Abstract

From the viewpoint of global-warming prevention, it is asked for the curtailment of the amount of CO$_2$ discharge in the advanced countries including Japan internationally. In Kyoto COP3 (The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change) in 1997, Japan is lifting the target value which will cut down the amount of CO$_2$ discharge 6% in 2010 compared with 1990. In this study, a planning and evaluation system for introducing distributed generators in city level was built using GIS. An arrangement planning of the distributed generators in the Tokyo’s 23 wards was performed using the planning and evaluation system. Curtailment of commercial and residential sector’s energy and CO$_2$ discharge was calculated from the field of energy-saving nature, environmental-preservation nature, and enterprise nature. The result showed that when the unused energy and CGS were introduced in 500m mesh, the rate of injection primary energy curtailment and CO$_2$ curtailment became 11.4% and 15.3% in the Tokyo’s 23 wards. The amount of CO$_2$ curtailment became the result equivalent to 76% of the amount of required curtailment of Tokyo.

Keywords: distributed generators; GIS; unused energy; CGS; Tokyo; CO$_2$

1. Introduction

After the industrial revolution, megalopolis beyond the population of 10 million appears one after another, and makes big impact to the earth environment. From the viewpoint of global-warming prevention, it is asked for the curtailment of the amount of CO$_2$ discharge in the advanced countries including Japan internationally. In Kyoto COP3 (The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change) in 1997, Japan is lifting the target value which will cut down the amount of CO$_2$ discharge 6% in 2010 compared with 1990. Compared with manufacturing industry sector, the increase of energy consumption in commercial and residential sector is remarkable. Especially the energy demand in city is large. Although as the countermeasure, the development of energy-saving technology is furthered, reconsideration of energy supply system in city level is important. In recent years, in addition to the request of reduction of energy saving and environmental load, development of the related technology of energy supply is at a quick pace. Especially, the small-scale distributed generators which are the on-site system manufactured and supplied in a building or an area is being introduced as a new energy system. Practical use of unused energy and Cogeneration system (referred to as CGS below) are basking in the limelight. Therefore, the effect of distributed generators introduction in city level is expected big effect to curtailment of the amount of energy consumption and CO$_2$ discharge.

In this study, a planning and evaluation system for introducing the distributed generators in city was built using the geographic information system. Furthermore as a case study, an arrangement plan of the distributed generators in the Tokyo’s 23 wards was performed, and curtailment of commercial and residential sector energy consumption and CO$_2$ discharge was calculated from the field of energy-saving nature, environmental preservation nature, and enterprise nature. It expects that the result of this study is also applicable to the environmental improvement of Asian megalopolis in the future.

2. Planning and Evaluation System of Distributed Generators Introduction Using GIS

2.1 Outline of the system

In this system, various existing city data were efficiently employed. A creation of city data-base, a display, and the city energy evaluation can be performed (See Fig. 1). The city energy evaluation system can roughly be divided into four layers. The “data-base layer”
which consists of internal GIS data-base and exterior data-base; the "display layer" which displays the information on "data-base layer" visually; the "analysis display layer" which analyzes and displays data of "data-base layer" using formula; and the "evaluation layer" which performs examination and evaluation using analysis data and the evaluation technique data-base. By changing setting conditions may become what have the optimum result obtained in the evaluation layer, analysis by carrying out a loop on the system can be performed.

2.2 Analysis of the Tokyo's 23 wards
2.2.1 Creation of energy demand distribution map of the Tokyo's 23 wards

This study used GIS data of Tokyo's 23 wards provided from the Tokyo City Planning Bureau, and the amount map of heating and cooling demand per year was shown in Fig. 2. We found that compared with cooling demand, heating demand is larger in the Tokyo's 23 wards. Although in the central part of the 23 wards, cooling and heating demand are high, cooling demand falls and the tendency that heating demand becomes high is seen in the suburbs. It is considered because housing institution with much heating demand is mostly distributed in suburb. Moreover, we also found that the amount of heating and cooling demand, and the amount of electric-power demand are very high in the center part of 23 wards, while the heating and cooling demand is higher in comparison with electric-power demand.

2.2.2 Distribution of various heat sources and calculation of a quantity of existing unused energy source

In this study, a data-base of various heat sources in Tokyo's 23 wards was made, and the images of data-bases show in Fig. 3. As a result, the average quantity of existing heat release of subway is 10-18 TJ/Y in one station. Because it is very small compared with the other heat sources, existing heat release of subway was not calculated in this study. The quantity of waste
incineration plants, sewage disposal plant and river were shown in Fig. 4. The quantity of rivers was calculated with fixed flow quantity. The fixed flow quantity cannot be used in other place on river, since it can be transcribed the quantity only to one place on a river.

3. A Calculation of a Practical Use Effect of Unused Energy in Tokyo’s 23 Wards

3.1 Setting of useable quantity

3.1.1 Setting of useable heat release quantity of waste incineration plants

Since heat release of waste incineration plants is high temperature steam or high-temperature water, long distance transportation can be performed. Refer to the record date of Hikarigaoka (Tokyo) waste incineration plant which using heat release from the plant, the ratio of useable heat release was about around 60% on average per year. Therefore the ratio of useable heat release capacity was set up to 60%.

3.1.2 Setting of useable heat release quantity of sewage disposal plant

Since heat release of sewage disposal plant is low temperature and transportation distance is limit, it may not supply all the quantity of existence. Therefore, refer to the record date of Makuhari (Tokyo) new capital hi-tech business district which using heat release from the sewage disposal plant, the distance of transportation was set up to 1.5km.

3.1.3 Setting of useable heat release quantity of river

Since the heat use from river is a low-temperature use, its transportation distance is limit. Refer to the record date of Hakozaki (Tokyo) district using heat release from river, the distance of transportation was set up to 500m.

3.2 Calculating the supply area of waste incineration plants and sewage disposal plants

About heat supply area of waste incineration plants, the ratio of useable heat release capacity was set up to 60%. From the calculation result of waste disposal data of existing waste incineration plants in Tokyo, the distance of transportation was set up. At the same time, the maximum heat supply area was set up by the calculation result from disposal ability of existing waste incineration plants (See Fig. 4). The result also showed that most waste incineration plants burn up trash to a processing ability limit.

About heat supply area of sewage disposal plants, the distance of transportation was set up to 1.5km as possible area of heat supply. At the same time, the maximum heat supply area was set up by the calculation result from the whole heat release of existing sewage disposal plants (See Fig. 4). The result also shows that judging from
capacity of heat release of sewage disposal plants, the area which cannot be used exists mostly.

The map of the heat supply area with unused energy source in Tokyo’s 23 wards shows in Fig. 5.

3.3 The calculation of practical-use effect of unused energy

By the assumption that cooling, heating and hot water supply of a year were covered with unused energy, the reduction rate for injection primary energy and CO₂ discharge quantity of a year could be reduced 3.7% and 5.7% respectively in Tokyo’s 23 wards. At the same time, the air pollution matters such as NOx and SOx could also be reduced.

4. Calculating the Introduction Effect of New CGS in Tokyo’s 23 Wards

4.1 The choice of CGS introduction area with 500m mesh

As a choice condition of an area suited for new CGS introduction with 500m mesh in Tokyo’s 23 wards, the heat and electricity balance and the heat load density index were selected as examination standard. By the machinery efficiency of CGS, the heat and electricity balance was set up to 1.6. Two cases were set up by the heat and electricity balance. One was less than 1.6. The other was equal to or less than 1.6 more than 1.0.

By the standard value of district heating and cooling introduction district in Tokyo, two cases were set up by the value of heat load density index. One was less than 1.0 more than 0.5. The other was over 1.0. The result shows in Fig. 6.

4.2 Evaluation of new CGS introduction

The energy-saving nature, environmental nature and enterprise nature were evaluated for CASE1 to CASE4. The whole 23 wards and individual area of 500m mesh which introduced CGS were examined, and the comparison object was set up to individual supply system (See Fig. 7).

4.2.1 Energy-saving nature evaluation

The result from the evaluation in terms of energy-saving nature is shows in Fig. 8. In the introduction area of CGS, the rate of reduction of CASE2 and CASE4, which the heat and electricity balance was severe, were high. We found that high reduction efficiency area can be extracted by setting the heat and electricity balance strictly. On the other hand, the rate of reduction of CASE1 and CASE2, in which the value of heat load density index was set up to 0.5, is high in the whole 23 wards.

4.2.2 Environmental nature evaluation

The result of environmental nature evaluation shows in Fig. 9. The most quantities of reduction of CO₂ were CASE1, and the reduction effect of 9.5% was expected in the whole 23 wards in a year. From CO₂ discharge with ratio 6% decrease (an aim value of COP3) in 2010, it is necessary to reduce 6,768,000t -CO₂/ year from the results value of 1990 in Tokyo. The quantity of reduction of CASE1 (3,201,000t -CO₂/ year) becomes the 47%
for it. At the same time, the reduction of NOx and SOx can also be contributed.

4.2.3 Enterprise nature evaluation
From initial cost, CASE1 is very high with 2.5 trillion Japanese yen. On the other hand, CASE4 cover it with 1.0 trillion Japanese yen less than half of CASE1.

4.3 The planning of CGS introduction in the Tokyo’s 23 wards
As the result of performing evaluation in CASE1 to CASE4, CASE1 had the highest curtailment effect from the viewpoint of energy-saving nature and environment nature. However, from the view point of enterprise nature, compared with lowest CASE4 of initial cost, CASE1 will require the cost beyond twice. Therefore, although CASE1 is finally desirable, introducing gradually is more realistic. As the first phase, the introduction is begun from the area of CASE4 which the heat load density index and the heat and electricity balance were made severe. In the second phase, restriction of the heat load density index is loosened and the introduction area can be expanded to CASE2. And as the last stage, it proposes loosening restriction of the heat and electricity balance, and performing the introduction area to CASE1.

5. The Arrangement Plan of the Distributed Generators in the Tokyo’s 23 Wards
The final arrangement plan is shown in Fig. 10. As opposed to the Tokyo’s 23 wards, by setting to the introduction of unused energy and CGS in 500m mesh, the result of energy-saving nature and environment nature were evaluated. The rate of injection primary energy curtailment and CO2 curtailment became 11.4% and 15.3% respectively. Moreover, the amount of CO2 curtailment (5,168,000t-CO2/year) is equivalent to 76% of the amount of required curtailment (6,768,000t-CO2/year) of Tokyo.

6. Conclusion
In this study, a planning and evaluation system for introducing distributed generators in city was built using GIS. This became possible to grasp city structure from detailed data of each building. Moreover when the renewal of GIS data will be needed from now on, same examination can be performed easily by substituting data of a data-base layer. Furthermore an arrangement planning of the distributed generators in the Tokyo’s 23 wards was performed using the planning and evaluation system. Curtailment of commercial and residential sector’s energy and CO2 discharge was calculated from the field of energy-saving nature, environmental preservation nature, and enterprise nature. The result showed that when the unused energy and CGS were introduced in 500m mesh, the rate of injection primary energy curtailment and CO2 curtailment became 11.4% and 15.3% in the Tokyo’s 23 wards. The amount of CO2 curtailment became the result equivalent to 76% of the amount of required curtailment of Tokyo.

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