# Estimation of potential demand of “Networked Area Energy Use” in Yokohama city

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## 1. ABSTRACT

In Smart Energy Network, the energy conservation and $CO_2$ reduction is realized through Networked Area Energy Use (NAEU). Not only energy conservation but also reduction of $CO_2$ is promoted by the energy management in a community, instead of that in each building.

NAEU, actually, is not a new idea. District Heating & Cooling (DHC) is its good example, and it is NAEU of heat. Since 1970s, Tokyo Gas has been constructing and operating DHCs where heat is delivered and utilized among buildings in a community to improve the energy system efficiency. NAEU has been playing a great role in the efficiency improvement of the energy application in a community.

In this paper, the approach to evaluate the effect of NAEU in energy conservation and $CO_2$ reduction perspectives is discussed, and the area where energy conservation and $CO_2$ reduction is likely to be achieved by NAEU is estimated.

***<u>C O N T E N T S</u>***

# 2. BODY OF PAPER

## 2.1. Introduction

Currently Network Area Energy Use (NAEU) is examined in various situations[1)2)3)]. The energy delivered among buildings and facilities in a community with NAEU is believed to improve the energy efficiency. The advantages of NAEU are as follows;

(1)Load leveling by the aggregation of the energy demand

The capacity of the facility for air conditioning or electrity is designed to match the maximum demand. Load leveling by the aggregation of multiple customers decreased the maximum load, which makes the facility compact.

Load leveling increases the minimum demand and enables a high load factor. In other words, the faclity installed is likely to be operated at high efficiency due to the high load factor compared to a system that does not use aggregation. This increase in minimum demand also increases the capacity of the system installed. Generally the efficiency of Combined Heat and Power (CHP) which is often used in NAEU is improved with an increase in capacity, especially in CHP utilizing a gas engine. This means an additional efficiency improvement can be expected

(2)Overall efficiency improvement by the prioritized operation of the energy system with high efficiency

In NAEU, the facility with high effiency is likely to be often operated especially in a period with low or middle demand, as the operation of the facility with relatively low efficiency is not necessary. On the contrary, each facility installed in each building is operated to match the demand of each building, which is likely to end up with the relatively long operation of the less efficient facility.

These effects above are highly dependent on the conditions such as magnitude of the area targeted, energy density of demand, the distance among/between the buildings connected and the purpose of the use of the buildings. Generally high energy demand, closed allocation of each building and different pattern of demand are supposed to enable the efficient energy use in NAEU. The quantitative estimate of effects of NAEU and its application for the cost-effective area is essential.

The target of this research is to evaluate the potential demand of NAEU and figure out the effect of energy conservation and $CO_2$ reduction by NAEU in Yokohama city by quantitative approach. In this paper, the area where high energy conservation and $CO_2$ reduction by NAEU is expected in the city is discussed as the first step of the research.

The outline of the estimate of potential demand of NAEU in Yokohama city Yokohama city (Population: 3,680,000, 437 $km^2$) is as follows;

1) Evaluate the heat demand in each 250m-mesh of the city
2) Categorize the heat demand pattern of every mesh
3) Choose the NAEU-applicable mesh

These approach is discussed in the following chapters.

## 2.2. Estimate of Heat Demand in each 250m-mesh area in Yokohama city

In this chapter, the approach to evaluate the heat demand of each 250m-mesh is discussed. Figure 1 shows the calculation Process of Heat demand in each mesh.

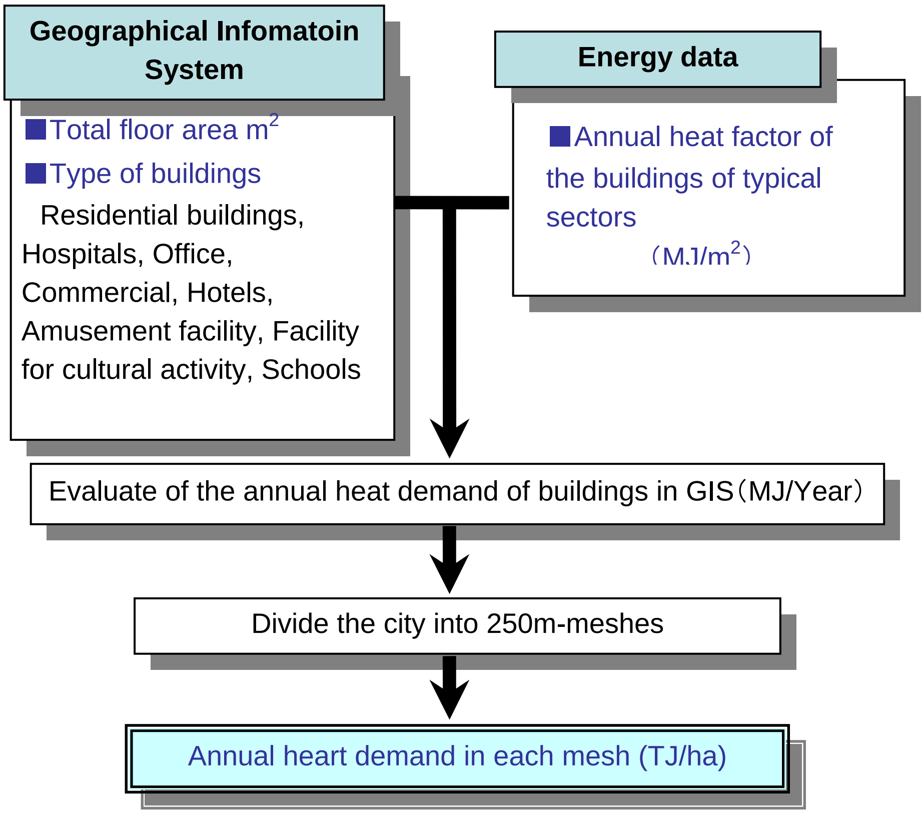


Figure 1. Calculation Process of Heat demand in each mesh

The Geographical Information System (GIS) gives us the total floor area of each buildings in Yokohama city and the use of the buildings such as residential buildings (apartments), hospitals, office buildings, commercial buildings such as a supermarket, hotels, amusement facilities, facilities for cultural activities and schools. The heat demand factor of each building is shown in table 1. From the information of the buildings in the city and the heat factor in table 1, the annual heat demand of the buildings in Yokohama is estimated. The city was divided into 250m-meshes and the heat demand of the buildings in each mesh was calculated, and the annual heat demand of each mesh was obtained.

Table 1 . Annual Heat demand of buildings of each sector

| | unit | residential | hospitals | office | commercial | hotels | amusement | cultural | schools |
|---|---|---|---|---|---|---|---|---|---|
| Heating | MJ/㎡ | 71 | 335 | 209 | 75 | 494 | 180 | 360 | 239 |
| Hot water | MJ/㎡ | 201 | 862 | 54 | 96 | 1298 | 268 | 0 | 0 |
| Heat demand | MJ/㎡ | 272 | 1197 | 264 | 172 | 1792 | 448 | 360 | 239 |
| Energy for Cooling | MJ/㎡ | 75 | 515 | 297 | 360 | 272 | 293 | 180 | 92 |
| Electricity | kWh/㎡ | 46 | 185 | 170 | 291 | 133 | 200 | 63 | 55 |

In figure 2, the distribution of the annual heat demand is shown. It is divided in 5 groups. As district heating is recommended for area with annual heat demand larger than 1Tcal/ha, which is equal to 4.2TJ/ha, referred in the municipal ordinance in Tokyo, the value of 4.2 TJ/ha was chosen to categorize the annual heat demand. Below the quarter of 4.2 TJ/ha, between the quarter and the half, between the half and the value, between 4.2 and its double and above the double is corresponding to group I, II, III, IV and V of heat demand of the mesh, respectively. Figure 3 is the result of the heat demand calculation of each mesh. In this category, the group IV and group V, groups of areas with over 4.2TJ/ha heat demand, are considered to be suitable for NAEU, as they have annual heat demand DHC-applicable.

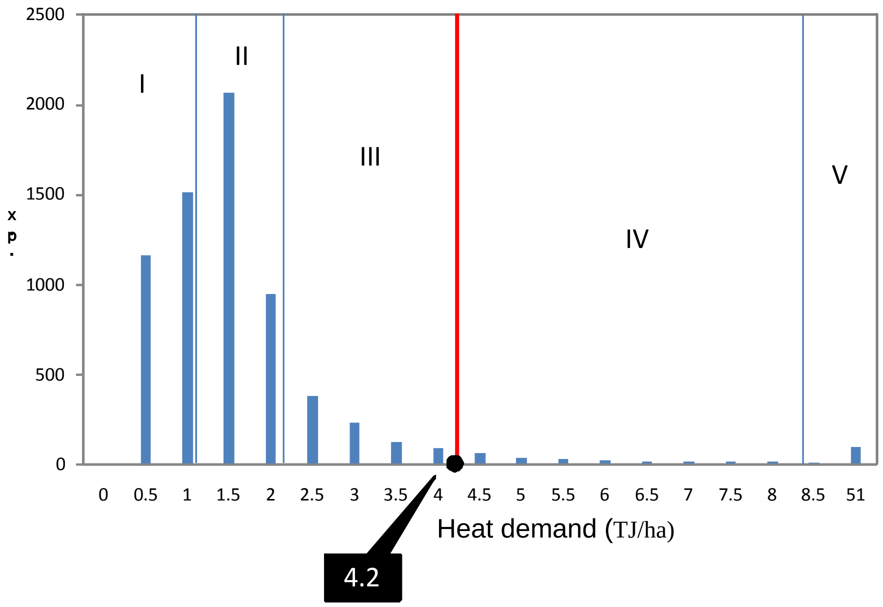


Figure 2. Number of the meshes categorized by annual heat demand density

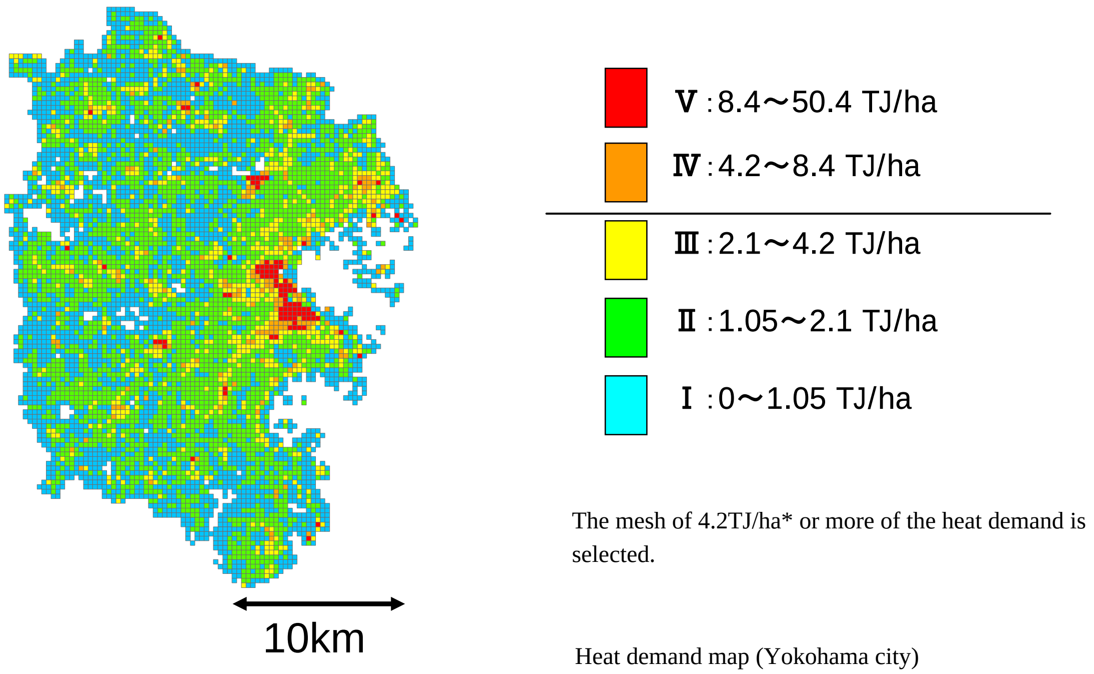


Figure 3. Density of heat demand of each mesh in Yokohama city

### *2.3. Heat demand curve of a day*

In this chapter the segmentation of the energy demand of each mesh is described.

The daily pattern of the heat demand is shown figure 4. In residential buildings and hotels, the heat demand of each building is low in daytime and high at night. On the contrary, office buildings and hospitals have high demand in daytime and low demand at night.

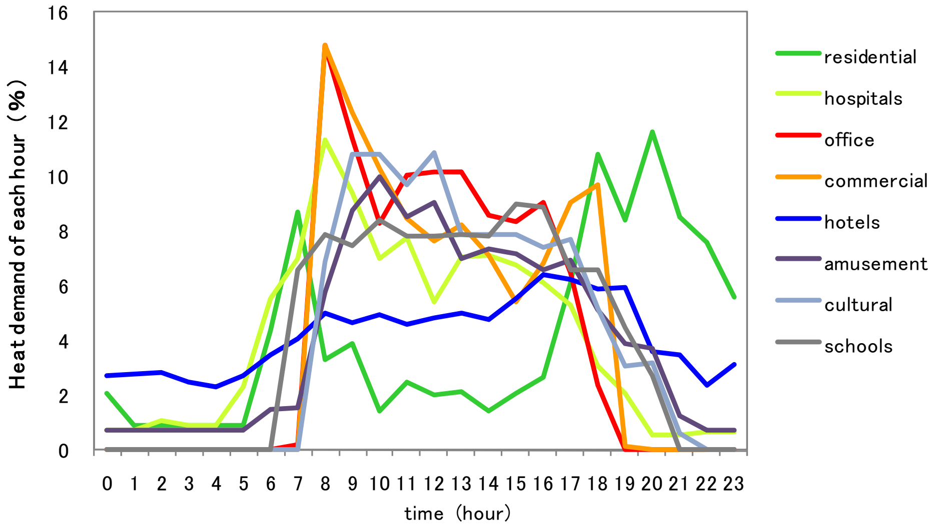


Figure 4. Daily heat demand of the buildings in each sector

The heat demand in each mesh has its own daily pattern of heat demand. The cluster analysis categorized all the meshes into 5 segments in Figure 5. Segment A is residential building -dominated, and segment E is office building-dominated, for example. Using the demand pattern in Figure 4 and the ratio of the floor area of each segment in figure 5, the pattern of the daily heat demand was figured out, which is shown in figure 6. Each segment has its own daily demand pattern.

The ratio of segment C in figure 5 shows that no certain building is dominating the segment, which leads to the load leveling by the aggregation of various kinds of buildings. In segment C, which has relatively flat demand pattern, the effect of load leveling by NAEU is likely to enable the energy conservation and the reduction of $CO_2$ emission. Under this “flat” demand pattern the CHP is operated at high load factor. Segment A and E, however, are dominated by residential buildings and office buildings, respectively. As for these segments, load leveling is not expectable.

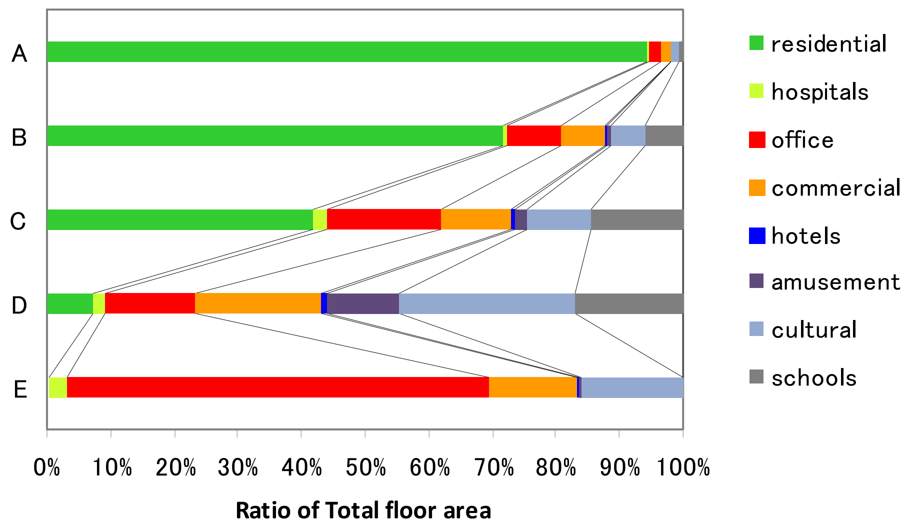


Figure 5. Segmentation of all the meshes and the ratio of floor area

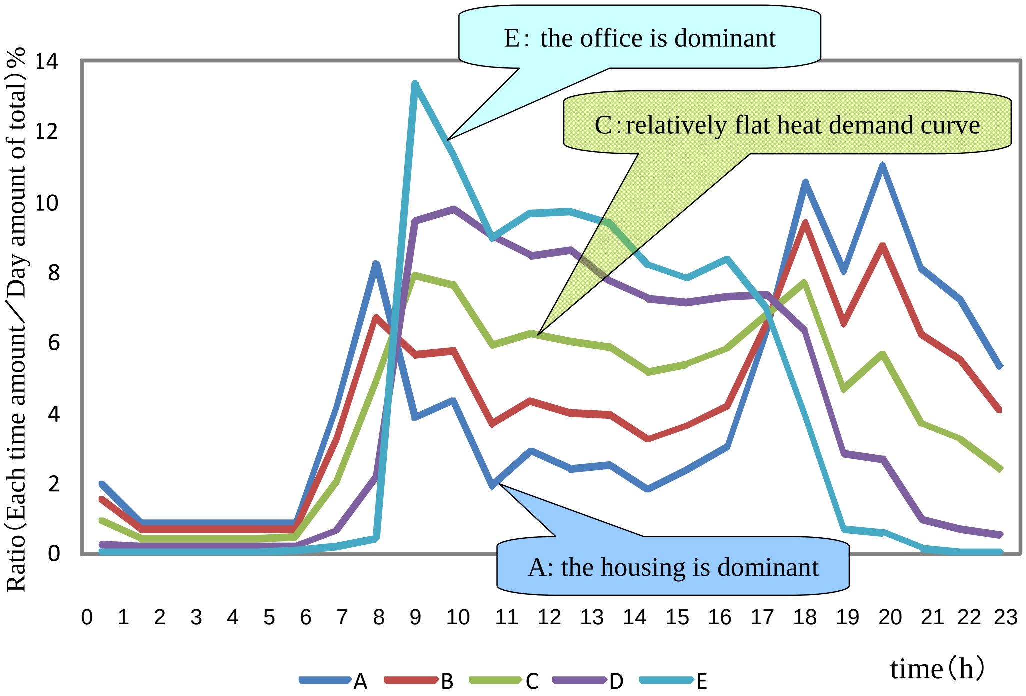


Figure 6. Daily heat demand of five segments

In table 2, all the meshes are classified by magnitude and segmented demand curve of heat demand. It is found that there are 19 “most” suitable meshes for “Networked Area Energy Use” in 6,839 mesh Yokohama city.

“most” suitable meshes for “Network Area Energy Use”

| ②Heat demand curve | Ⅰ (0–1.05) | Ⅱ (1.05–2.1) | Ⅲ (2.1–4.2) | Ⅳ (4.2–8.4) | Ⅴ (8.4–50.4) |
|---|---|---|---|---|---|
| A | 1637 | 1813 | 147 | 12 | 1 |
| B | 492 | 742 | 330 | 43 | 3 |
| C | 179 | 209 | 170 | 72 | 19 |
| D | 259 | 77 | 73 | 52 | 44 |
| E | 324 | 55 | 40 | 13 | 33 |

①Heat demand (TJ/ha)

Table 2. Classification of 6,839 meshes in Yokohama city

The examples of the meshes with annual heat demand over 4.2TJ/ha are shown in figures 7-a, 7-b and 7-c.

Even though the mesh in figure 7-a (IV-A) has relatively high density of heat demand, most of the buildings are detached houses, which results in that the NAEU is less cost-effective. The mesh in figure 7-b (V-E) also has high density of heat demand, but this mesh is dominated by office buildings. Energy conservation and reduction of $CO_2$ emission by load leveling can not be expected in this mesh. On the contrary, figure 7-c (V-C) has various sector of building as well as high density of demand. In this mesh the load leveling can be expected and NAEU is effective in energy conservation and reduction of $CO_2$ emission.

Heat density Ⅳ(4.38TJ/ha)、Daily demand pattern A

⇒ **Residential buillding dominant**

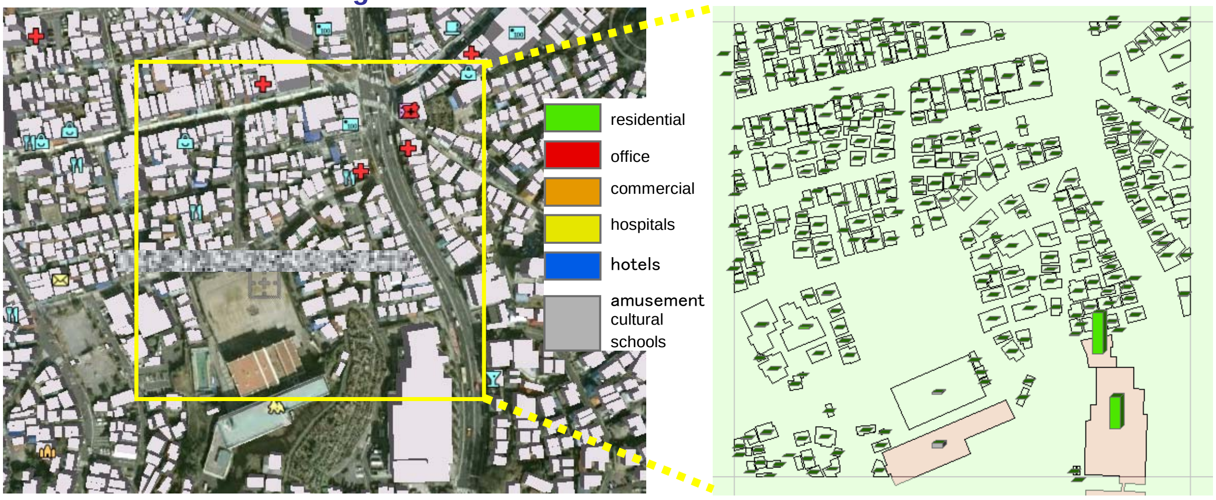


Figure 7-a. Mesh IV-A

Heat density Ⅴ(24.29TJ/ha)、Daily demand pattern E

⇒ **Office building dominant**

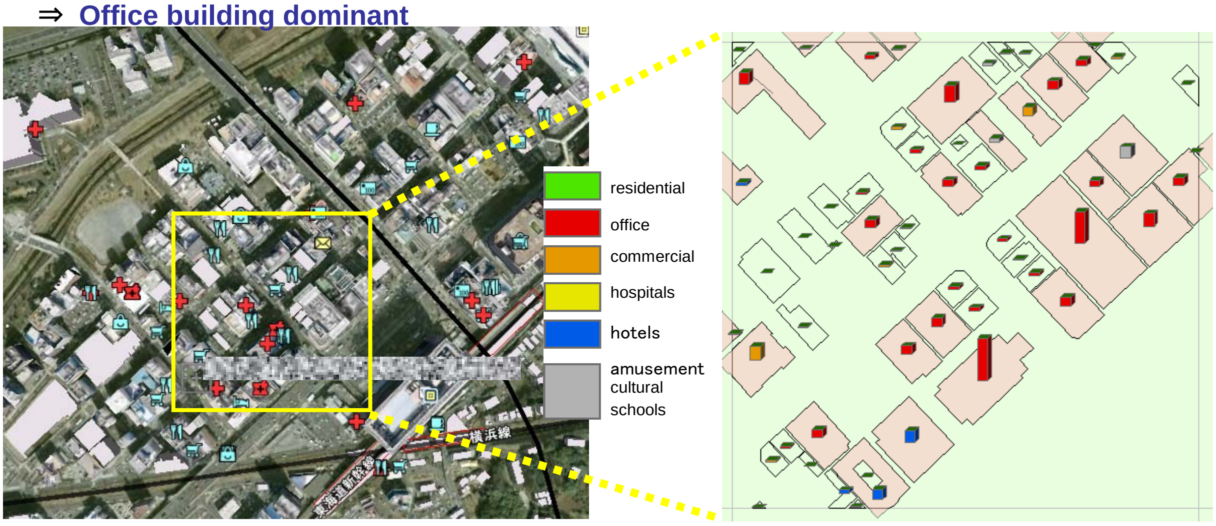


Figure 7-b. Mesh V-E

Heat density Ⅴ(11TJ/ha)、Daily demand pattern **C**

⇒ **High density of heat demand, various sectors of buildings**

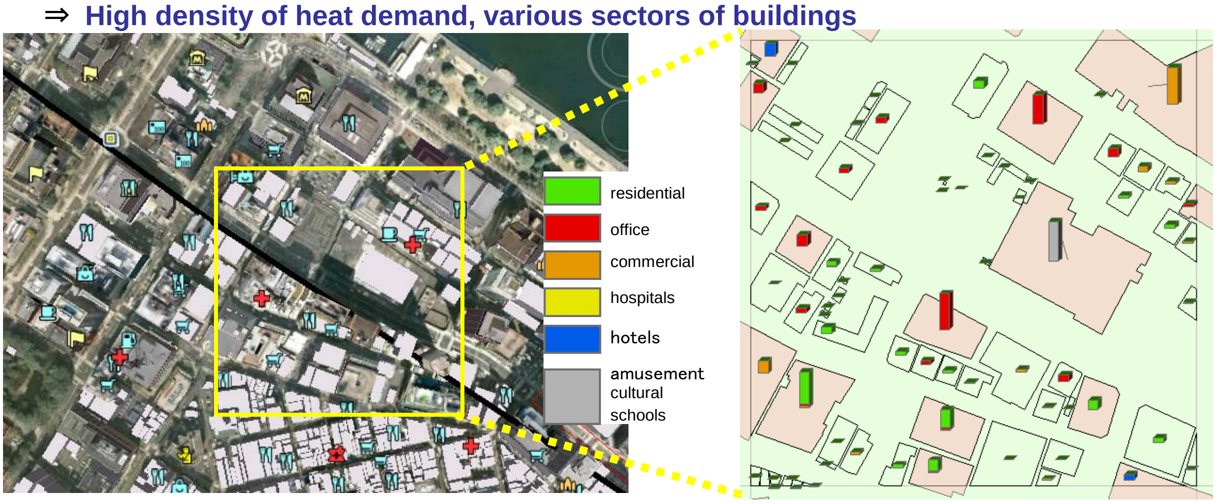


Figure 7-c. Mesh V-C

### 2.4. Estimation of the ratio of Central Heating System

It is necessary to have a Central Heating System for air conditioning system to flexibly manage energy between buildings and promote energy conservation and reduction of $CO_2$ by NAEU. So NAEU cannot be applied in Individual Heating System.

To estimate the potential demand of NAEU, it is necessary to calculate the ratio of Central Heating System.

Sadohara Laboratory in Yokohama National University has performed a research to send questionnaires about air conditioning system to the owners or facility managers of the buildings around the central of Yokohama city. The result indicates the relationship between the total floor spaces and the type of air conditioning systems.

Figure 8 shows that 75% of the buildings whose floor spaces exceeds 40,000㎡ have Central Heating Systems. On the other hand, the ratio of Central Heating System in the buildings whose floor spaces is under 30,000㎡ is only 20%. For the further analysis, the ratio of the building is to be applied.

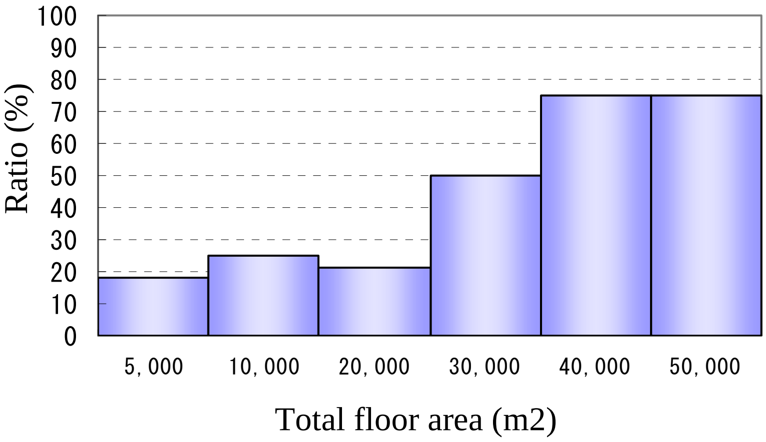


Figure 8. Ratio of central heating system in the buildings

### 2.5. Conclusions

In this study, it is shown that the application of NAEU should target the 19 meshes of type C-V from the magnitude of heat demand (Annual heat demand is over 8.4 TJ/ha.) and load leveling effect by NAEU in Yokohama city. NAEU is not necessarily an effective tool for energy conservation and reduction of $CO_2$ emission in all areas.

Considering the initial cost for the installation of NAEU, its application does not always reduce the lifecycle cost of NAEU. The evaluation of effect of NAEU needs more detailed quantitative analysis. In the next step of this research, the quantitative analysis of NAEU is to be conducted, and energy conservation effect in each mesh is to be evaluated applying this quantitative approach.

## 3. REFERENCES

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3) T.Ogata ,et al. (2010) Feasibility study of block scale energy management among multiple DHC areas part 3&4, Summaries of technical papers of annual meeting architecture institute of Japan,pp715-718.

## 4. *LIST OF TABLES*



## 5. *LIST OF FIGURES*