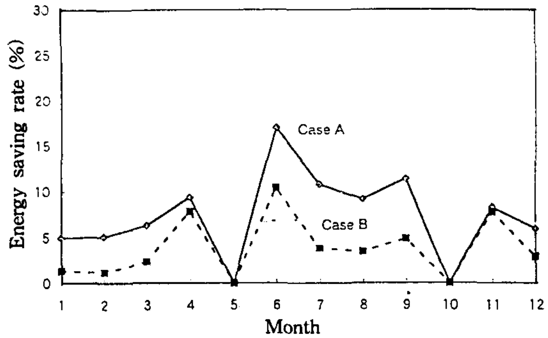



**Fig.8** The change of monthly energy saving rate on the heating and cooling

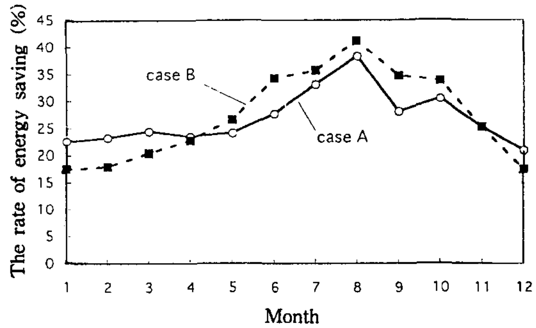



**Fig.10** The monthly change of the rate of energy saving on hot water supply

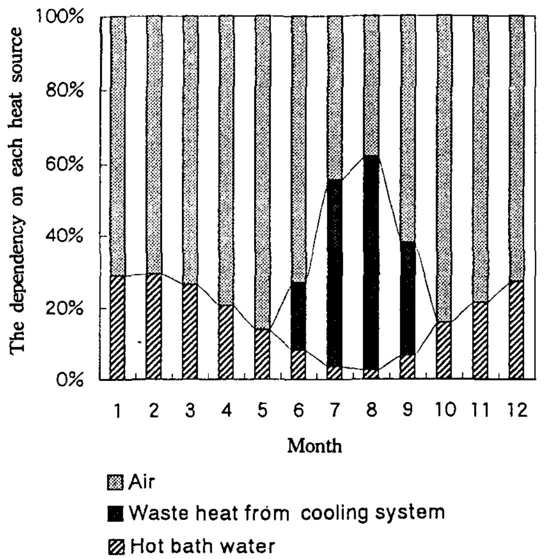



**Fig.9** The monthly change in the dependence of hot water supply on each heat source (case A)

rate of heat load treated by using the city-water increased during the month of low heat load. The change in monthly energy saving rate in case A and case B on heating and cooling is illustrated in Fig. 8. By the comparison of estimated primary energy consumption to the conventional system(case D), energy saving rate was calculated. The rate of energy savings for case A becomes higher in cooling time and it is nearly 10% to 15%. If the city-water without temperature modification is used as a heat source in case B, the rate of energy saving will be lower and would not lead to the efficient energy savings.

### 3.2 Concerning with hot water supply

The monthly change of hot water supply for each heat source with case A is shown in Fig. 9. The recovery heat from hot bath water increases in winter and the dependency of waste heat from cooling system becomes higher in summer. Monthly change of energy saving rate for hot water supply in case A and case B are given in Fig. 10. The rate of energy savings increases in summer because waste heat can be used and the efficiency of performance of heat pump becomes higher. The rate of energy savings for case A is lower than that of case B in summer when the city-water becomes cool. Also the rate of cnergy savings for case A is increased in winter when the city-water is heated.

### 3.3 Evaluation of each operation mode

As shown Fig. 11, case A has a few differences in energy saving rate on hot water supply.

This is caused by the decrease in energy savings in summer(refer to Fig. 9). Since the amount of city-water decreases in winter, the

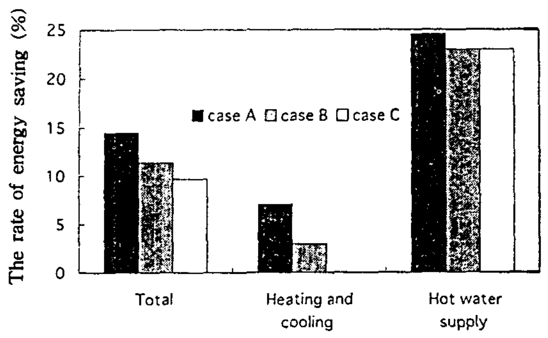



Fig.11 The yearly rate of energy saving for various cases on each operation mode

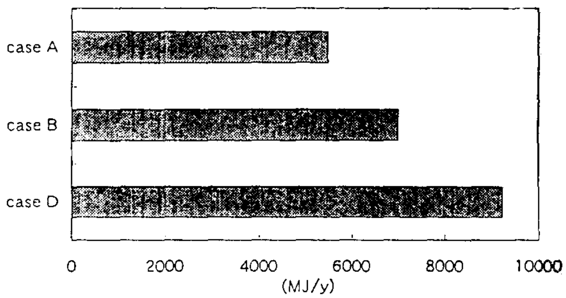



Fig.12 The yearly amount of waste heat to air for each case

rate of energy savings on heating and cooling is less than 3% for case B and 7% for case A. The total rate of energy savings is about 10% for case B and 15% for case A.

### 3.4 Decrease in waste heat discharge

From the view point of urban climate in summer, it is supposed that sensible heat discharged from cooling system is great cause on urban heat island.[6] In this system, when the sensible waste heat from cooling mode is discharged into city-water, there is a decrease in the amount of sensible waste heat to air. Figure 12 shows yearly amount of waste heat to air for cach case. The amount of waste heat discharge decreases 38% for case A and 17% for case B when compared with conventional system of case D. From these results, it can be concluded that there is a

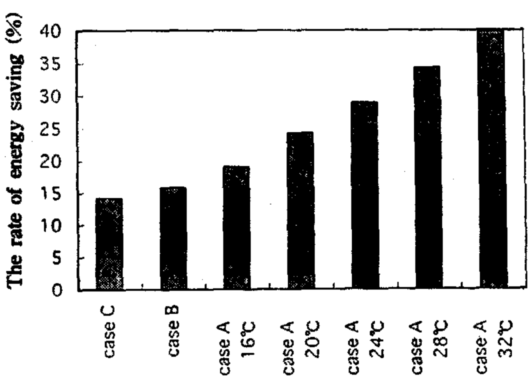



Fig.13 The yearly rate of energy savings at the variable temperatures of city water

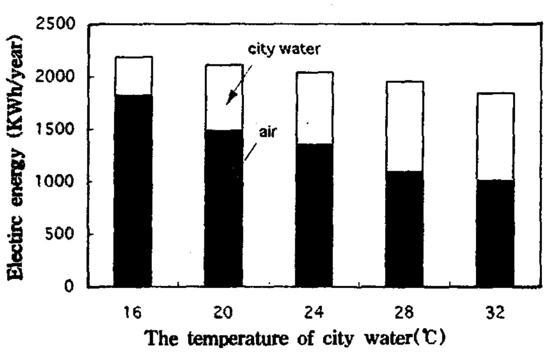



Fig.14 The yearly electric energy consumption with changing the temperature of city water on the heating mode

prevention effect on heat island in cases A and B.

## 4. System evaluation concerning with variable temperature of city-water

The simulation on the above system for case A was performed with a hypothesis that the city-water is controlled at 16℃, colse to the underground temperature to neglect the heat loss from existing city-water pipeline. The evaluation on the efficiency of performance, concerning with the various temperatures of city-water, is done here for case A.

### 4.1 The change of yearly rate of energy savings wity the variable temperatures of city-water.

Figure 13 shows the yearly rate of energy savings on the total operation mode at the supply temperature values of city-water varied from 16℃ to 30℃. It is found that the increase in energy saving rate is bigger with the increased temperature of city-water supply. To calculate the detailed rate of energy savings, the total mode is divided into various modes disscussed as follows.

(1) In the heating mode

The relation of the city-water temperature to the electric energy consumption and the ratio of city-water to air as heat sources for the multiple heat pump are shown on heating mode in Fig. 14. In the heating mode, the increased use of city-water as a heat source leads to a decrease in yearly consumption of electric energy as the temperature of city-water increases.

(2) In the cooling season

In contrast to the heating mode, the electric energy for cooling is decreased, but the electric energy for hot water supply is increased with continuous decrease in the temperature of city-water. It shows a trade-off relation between the electric energy of cooling and that of hot water supply during the cooling season. It is necessary to have the detailed evaluation about the balance of electric energy on both sides.

The relation of the supply temperature of city-water to the electric energy consumption and the ratio of city-water to air as heat sources for the multiple heat pump are shown on cooling mode in Fig. 15. The decrease of city-water usage as a heat source leads to on increase in yearly consumption of electric energy as the temperature of city-water increases.

In Fig. 16, the relation between the city-water temperature and the electric energy consumption in the cooling season, which contains the cooling and hot water supply, is analyzed. The electric energy for hot water supply is decreased with continuous increase in the temperature of city-water, but the total electric energy is not affected by the variable temperature of city-water in the cooling season.

### 4.2 Discussion on recommendable city water temperature

From these results, the system using the city-water as a heat source shows energy sa-

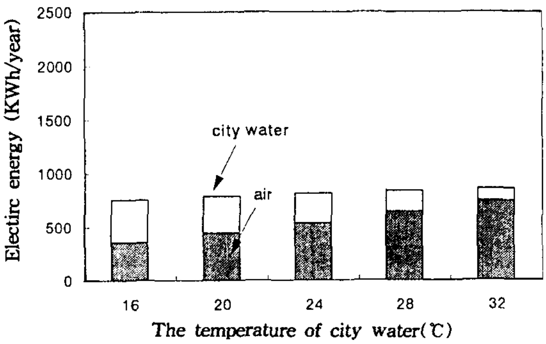



**Fig.15** The yearly electric energy consumption with changing the temperature of city water on the cooling mode

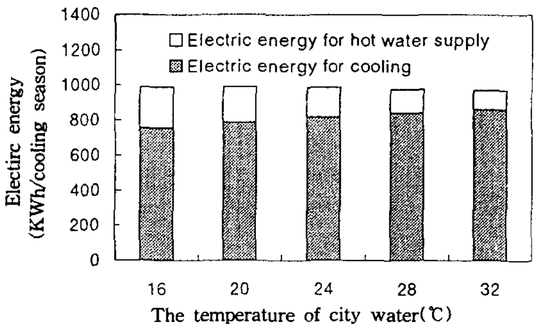



**Fig.16** The detailed electric energy consumption on cooling and hot water supply at cooling season

vings with on-going increase in the temperature of city-water during the heating mode.

The high supply temperature of city-water without reducing chlorination and heat loss is recommended as a heat source in heating mode. In the cooling mode, however it has no advantage in energy savings as the temperature of city-water increases continuously. It means that any temperature of city-water can be supplied as a heat source. To the aspect of the house which does not have a cooling system the natural temperature is recommend as the supply temperature of city-water for a heat source, which has no effect on the house life. However, decreasing the city-water temperature is a good method to prevent the heat island effect with continuous control in the sensible waste heat.

## 5. Summary

In the present paper, the dwelling side is focused using city-water. It was controlled thermally by unused energy as a heat source and transported by city-water pipeline. By using the city-water at various temperatures, the electric energy is shown to be saved when compared with a conventional model. The natural temperature of city-water is recommended as supply temperature in the cooling mode whereas higher temperature is recommended in the heating mode. From the quantitative analysis of the sensible waste heat, it can be said that this system has a prevention effect on heat island. Only dwelling side using city-water without heat loss from the pipeline as a heat source has been discussed in this study. It is necessary to study more about the heat loss from the pipeline. Furthermore, using the city-water in the network system will be conducted as a future work.

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이 논문집은 한국과학기술단체 총연합회의 일부 재정지원에 의하여 발간되었습