IMPORTANCE OF DEMAND-SIDE ENERGY USE MANAGEMENT FOR SUSTAINABLE COMMUNITIES

- A Case Study On Portable Electric Water Heaters -

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ABSTRACT---The results of a survey on energy use pattern and a measurement of the thermal characteristics of portable electric water heaters widely used at homes and at offices in Tokyo area are described. The paper also discusses the effects of improving the thermal insulation of the water heaters and of changing the pattern of using the water heaters on the electric power demand and the annual use of liquified natural gas for producing electric power.

The result of the survey showed that 15 % of the homes surveyed keep the electric water heaters on throughout day and night. The result of the measurement showed that the heat loss coefficient of the portable electric water heaters is seven times that of portable insulated hot-water containers without heater.

The change in boiling time from twenty to thirty minutes is equivalent to reducing a couple of 1-GW-class power plants, assuming that twenty million electric water heaters are used at homes and at offices throughout Japan. Making the thermal insulation of the electric water heaters almost the same as that of the portable insulated hot-water containers without heater is equivalent to reducing the annual amounts of liquified natural gas supplied to the power plants in Japan from 1.17 Mton to 0.42 Mton. This reduction is equivalent to thirteen tankers, each of which can deliver 65 kilo-tons of liquified natural gas.

These suggest that the change in our lifestyle and wise demand-side energy-use management are essential for a sustainable community.

1. INTRODUCTION

The thermal characteristics of buildings affect the amounts of energy use for space heating and cooling. The same applies to hot-water heating; it is important to use well-insulated tanks for storing hot water.

Portable electric water heaters whose volume is about 2 L have been widely used for the convenience of having tea, coffee, and noodles instantaneously at homes and at offices throughout Japan. Their popularity is owing to the fact that boiling water is available whenever necessary. However, their thermal characteristics have not been studied extensively compared to those of building envelopes.

We therefore focused on the thermal characteristics and the use pattern, the electric power demand and the annual energy use of portable electric water heaters. This article describes the results of our survey on the use pattern and of the

measurement of the thermal characteristics and discusses the possibility and the importance of the demand-side energy management.

2. OUTLINE OF THE SURVEY AND THE MEASUREMENT

The use pattern of portable electric water heaters, that is, from what time to what time they are used and how often the city water is poured, was surveyed with the questionnaire. We also asked whether a method other than portable electric water heaters is used to boil water. The questionnaires were distributed to 200 homes and to 100 offices in autumn in 1994. The number of sheets returned were 166 from the homes and 62 from the offices. It was found that 37 % of the 166 homes and 58 % of the 62 offices use electric water heaters. Almost all of the rest of the 166 homes, 61 %, use kettles. The 16 % of the 62 offices use kettles and 13 % use rather large-sized hot water heaters.

The 41 % of homes and 22 % of offices having the portable electric water heaters keep on throughout day and night. The 43 % of the homes and 75 % of the offices having electric water heaters answered that they keep the electric water heaters on for 8 to 20 hours per day. Almost all users of electric water heaters leave plugged in at least for more than a half day. Most of the users of the electric water heaters claimed that they change the water once or twice per day and that they renew electric water heaters within five years.

We made the measurement of the thermal characteristics of two portable electric water heaters and two portable insulated hot-water containers without heater in a room of our laboratory in Musashi Institute of Technology in autumn in 1994. We measured the electric power supplied to the electric water heaters, the temperatures of water, the wall-surface of the heaters, the room air, and others. The water was first boiled in the case of the portable electric water heaters and then as soon as the water was boiled their switches were turned off. On the other hand, in the case of the portable insulated hot-water containers without heater the boiled water was poured and then the lids were closed. We measured the temperature variation of the water for 25 hours after the boiling water was provided. The heat loss coefficient, K [W/K], of each container was estimated fitting the equation for calculating water temperatutre derived from the energy balance equation of the water heaters and the containers.

The average heat loss coefficient, K, of the portable electric water heaters turned out to be 0.35 W/K while that of the portable insulated hot-water containers without heater to be 0.05 W/K.

3. CASE STUDY AND DISCUSSION

We first discuss the relationship between boiling time and the electric power demand and then the effect of improving thermal insulation on the annual energy use and on the exergy consumption from the power plants to the heaters.

The electric power demand as a function of boiling time was obtained by solving analytically the energy balance equation of an electric water heater, assuming that the electric power supplied to the heater and the surrounding

temperature of heater are constant. The temperature of the water in the beginning was assumed to equal the monthly average of outdoor temperature in Tokyo. We assumed that desired temperature is 100 °C or 80 °C. The surrounding temperature of the heater was assumed to be 22 °C in winter and 26 °C in summer.

Figure 1 shows the electric power demand versus the boiling time in the case of heat loss coefficient of 0.35 W/K.

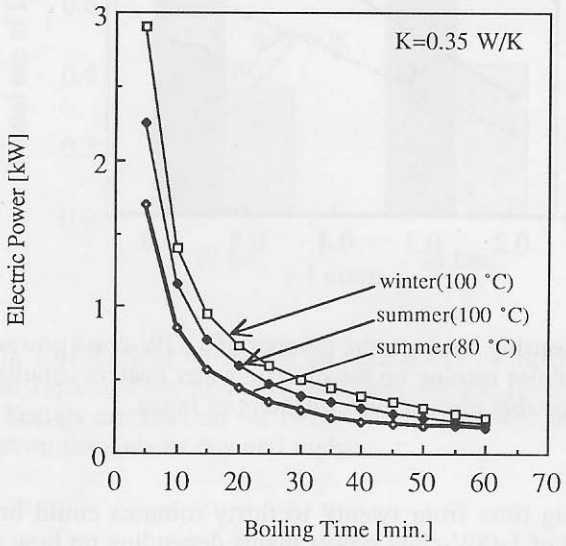

Figure 1 Relationship between boiling time and the electric power demand.

Portable electric water heaters commerecially available are equipped with the electric heater of 1 kW. This implies that they are designed so that the water is boiled within 10 to 15 minutes. If we can wait for 20 to 30 minutes until the water is boiled, then we only need the electric heater of 500 W. It suggests that a mere change of our lifestyle can lead to a significant reduction of electric power demand.

The difference in the electric power demand between in the case of 0.05 W/K and in the case of 0.35 W/K was negligible. This means that while the water is being boiled the energy stored in the water is much greater than the energy lost from the envelope.

Figure 2 shows the relationship between the number of 1-GW-class power plants and the ratio of those turning on the electric water heaters simultaneously to all users of portable electric water heaters in the case of heat loss coefficient of 0.35 W/K in Japan. Two lines correspond to the case of twenty minutes and thirty minutes of boiling time, respectively. We assumed that total number of electric water heaters being used at homes and at offices throughout Japan are twenty million according to our survey and the interview to some of the manufactures of portable electric water heaters in terms of the annual sales of the products. Boiling temperature was assumed to be 100 °C.

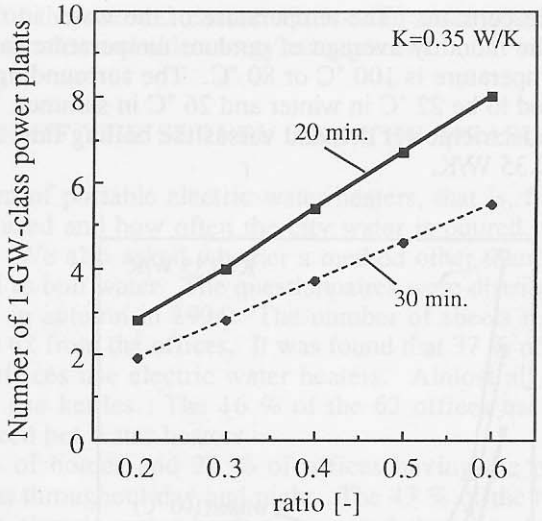

Figure 2 Relationship between the number of 1-GW-class power plants and the ratio of those turning on the electric water heaters simultaneously to all users of portable electric water heaters in Japan.

The change in boiling time from twenty to thirty minutes could bring about the reduction of a couple of 1-GW-class power plants depending on how many portable electric water heaters are turned on simultaneouly.

Figure 3 shows the effect of the change in thermal insulation from 0.35 W/K to 0.05 W/K on the annual use of liquified natural gas supplied to the power plants in Japan. We assumed that two cases of the period in which the heaters are kept on: one is 12 hrs and the other 24 hrs. In both cases, three liters of water is assumed to be used for one day. It was assumed that two liters of water at the temperature of city-water is poured at nine o'clock in the morning and a half liter of water is poured at six o'clock in the evening. We assumed that the water temperature is at 100 °C, the boiling time is 20 minutes, and the number of water heaters is twenty million throughout Japan.

Making the thermal insulation of portable electric water heaters the same as that of portable insulated hot-water containers without heater results in the reduction of annual use of liquified natural gas supplied to the power plants in Japan from 1.17 Mton to 0.42 Mton in the case that the water heaters are kept on throughout day and night. This reduction is equivalent to thirteen tankers, each of which can deliver 65 ktons of liquified natural gas.

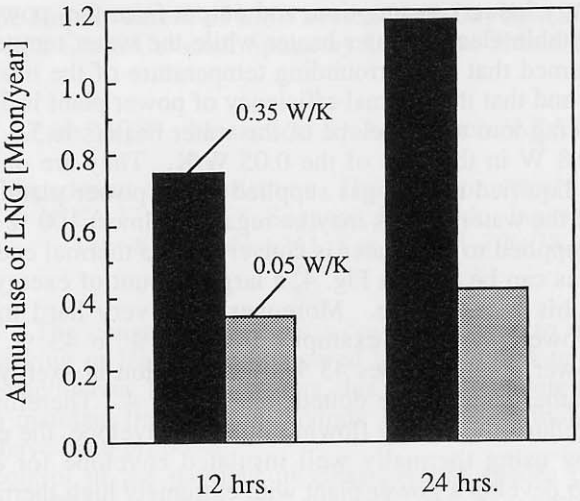

Figure 3 Effect of thermal insulation on annual use of liqified natural gas at the power plants in Japan. Two cases are assumed. In the former case, the portable electric water heaters are kept on for twelve hours per day. In the latter case, the heaters are kept on throughout day and night.

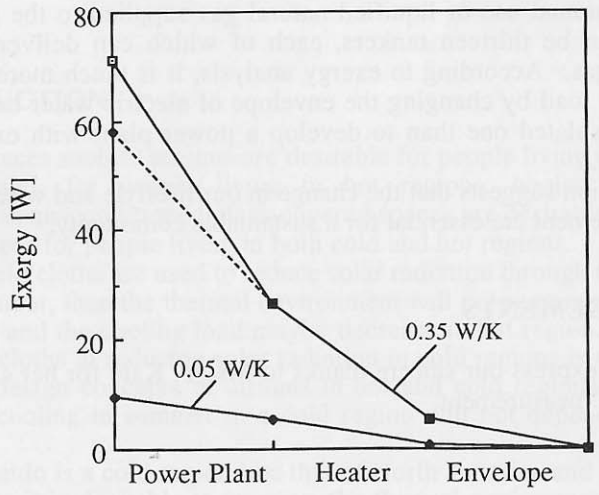

Figure 4 Exergy input, consumption, and output from the power plant to the envelope of one electric water heater while the water temperature is kept at 100 °C.

Figure 4 shows exergy input, consumption, and output from the power plant to the envelope of one portable electric water heater while the water temperature is kept at 100 °C. We assumed that the surrounding temperature of the heater for exergy calculation is 25 °C and that the thermal efficiency of power plant is 35 %.

The exergy flowing into the envelope of the water heaters is 5.3 W in the case of 0.35 W/K and 0.8 W in the case of the 0.05 W/K. They are only 8 % of the chemical exergy of liquified natural gas supplied to the power plant. The thermal energy efficiency of the water heaters may be regarded almost 100 % because all of the electric power supplied to the heater is converted into thermal energy contained by the water. But, as can be seen in Fig. 4, a large amount of exergy is consumed within the heater; this is inevitable. Moreover, it is very hard to improve the efficiency of the power plant, for example, from 35 % to 43 %. Even if the efficiency of the power plant becomes 43 %, the reduction in exergy consumption to be achieved is rather small. See dotted line in Fig. 4. Therefore, it is much more beneficial to reduce the exergy flowing into the envelope, the exergy load of the water heater, by using thermally well insulated envelope for electric water heaters than to try to develop a power plant with extremely high thermal efficiency. This suggests how important the demand-side energy use management is.

4. CONCLUSION

Boiling time affects the electric power demand. Allowing a longer boiling time, that is, a change in lifestyle can result in a significant reduction in the number of power plants. Making the thermal insulation of electric water heaters almost the same as that of insulated hot-water containers without heater can being about the reduction in the annual use of liquified natural gas supplied to the power plants. The reduction can be thirteen tankers, each of which can deliver 65 ktons of liquified natural gas. According to exergy analysis, it is much more important to reduce the exergy load by changing the envelope of electric water heaters into the thermally well insulated one than to develop a power plant with extremely high thermal efficiency.

Our investigation suggests that the change in our lifestyle and wise demand-side energy use management are essential for a sustainable community.

ACKNOWLEDGEMENTS

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REFERENCE

[1] Kato Y., Saito M., and Shukuya M.(1995), Study on the use and thermal characteristics of portable electric water heaters, Annual Meeting of Architectural Institute of Japan, Environmental Engineering Section, pp.533-534 (in Japanese).