Study of techniques for inter-regional comparison about air temperature sensitivity of electric power supply

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1. Introduction

Many previous studies on warming mitigation use their estimate effects in air temperature, in order to evaluate a mitigation measures against UHI. However this kind of evaluation may underestimate profits from these countermeasures. Hirano (2005) proposed to evaluate warming measures with "air temperature sensitivity of power consumption". However regional power supply data was non-public in Japan, this index was not so popular.

The East Japan Great Earthquake in 2011, the following nuclear accident and requested electricity saving changed this situation. After 2011, hourly power supply data in each 10 wide blocks in Japan turn to public. To calculate air temperature sensitivity, a representative hourly air temperature of the wide area will be needed. Kittaka et al. (2014) proposed a population weighted air temperature to apply these data to analyze wide area air temperature sensitivity.

The air temperature sensitivity of power supply is confined to a certain region. So, it is impossible to compare among different blocks with their regional air temperature sensitivities. Therefore, this study aims to develop a new index to compare and evaluate air temperature sensitivities of power supply from different regions.

2. Air temperature sensitivity using population weighted mean air temperature

2.1 population weighted mean air temperature

In this study, we need to use the temperature that representative of the area because we consider air temperature sensitivity in wide area. So, we used population weighted mean air temperature. In previous study, it is considering a population weighted mean air temperature by municipalities unit. To aim more precise population weighted mean air temperature, we newly created a population weighted mean air temperature by town and village unit, and examined. We used national census population data of 2010, which was counting by town and village unit. And we used hourly temperature data of Automated Meteorological Data Acquisition System (AMeDAS) observation point. Among the AMeDAS observation points, we removed the observation points in remote islands and mountainous regions that did not form part of the city area.

2.2 Target area and period

The study target area is TEPCO (prefecture of Gunma, Tochigi, Ibaraki, Saitama, Tokyo, Chiba, Kanagawa, Yamanashi, a part of Shizuoka) and HEPCO (prefecture of Hokkaido). The study target period is weekdays from June 1, 2010 to September 30, 2010(except for the Obon period). According to the Japan Meteorological Agency press release document about the weather of summer (June-August, 2010), in the Kanto region, summer of the 2010 was heat wave (average year + 1.9℃), in the Hokkaido region, summer of the 2010 was heat wave (average year + 2.3℃).

2.3 Evaluation of population weighted mean air temperature

In the Fig1, we show a population weighted mean air temperature by municipalities unit and town and village unit, all AMeDAS observation points average temperature in the district under jurisdiction of each power company,and temperature according to date in summer (from August 1, 2010 to August 7, 2010) of Tokyo and Hokkaido AMeDAS. The results are as follows:

- The difference between "by municipalities unit" and "by town and village unit" population weighted mean air temperature is small, and it roughly became the value between Tokyo or Sapporo AMeDAS air temperature and all observation point average air temperature.
- It is because we thought that temperature observation points for the precision improvement of population weighted mean air temperature are not enough.

- The difference of various temperatures was relatively small particularly in the morning, and there were no noticeable changes in the ranking.

Based on these results, in the following discussion, we used a population weighted mean temperature by municipalities unit to temperature index.

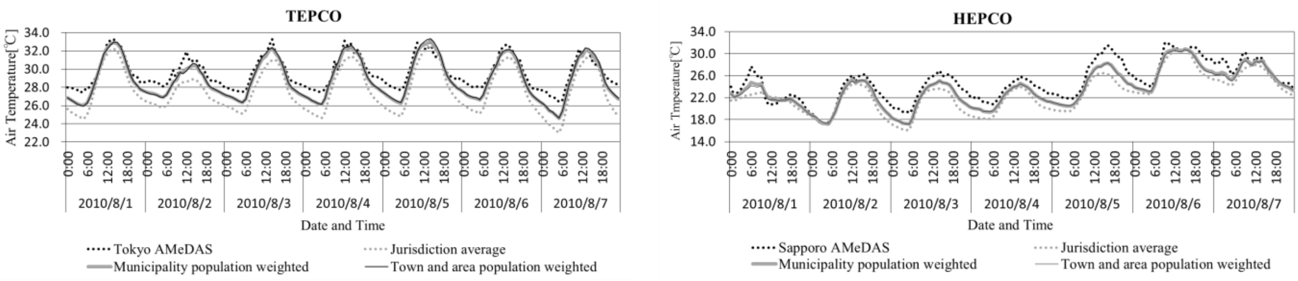

Fig.1 Variation of air temperature

3. Techniques for inter-regional comparison about air temperature sensitivity of electric power supply

In the Fig.2, we show the scatter diagram depicting the temperature (population weighted mean air temperature by municipalities unit) from 9:00 to 18:00 on 2010 summer (June to September) weekdays (except for the Obon period) and electric power supply in TEPCO and HEPCO. The power supply was recorded from approximately 35,000,000 kW at minimum to approximately 60,000,000 kW at maximum in TEPCO. On the other hand, the power supply was recorded from approximately 3,800,000 kW at minimum to approximately 5,000,000 kW at maximum in TEPCO. Among them, the power supply difference of about 12 times the maximum value is observed, and it seems that they are large difference. In order to perform the inter-regional comparison about air temperature sensitivity of electric power supply, we think that it is necessary to correct each electric power supply to comparable new index because there is a large difference in the amount of electric power supply and business scale for each power jurisdiction. Therefore, we considered the effects on the air temperature sensitivity by the correction of the electric power supply about four correction methods in the following.

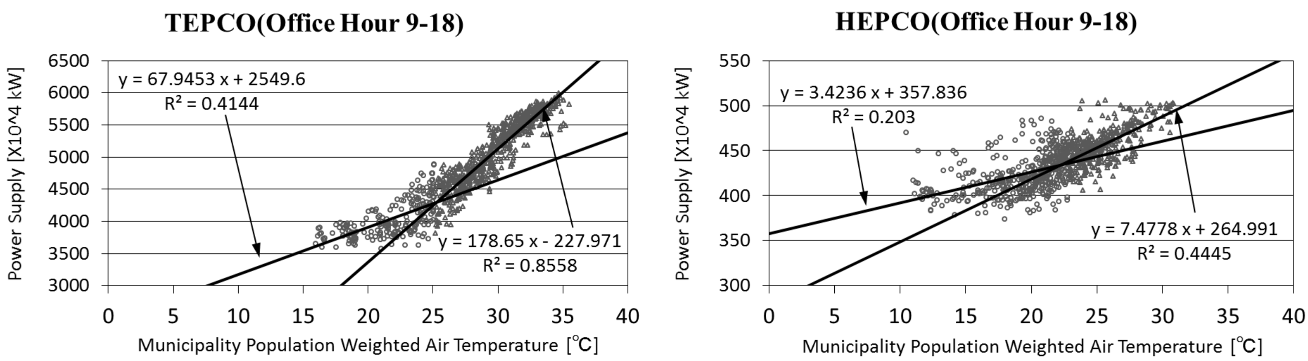

Fig.2 Air temperature sensitivity using power supply (in 2010, summer)

3.1 Target area and period

The study target area is the same area as the previous chapter. The study target period is office hour time zone (weekdays at 9:00 to 18:00, except for the obon period (8/12, 8/13)) of the same period as the previous chapter. And for an electricity supply, we used electricity usage results data (one hour value) that each electric power company showed.

3.2 Approximate line in the scatter diagram depicting the temperature (population weighted mean air temperature by municipalities unit) and electric power supply

In previous study, it points out that sensitivity of the electric power consumption and temperature become different sensitivity at low and the high temperature side. In this study, because the data distribution of the different slopes is seen in a low and the high temperature side in Fig.2, we evaluated an approximation line about each temperature side and considered it.

3.3 Way of using normalized electric power supply

In the Fig.3, we show the scatter diagram depicting the temperature (population weighted mean air temperature by municipalities unit) and normalized electric power supply in TEPCO and HEPCO. Normalized electric power supply is the index that divided the difference between every electric power supply and minimum of electric power supply within the target period by difference between the maximum of electric power supply within the target period and the minimum of electric power supply within the target period. The results are as follows:

- A vertical axis numerical value range of the both electric power district consists of between 0.0 to 1.0, and it is considered to be able to compare it in the same electric power supply index by normalizing the amount of power supply.
- In the Fig.2, air temperature sensitivity in high-temperature side in TEPCO is 178.65[ten thousand kW/℃] and in HEPCO is 7.4778[ten thousand kW/℃], and ratio of sensitivity is 0.042 times (it is small values). On the other hand, in the Fig.3, air temperature sensitivity in high-temperature side in TEPCO is 0.0826[/℃] and in HEPCO is 0.0574[/℃], and ratio of sensitivity is 0.69 times.
- The coefficient of determination in the approximate line of the scatter diagram in high-temperature side in TEPCO is 0.6836 and in HEPCO is 0.4309. It followed that correlation decreased both in comparison with Fig.2.

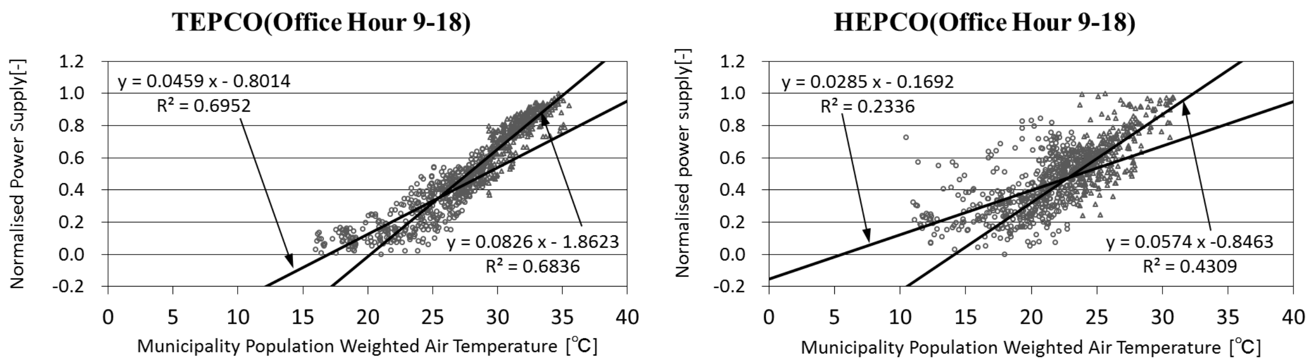

Fig.3 Air temperature sensitivity using normalized of power supply (in 2010, summer)

3.4 Way of using dimensionless electric power supply

In the Fig.4, we show the scatter diagram depicting the temperature (population weighted mean air temperature by municipalities unit) and dimensionless electric power supply in TEPCO and HEPCO. The dimensionless electric power supply is the index that divided the difference between the difference between the electric power supply and the average electric power supply within the target period by deviation value of the electric power supply. The results are as follows:

- Air temperature sensitivity in high-temperature side in TEPCO is 0.2620[/℃] and in HEPCO is 0.2427[/℃], and ratio of sensitivity is 0.93 times.
- The coefficient of determination in the approximate line of the scatter diagram in high-temperature side in TEPCO is 0.8641 and in HEPCO is 0.4993. It followed that correlation increased both in comparison with Fig.2.

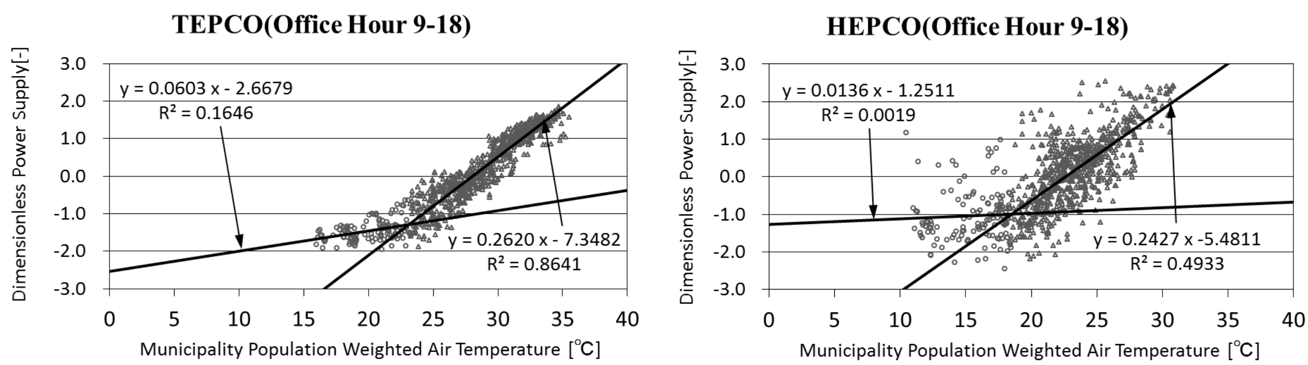

Fig.4 Air temperature sensitivity using dimensionless of power supply （in 2010, summer）

3.5 Way of using power supply ratio against maximum supply potential

In the Fig.5, we show the scatter diagram depicting temperature (population weighted mean air temperature by municipalities unit) and power supply ratio against maximum supply potential in TEPCO and HEPCO. The power supply ratio against maximum supply potential is the index that ratio of the power supply amount to the maximum amount of power supply within the target period. The results are as follows:

- The upper limit value of the vertical axis becomes 1.0. On the other hand, the lower limit value of the vertical axis is different by each of electric power districts.
- Air temperature sensitivity in high-temperature side in TEPCO is 0.0340[/℃] and in HEPCO is 0.0146[/℃], and ratio of sensitivity is 0.43 times.

- The coefficient of determination in the approximate line of the scatter diagram in high-temperature side in TEPCO is 0.6428 and in HEPCO is 0.4328. It followed that correlation decreased both in comparison with Fig.2.

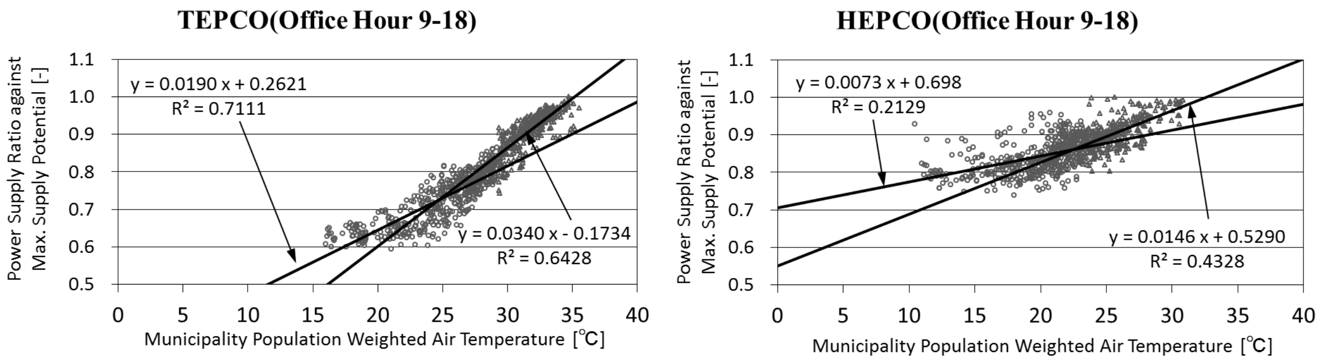

Fig.5 Air temperature sensitivity using power supply ratio against maximum supply potential (in 2010, summer)

3.6 Way of using power supply ratio against population

In the Fig.6, we show the scatter diagram depicting temperature (population weighted mean air temperature by municipalities unit) and power supply ratio against population. The power supply ratio against population is the index that the amounts of electric power supply per thousand people in each electric power district. The results are as follows:

- Way of using power supply ratio against population can standardize the vertical axis index criteria, but it can't standardize the vertical axis numerical value range.
- It is because we thought that population scale varies in both electric power districts like an electricity supply.
- Air temperature sensitivity in high-temperature side in TEPCO is 38.7624[kW/℃] and in HEPCO is 11.6413[kW/℃], and ratio of sensitivity is 0.30 times.
- The coefficient of determination in the approximate line of the scatter diagram in high-temperature side in TEPCO is 0.8557 and in HEPCO is 0.4933. It followed that correlation in TEPCO is almost same in comparison with Fig.2, but in HEPCO slightly increased in comparison with Fig.2.

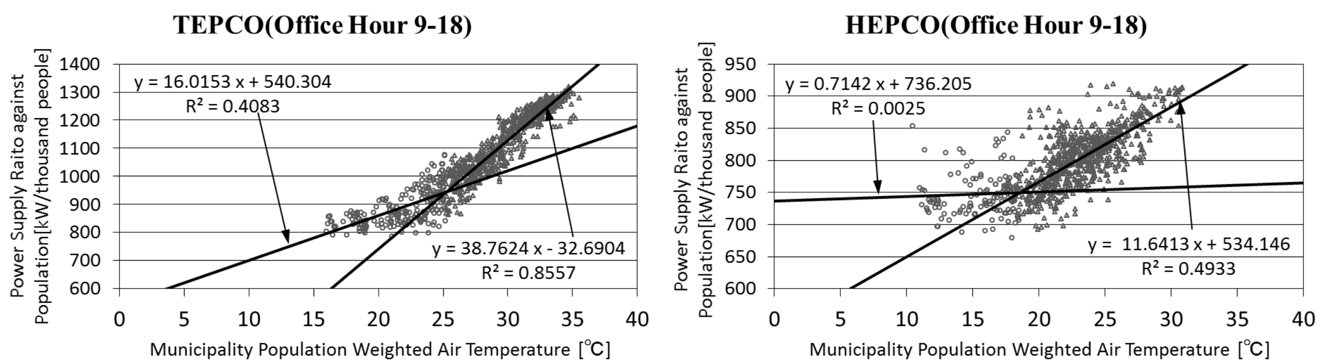

Fig.6 Air temperature sensitivity using power supply ratio against population (in 2010, summer)

3.7 Evaluation of each revision technique

Table 1 Numerical value of each technique

Correction technique			Original	Normalised	Dimensionless	Ratio against max.supply potential	Raito against population
TEPCO	Low temretature side	Air temperature sensitivity	67.9453	0.0459	0.0603	0.0190	16.0153
		Coefficient of determination	0.4144	0.6952	0.1646	0.7111	0.4083
	High temperature side	Air temperature sensitivity	178.6500	0.0826	0.2620	0.0340	38.7624
		Coefficient of determination	0.8558	0.6836	0.8641	0.6428	0.8557
HEPCO	Low temretature side	Air temperature sensitivity	3.4236	0.0285	0.0136	0.0073	0.7142
		Coefficient of determination	0.2030	0.2336	0.0019	0.2129	0.0025
	High temperature side	Air temperature sensitivity	7.4778	0.0574	0.2427	0.0146	11.6413
		Coefficient of determination	0.4445	0.4309	0.4933	0.4328	0.4933
Raito of air temperature sensitivity	Low temretature side	HEPCO/TEPCO	0.0504	0.6209	0.2255	0.3842	0.0446
	High temperature side		0.0419	0.6949	0.9263	0.4294	0.3003

In the Table 1, we show the numerical value in scatter diagram about original date and four correction techniques that we treated in this chapter. The results are as follows:

- The difference between the original data and four correction techniques about the coefficient of determination in the approximate line of the scatter diagram in TEPCO is at maximum 0.2967 and in HEPCO is at maximum 0.2011 in low-temperature side, in TEPCO is at maximum 0.2113 and in HEPCO is at maximum 0.0488. It followed that the difference appears in the correlation by four correction techniques and high or low temperature side.
- In HEPCO area, population weighted mean air temperature by municipalities unit within the target period sometimes become around 10℃, and we can observe the winter air temperature sensitivity. It is one of the factor that coefficient of determination of the approximate line in low-temperature side in HEPCO becomes small.
- Air temperature sensitivity of HEPCO against TEPCO is 5.0% in the low-temperature side and 4.1% in the high-temperature side, and is a low percentage. But by correcting it, it becomes between 4.4% to 62% in low-temperature side and between 30% to 92% in high-temperature side.
- Ratio of air temperature Sensitivity in low-temperature side wasn't almost seen in case of the data that each region of the power supply situation is reflected like original date or way of using power supply ratio against population, but was seen in other correction data.
- In the four correction techniques, way of using normalized electric power supply and way of using dimensionless electric power supply has doubt to consider the degree of leaning of the approximate line after the correction as a temperature response degree because they change the distribution shape of data in a correction process. And way of using power supply ratio against population is greatly affected by each local industry structure and economic activities. We thought that these are the problem.
- Against above, way of using power supply ratio against maximum supply potential can make the correction that reflects the electric power supply status of each electric power district. So, it is the best way for inter-regional comparison in the four correction techniques.
- According to way of using power supply ratio against maximum supply potential, air temperature sensitivity in low-temperature side in TEPCO is 0.0190 and in HEPCO is 0.0073, and high-temperature side in TEPCO is 0.0340 and in HEPCO is 0.0416.It followed that air temperature sensitivity in TEPCO records bigger than that in HEPCO in both temperature side. We considered that it is because difference in the climate conditions and the thermal institution performance of the building.

4. Conclusions

This study revealed the following:
- The difference between "by municipalities unit" and "by town and village unit" population weighted mean air temperature is small in both TEPCO and HEPCO.
- The coefficient of determination in the approximate line of the scatter diagram in high and low temperature side in TEPCO and low-temperature side in HEPCO records different values by the correction techniques, but high-temperature side in HEPCO records roughly between 0.43 to 0.49.
- Considering the influence on the data in the correction process, way of using power supply ratio against maximum supply potential is the best way for inter-regional comparison about air temperature sensitivity of electric power supply in the four correction techniques.
- According to way of using power supply ratio against maximum supply potential, air temperature sensitivity in TEPCO records bigger than that in HEPCO. We considered that it is because regional features like difference in the climate conditions and the thermal institution performance of the building.

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