B-53.1.1 Evaluation of technologies for utilizing urban unused energy

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Abstract There is a growing interest in utilization of unused but possible energy sources to reduce the carbon dioxide emission and the fossil-energy consumption. Amounts of the reductions, however, have not been fully estimated yet for the nationwide utilization of such energy sources.

Latent heat energy of river water and treated sewage water, and waste heat energy from incineration plant of municipal solid waste and underground train system were taken into calculation in the paper, where extractable energy, usable energy and effect on the fossil-energy saving were estimated. The extractable energy of river was derived from flow volume and water temperature, considering limitations of environmental and technical aspects. The usable energy was determined by applying to the extractable energy some equipment efficiencies such as heat loss efficiency in heat pipes. Fossil-energy saving was calculated by replacing a popularly used heating system with a system using the new energy sources.

The reduction in the carbon dioxide emission by nationwide use of the new energy sources was also estimated, which was about 10% of the reduction targeted by Japanese government in 1996. More detailed studies in consideration of plant location, land use and Life Cycle Analysis appeared to be valuable and needed to confirm the advantage of the new energy source usage.

We developed an estimating method for life cycle analysis of an unused energy utilizing system in consideration of matching supply to demand. Application of the methods to a certain area revealed that limitation of distance from heat source to the area was existing to gain energy saving and CO2 reduction.

Key Words Municipal Solid Waste Generation, Sewer, River Water, Temperature Difference Energy, District Heating and Cooling

1. Introduction

It goes without saying that global warming mitigation necessitates reducing the emissions of CO_2 and other greenhouse gases. Because the emission of CO_2 is intimately linked to energy consumption, energy conservation is one vital means of addressing global warming. But as energy conservation measures are already quite advanced in Japan, attention is now focused on the use of untapped energy such as the heat in river water.

Implementing measures to arrest global warming requires determining the extent to which untapped energy sources can contribute to energy conservation, and then prioritizing them along with other measures for counteracting global warming. Japan's total amount of untapped energy has already been calculated. But the amount of energy represented by these untapped sources is not itself the amount of energy that could be conserved because the amount of untapped energy that can actually be extracted and used is subject to the restrictions presented by technological limitations and environmental impacts. Furthermore, not all usable untapped energy is supplied for use. If equipment efficiency is defined as the ratio of energy supplied to the intermediate energy invested in the supply facilities for untapped energy, then equipment efficiency is determined by factors including the heat loss in pipes, and by the energy efficiency (COP) of the chilled and hot water generating equipment. The COP is influenced by the temperature of heat source water and the like. The amount of energy supplied by the use of untapped energy is also affected by equipment efficiency. Finding the energy conservation effect also necessitates comparing conventional equipment that does not use untapped energy with systems that do use untapped energy. These matters have already been investigated for limited geographical areas, but there has been no research on the nationwide level except for a calculation of the amount of untapped energy. Therefore there are still many unanswered questions regarding the possibilities for using untapped energy sources on a nationwide scale.

This research attempted a more realistic assessment of untapped energy source use by considering the limitations, equipment efficiency, and conventional systems, and on that basis determining the potential for energy conservation that would be achieved through the nationwide use of untapped energy.

2. Method

2.1 The Untapped Energy Sources Studied

The untapped energy sources studied were river water, sewage, municipal waste incinerators, and subways. Energy was obtained from river water and sewage by heat exchange, what is known as thermal energy conversion. Energy obtained from incinerators was the waste heat produced when burning municipal wastes. Our research called for using this heat not only for space heating and cooling, but also for generating electricity. Energy from subways was the heat generated by trains, by the bodies of their passengers, and by the lighting in subway stations.

2.2 Calculation Procedure

Fig. 1 shows the procedure for calculating energy conservation efficiency achieved by using untapped energy sources. First of all we determined the amount of usable untapped energy from basic data such as river flow rate and water temperature, and from technologically and environmentally imposed restrictions. Then, in consideration of plant energy efficiency (COP), heat loss in pipes, and other factors, we estimated the amount of energy that is suppliable by using untapped energy. Because the calculation of supply potential includes both untapped energy and intermediate energy investment, it is possible that the supply potential for space heating will be larger than the amount of untapped energy used. Further, we calculated the energy needed for conventional equipment, which uses no untapped sources, to supply the same amount of energy, compared this to the already-calculated value for systems using untapped energy, and determined the amount of energy savings achieved by using untapped sources.

2.3 Conventional Systems

Estimating the energy conservation effect of using untapped energy requires that one have conventional systems for comparison. Here we chose two systems for comparison. Assuming individual space conditioning, they were case 1, which is air-source heat pumps, and case 2, which is absorption chilled water generators for heating and boilers for heating (Table 1). Air-source heat pumps have high energy efficiency (COP), and have found wide use recently, so it seems likely that the COPs of actual systems fall somewhere between those of cases 1 and 2.

Electricity generation by incinerators was compared with that of oil-fired power plants, for which reason the energy conservation effect was considered to be the amount of power generated from municipal wastes, expressed as primary energy.

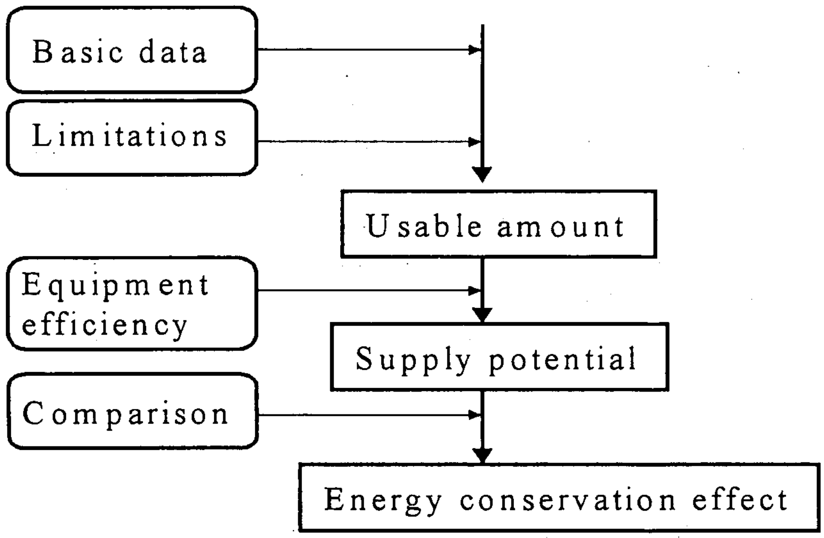

Fig. 1 Procedure for Calculating Potential Untapped Energy

3. Results

The results of estimations show for the 10 prefectures with the highest energy conservation effect in case 1, and for rivers nationally. The high positions are of course occupied by prefectures with the mouths of rivers having high flow rates. These 10 top-ranked prefectures accounted for at least 70% of the national totals of usable amount, supply potential, case 1 energy conservation effect, and case 2 energy conservation effect.

The same estimates show, this time for sewage. Here it is the urbanized prefectures that are top-ranked. Because sewage amount is dependent on population, the sewerage connection rate, and the per capita amount of sewage, it would seem the chosen regions are those in which these are high. The 10 top-ranked prefectures accounted for at least 70% of the national totals of usable amount, supply potential, case 1 energy conservation effect, and case 2 energy conservation effect.

The results on the use of waste heat from municipal waste incineration appear for heat supply only, and for combined heat and power (CHP). With respect to usable amount and supply potential, CHP was barely higher than heat supply alone. The former's advantage is likely because although heat supply is limited to space heating and cooling seasons, power production is possible all year. CHP's energy conservation effect was at least 1.5 times that of heat supply only, the reason being that because the generating efficiency of a power plant is lower than the COP of space heating and cooling equipment, the generating substitution effect of municipal waste was calculated at a high value. Our research subsequently adopted CHP for municipal waste incinerators. The 10 top-ranked prefectures are the same as for sewage, except that Kyoto Prefecture is replaced by Shizuoka Prefecture, showing that there is a high energy conservation effect in urbanized prefectures. Municipal wastes were likely characterized by population and per capita emissions, as well as differences in waste separation, i.e., the classifications of burnable waste types. In all four categories the 10 top-ranked prefectures accounted for about 60% of national totals.

The usable amount of subway waste heat was compared with other untapped energy sources. As the usable amount for subways was smaller than those for other sources, being less than 2% of total untapped energy, we did not perform next-stage calculations such as for supply potential.

Fig. 2 shows energy conservation effect achieved by using the combined untapped energy of rivers, sewage, and waste incinerators (case 1). The power and heat supplied by incinerators together account for 69% of the nationwide energy conservation effect. Many of the 10 top-ranked prefectures are those with high energy conservation effects achieved with treated sewage and waste incinerators, such as Metropolitan Tokyo and Osaka Prefecture. Although Hokkaido scored in the top ten with its total of rivers, sewage, and waste incinerators, it was fourth place overall. Niigata Prefecture was second place in rivers, but seventh place overall. River water accounted for about half of the effect in Hokkaido and Niigata. These 10 top-ranked prefectures together accounted for 58% of the nationwide energy conservation effect (case 1).

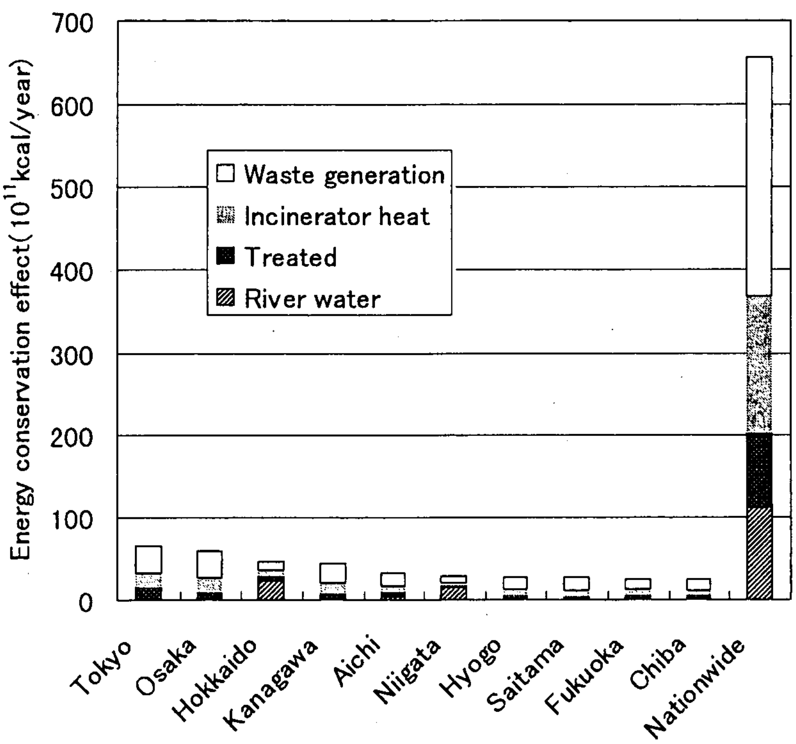

Fig.2 Energy Conservation Effect Achieved with Untapped Energy(Case1)

Fig. 3 shows the ratio of the actual amount of energy supplied using untapped sources to the untapped energy supply potential. While at 20% comparatively much potential energy from incinerators is used, very little of the other untapped sources is used, making the overall utilization of untapped energy less than 2%. There is accordingly a great deal of potential for using untapped sources.

We estimated the extent of CO_2 emission reduction that would be accomplished by using untapped energy. This was done by equating the energy conservation effect achieved with untapped sources to the electricity, gas, and other energy sources whose use would be reduced, and multiplying by CO_2 emission coefficients. The CO_2 emission coefficient for electricity was calculated from the fossil fuels consumed in generation and the total power generated. Results appear in Fig. 4. At the Third Conference of the Parties to the United Nations Framework Convention on Climate Change, held in Kyoto in December 1997, Japan's CO_2 emission reduction target was set at 6% of its 1990 level. Because Japan's CO_2 emissions have continued increasing since 1990, its required reduction stood at about 50 Mt C in 1996. We estimated that the potential for reducing CO_2 emissions by using untapped energy sources would be about 10% of the 1996 reduction target. If in some way CO_2 emissions were reduced to the 1990 level, the potential for further reduction of CO_2 emissions by using untapped energy would be about 25%.

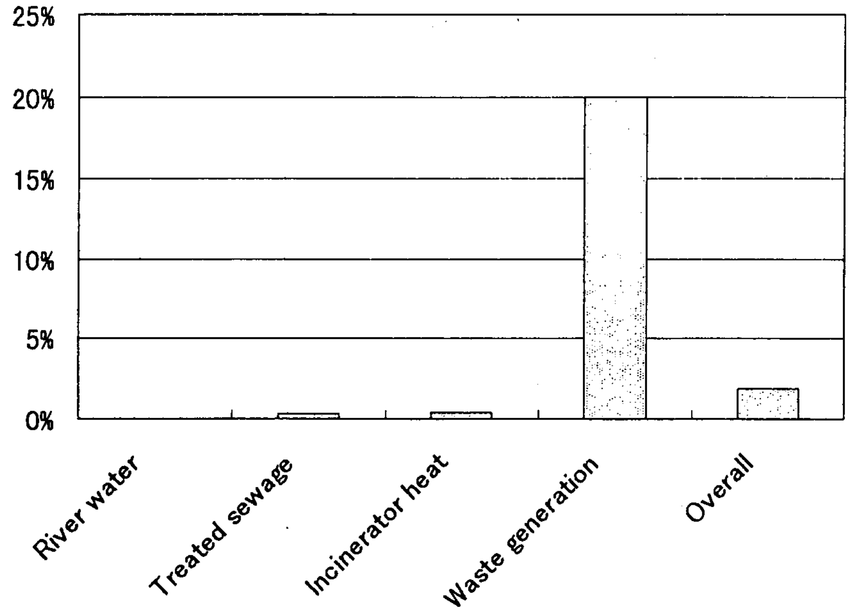

Fig.3 Untapped Energy Utilization Rates

4. Discussion

The CO_2 emission reduction that would be achieved by using untapped energy was estimated at about 10% of the 1996 reduction target. In the event that CO_2 emission reductions became difficult, that 10% would hold great promise. Rough calculations of the current used amounts of untapped energy sources yielded these percentages of supply potential: 0.05% for river water, 0.3% for sewage, 0.4% for heat supply from municipal solid waste incinerators, and 20% for municipal waste generation, yielding an estimate of under 2% of total untapped energy. There is plenty of room to expand the use of untapped sources. However, as the figures given are potentials, the actual energy conservation effect is anticipated to be smaller, and that necessitates a more detailed study of the energy conservation effect while taking into account user requisites and other factors. Of all the prefectures, Metropolitan Tokyo in particular showed the greatest energy conservation effect due to the use of untapped energy, calling for a more detailed analysis using information including that on land use.

The energy conservation effects of rivers, sewage and waste incinerators in the 10 top-ranked prefectures were at least 70%, at least 70%, and about 60%, respectively, and the total of these three untapped sources accounted for 58% of the whole in those 10 prefectures. These results indicate that untapped energy sources are distributed unevenly. Two requirements for using untapped energy are the presence of a usable amount and the demand for its use. While rivers account for 17% of the total national energy conservation effect, more study will be needed to determine the existence near rivers of demand that matches supply potential. We found a large energy conservation effect for sewage and municipal waste incinerators in the cities, leaving no doubt about the magnitude of demand, but because sewage treatment plants and waste incinerators are so-called unwelcome facilities, it is expected that their siting conditions, i.e., their distance from demand centers, will greatly affect the actual amount of energy supplied.

When implementing measures to cope with global warming it is necessary to consider them in the light of comparisons with other energy conservation steps. Life cycle analyses of entire systems will perhaps be needed for a stricter comparison.

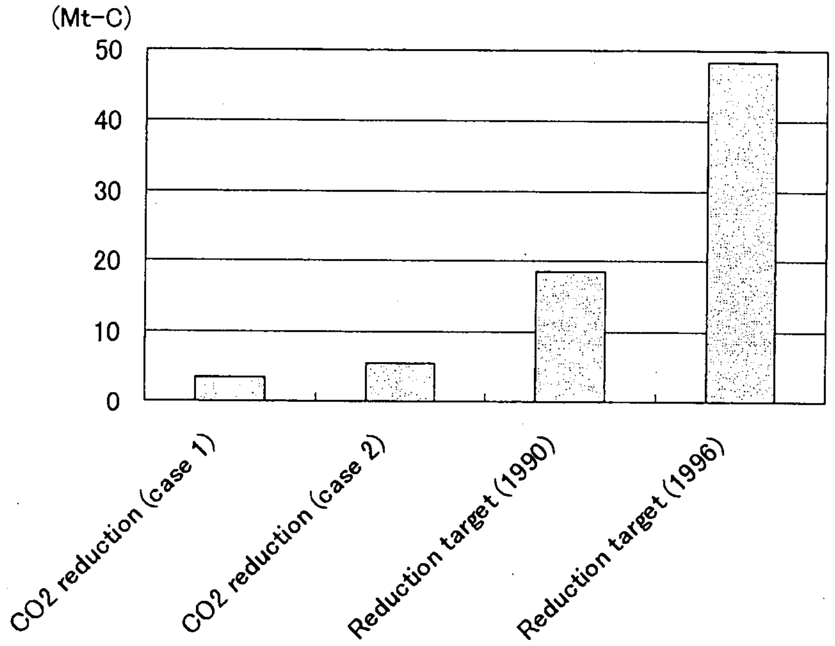

Fig.4 Assessment of CO2 Emission Reduction Through Use of Untapped Energy

5. Conclusion

We sought the energy conservation effect of using untapped energy sources by determining their usable amounts from basic data including river water volumes and from environmental and other limiting factors, and then, while taking into account equipment efficiency such as the heat loss rate of piping, comparing supply potentials with those of conventional systems. Results indicated the following.

The amounts of existing untapped energy varied greatly depending on the prefecture, creating an uneven distribution. Cities had much unused energy from sewage and municipal waste incinerators.

Waste incinerators accounted for 69% of the nationwide energy conservation effect due to untapped energy sources.

The nationwide CO_2 emission reduction achieved by using untapped energy was estimated at about 10% of the 1996 reduction target. Because the effect of using untapped energy is great, further study was deemed necessary to make comparisons with other CO_2 reduction measures. It is desirable to perform more detailed analyses that take into consideration the siting conditions of sewage treatment plants and municipal waste incinerators, as well as land use, life cycle analyses, and the like.