Estimate of the Electricity-Saving Effects Taking Account of Temperature Change Effects in the Service Areas of Tokyo Electric Power and Tohoku Electric Power

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Summary

Power generation facilities in the service areas of TEPCO(Tokyo Electric Power Company) and Tohoku Electric were significantly damaged by the Great East Japan Earthquake, raising concern over a possible electricity shortage. Starting in March 2011, rolling blackouts were implemented due to an electricity supply capacity shortage, producing a considerable impact on the people's lives. Later, the electricity supply capacity recovered quickly through efforts by electric power companies and other relevant parties, making it possible to do without rolling blackouts through steady electricity-saving efforts. In this paper, we clarify the correlation between temperature and electricity demand based on past records of electricity demand in the service areas of TEPCO and Tohoku Electric and analyze the reduction rate of electricity demand excluding the effects of temperature changes (electricity-saving rate). Based on this analysis, we estimate the net electricity saving effects achieved in the service areas of TEPCO and Tohoku Electric.

The analysis results show that the government's electricity-saving target of a 15% reduction compared with the previous year has mostly been attained in the service areas of both TEPCO and Tohoku Electric. The results also show that the effects of temperature changes were greater in July and August than in June and that the effects were greater in the service area of TEPCO than in the service area of Tohoku Electric. The electricity-saving rate excluding the effects of temperature changes is estimated at approximately 13% to 15% in the peak hours in June, July and August in the service areas of both TEPCO and Tohoku Electric, indicating that electricity-saving efforts have been effective in reducing demand. In the service area of Tohoku Electric in particular, the effects of the temporary shutdown of factories as well as the effects of electricity-saving efforts can be observed. However, given the possibility of unpredictable emergencies such as an unexpected temperature upsurge and a power plant accident, electricity-saving efforts should be maintained for the moment.

1. Changes in electricity demand and temperature

Figures 1-1 and 1-2 show hourly changes in temperature and electricity demand in June through the end August 2011 in the service areas of TEPCO and Tohoku Electric. In June through August, both temperature and electricity demand rose gradually. The figures also indicate that there is some correlation between temperature and electricity demand. As the absolute level of electricity demand was lower than the peak supply capacity in the service areas of both TEPCO and Tohoku Electric, rolling blackouts had not been implemented this summer as of the end of August thanks to the effects of steady electricity-saving efforts.

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Figure 1-1 TEPCO

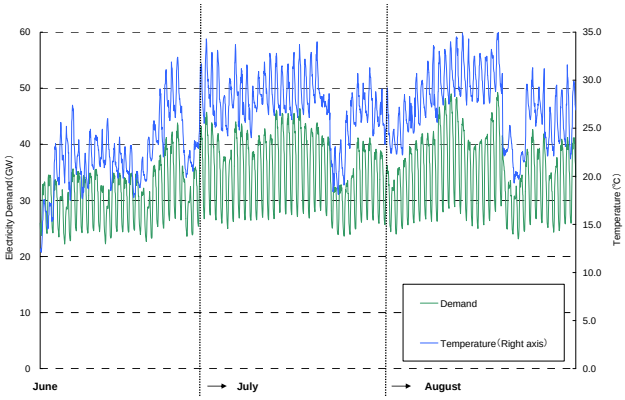
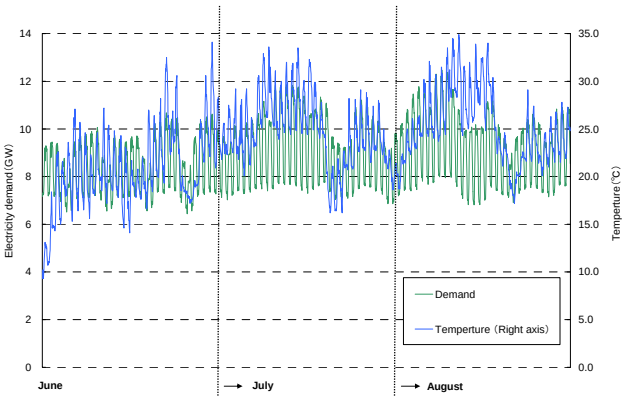


Figure 1-2 Tohoku Electric



Source : TEPCO, Tohoku Electric, Japan Meteorological Agency.

Note; The area of TEPCO refers the temperature in Tokyo as the representative of temperature in that Area. The area of Tohoku Electric refers the temperature in Sendai.

In the following chapters, we clarify the relationship between temperature and electricity demand based on past records of electricity demand and temperature in the service areas of TEPCO and Tohoku Electric in June, July and August, analyze the reduction rate of electricity demand excluding the effects of temperature changes (electricity-saving rate) and estimate the net electricity-saving effects achieved in the service areas of TEPCO and Tohoku

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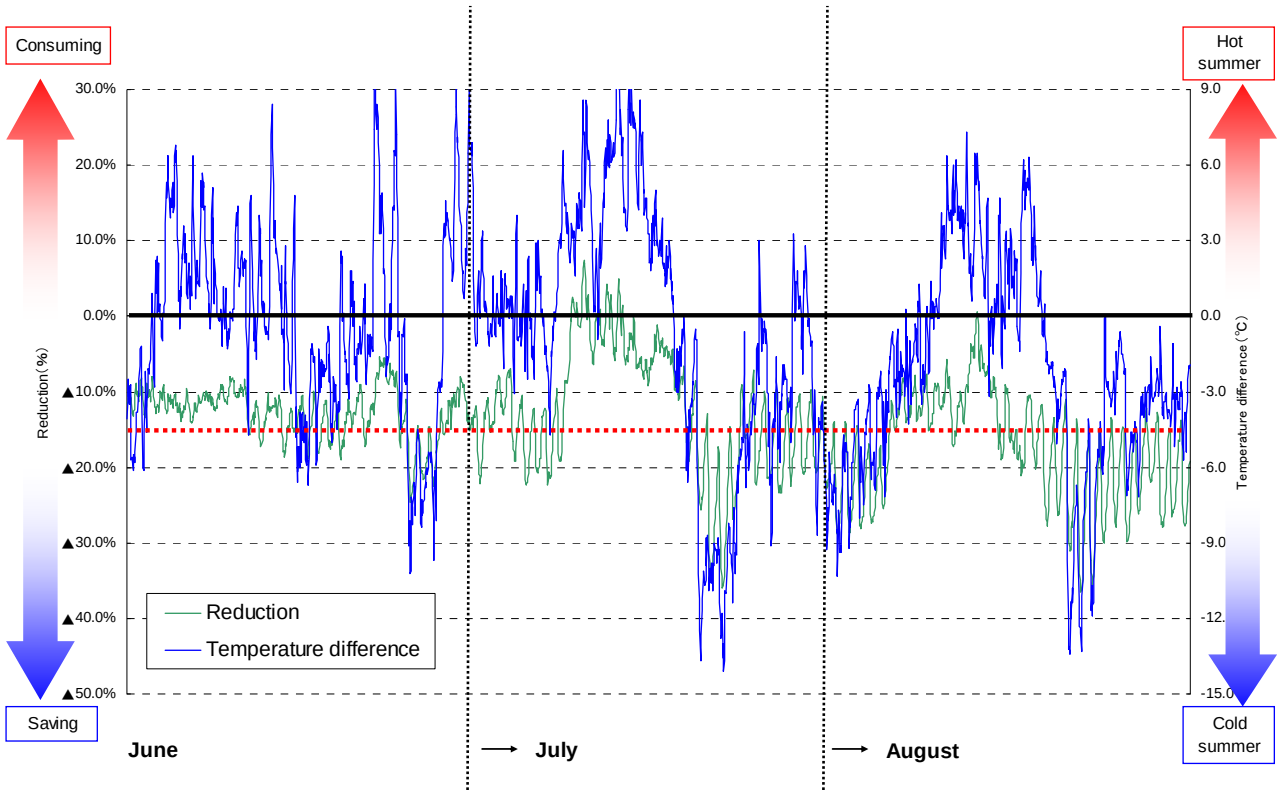
2. Year-on-year temperature changes and the reduction rate of electricity demand

In this chapter, we show how much electricity demand was reduced compared with the same day of the same month of the previous year (year-on-year reduction rate of electricity demand). Since there is some correlation between electricity demand and temperature as was mentioned in the previous chapter, we show the relationship between temperature changes and the reduction rate by indicating year-on-year temperature changes alongside the reduction rate.

2-1 In the service area of TEPCO

Figure 2-1 shows that the government's electricity-saving target of a 15% reduction has mostly been attained with regard to electricity demand in the service area of TEPCO. It also shows that there is a correlation between year-on-year temperature change and the reduction rate of electricity demand. In late July and late August in particular, electricity demand dropped sharply on a year-on-year basis in line with a steep year-on-year temperature drop. This presumably reflects a sharp decline in the use of air conditioners, which is susceptible to temperature change.

Figure 2-1 The temperature difference and the reduction of electricity demand over the previous year (TEPCO) (June-August)

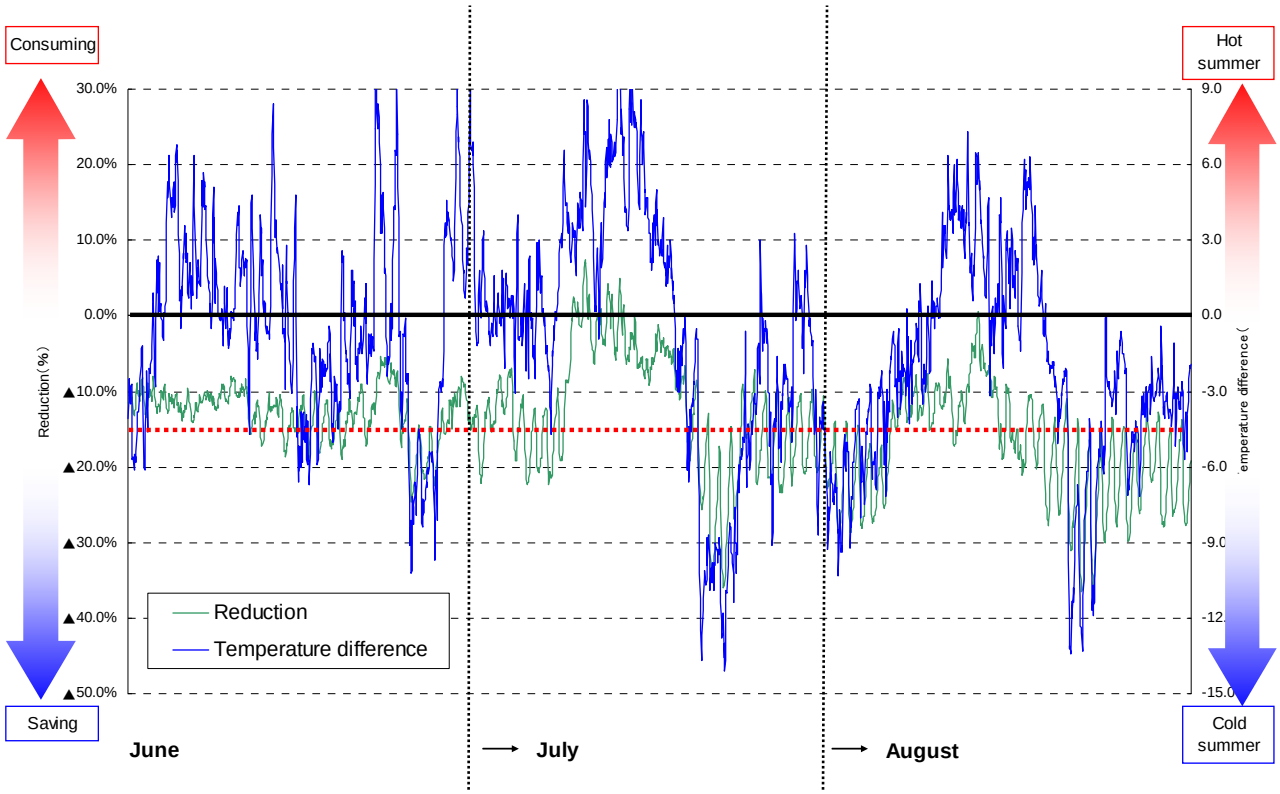


Source : TEPCO, Japan Meteorological Agency.
Note : The red line in the Figure shows the 15% reduction.

2-2 In the service area of Tohoku Electric

Figure 2-2 shows that the government's electricity-saving target of a 15% reduction has mostly been attained with regard to electricity demand in the service area of Tohoku Electric, too. It also shows that there is a correlation between year-on-year temperature change and the reduction rate of electricity demand, just as there was in the service area of TEPCO. In mid-July, the reduction rate of electricity demand declined sharply while electricity demand registered a year-on-year rise on some days, as the temperature was 5 degrees to 6 degrees Celsius higher on a year-on-year basis, with temperatures of above 30 degrees Celsius recorded for several consecutive days. In late July and late August, electricity demand registered a steep year-on-year decline due to a drop in demand for air conditioning as the temperature was far lower on a year-on-year basis, just as there was in the service area of TEPCO.

Figure 2-2 The temperature difference and the reduction of electricity demand over the previous year (Tohoku Electric) (June-August)



Source : Tohoku Electric, Japan Meteorological Agency.
Note : The red line in the Figure shows the 15% reduction.

As described above, electricity demand was reduced significantly in the service areas of both TEPCO and Tohoku Electric. Meanwhile, it is difficult to estimate the net electricity demand reduction effects achieved by various electricity-saving measures, because the reduction rate reflects the effects of weather factors such as temperature changes.

In the next chapter, we will clarify the correlation between temperature and the reduction rate and estimate the reduction rate of electricity demand excluding the effects of temperature changes.

3. Correlation between temperature and the electricity demand reduction rate by time of day

Generally speaking, there is a significant correlation between electricity demand and temperature. The correlation between electricity demand and temperature is expressed as temperature sensitivity, which indicates how much electricity demand changes in response to a one degree change in temperature. According to an estimate by Nishio (2011), the daytime temperature sensitivity in the service area of TEPCO in 2010 was approximately 3%. In this chapter, we will estimate the temperature sensitivity in the service areas of TEPCO and Tohoku Electric this summer based on the analysis of the correlation between temperature and electricity demand. We will also estimate the reduction rate of electricity demand and the net electricity saving rate excluding the effects of temperature changes by using the temperature sensitivity as a basis of the estimate.

3-1 In the service area of TEPCO

Figures 3-1 to 3.6 show the distribution of year-on-year temperature changes and the reduction rates of electricity

demand in the peak hours (9 a.m. to 8 p.m.) and off-peak hours (9 p.m. to 8 a.m.) in June, July and August. These figures indicate a significant correlation between temperature change and the reduction rate of electricity demand. In this paper, by expressing the correlation between the two as a first approximation, we formularize the correlation. In this case, the gradient of the first approximation formula corresponds to the temperature sensitivity and the intercept of the formula corresponds to the net electricity-saving rate.

Figure 3-1 Correlation of between temperature difference and reduction （9 a.m.-8 p.m.） （June）

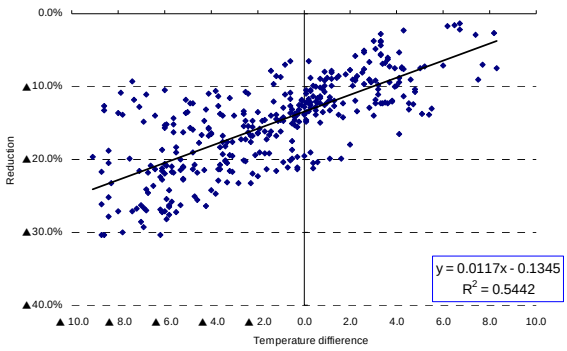


Figure 3-2 Correlation of between temperature difference and reduction （9 p.m.-8 a.m.） （June）

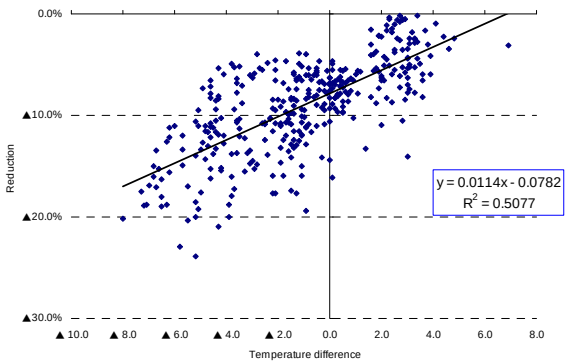


Figure 3-3 Correlation of between temperature difference and reduction （9 a.m.-8 p.m.） （July）

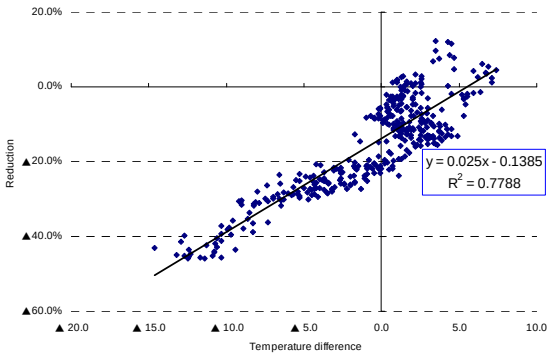


Figure 3-4 Correlation of between temperature difference and reduction （9 p.m.-8 a.m.） （June）

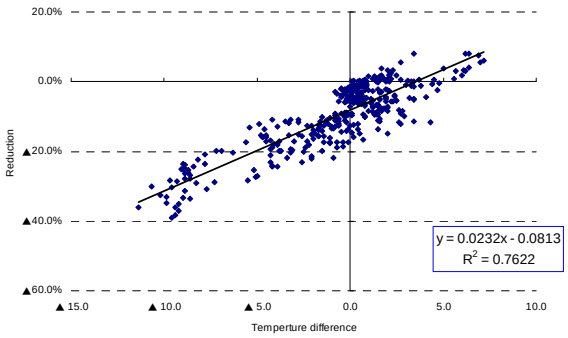


Figure 3-5 Correlation of between temperature difference and reduction （9 a.m.-8 p.m.） （August）

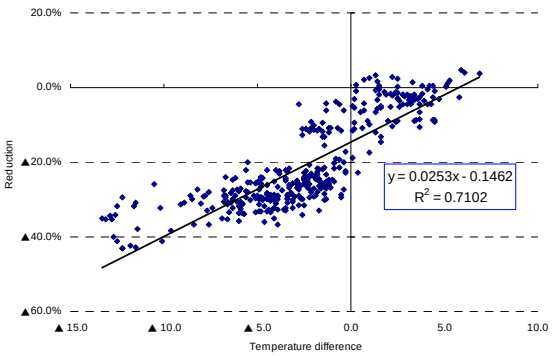
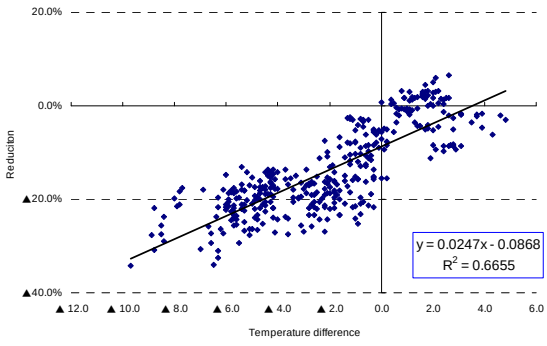


Figure 3-6 Correlation of between temperature difference and reduction （9 p.m.-8 a.m.） （August）



The contents of the above figures are summarized in Table 3-1.

Table 3-1 Temperature sensitivity and electricity demand reduction in the area of TEPCO

	June		July		August	
	Temperature Sensitivity	Reduction	Temperature Sensitivity	Reduction	Temperature Sensitivity	Reduction
Peak (9 a.m.-8 p.m.)	1.17%/℃ (0.48GW)	13.5% (15.0%)	2.50%/℃ (1.18GW)	13.9% (15.9%)	2.53%/℃ (1.25GW)	14.6% (20.6%)
Off peak (9 p.m.-8 a. m.)	1.15%/℃ (0.35GW)	7.82% (9.0%)	2.32%/℃ (0.78GW)	8.13% (9.7%)	2.47%/℃ (0.87GW)	8.68% (13.8%)

Note : Upper numbers in reduction column are estimated electricity demand reduction ration excluding temperature effect. Lower numbers in parentheses are actual electricity demand reduction ratio.

Table 3-1 shows a wide difference between the level of temperature sensitivity in June and the levels in July and August. That is presumably because the absolute level of temperature in July and August is higher than in June, as a result of which more people used air conditioning in response to a one degree rise in temperature in July-August than in June, leading to a higher level of temperature sensitivity. On the other hand, the reduction rate of electricity demand excluding the effects of temperature changes in the peak hours is estimated at 13% to 15% in June, July and August, indicating that the government's electricity-saving target has mostly been attained. In particular, on July 1, the governmental order for the restriction of electricity usage entered force and a rotating holiday system was introduced by various industries, and as a result, the reduction rate in July and August was higher than the reduction rate in June. In mid-July and later, electricity demand was reduced sharply, with the overall reduction rate of electricity demand that reflects the effects of temperature changes exceeding 15% in the peak hours in mid-July and later, since the temperature remained lower than in the previous year on many days as shown in Figure 2-1.

3-2 In the service area of Tohoku Electric

As in the case of the service area of TEPCO, we show the correlation between temperature change and the reduction rate of electricity demand in the figures below.

Figure 3-7 Correlation of between temperature difference and reduction (9 a.m.-8 p.m.) (June)

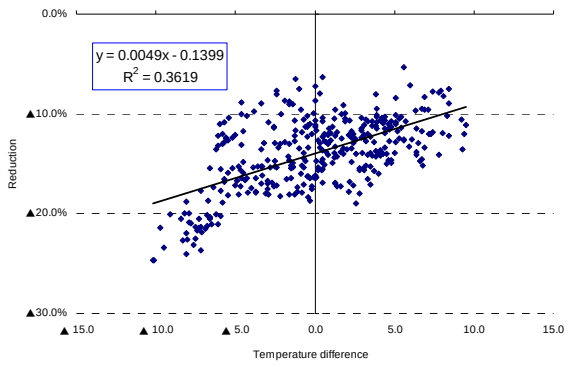


Figure 3-8 Correlation of between temperature difference and reduction (9 p.m.-8 a.m.) (June)

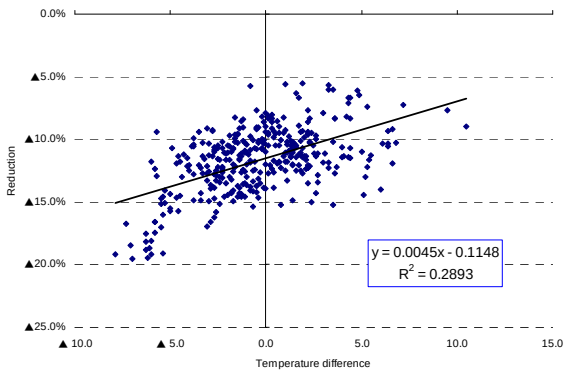


Figure 3-9 Correlation of between temperature difference and reduction （9 a.m.-8 p.m.） （July）

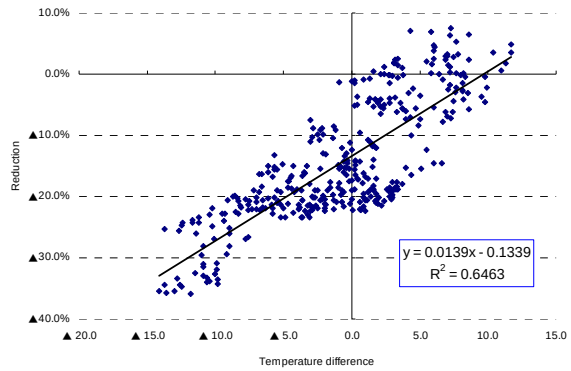


Figure 3-10 Correlation of between temperature difference and reduction （9 p.m.-8 a.m.） （July）

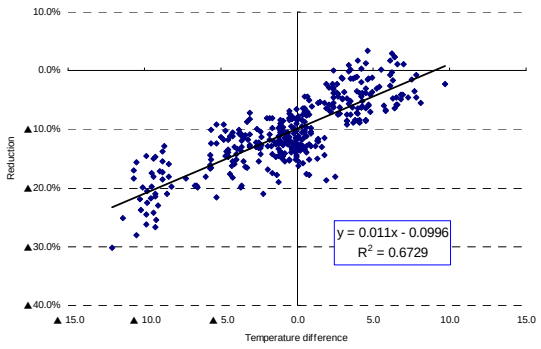


Figure 3-11 Correlation of between temperature difference and reduction （9 a.m.-8 p.m.） （August）

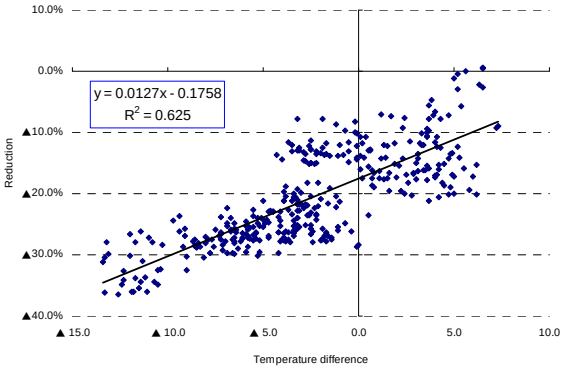


Figure 3-12 Correlation of between temperature difference and reduction （9 p.m.-8 a.m.） （August）

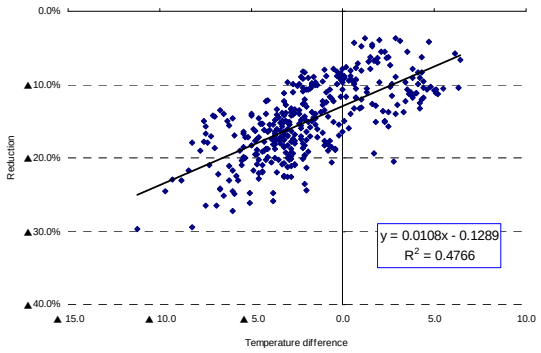


Table 3-2 Temperature sensitivity and electricity demand reduction in the area of Tohoku Electric

	June		July		August	
	Temperature Sensitivity	Reduction	Temperature Sensitivity	Reduction	Temperature Sensitivity	Reduction
Peak (9 p.m.-8 a. m.)	0.49%/℃ (0.05GW)	14.0% (15.0%)	1.39%/℃ (0.17GW)	13.4% (14.5%)	1.27%/℃ (0.16GW)	17.6% (20.8%)
Off peak (9 p.m.-8 a. m.)	0.45%/℃ (0.04GW)	11.5% (11.7%)	1.10%/℃ (0.10GW)	10.0% (10.5%)	1.08%/℃ (0.10GW)	12.9% (14.8%)

Note : Upper number in reduction column are estimated electricity demand reduction ration excluding temperature effect. Lower number in parentheses are actual electricity demand reduction ratio.

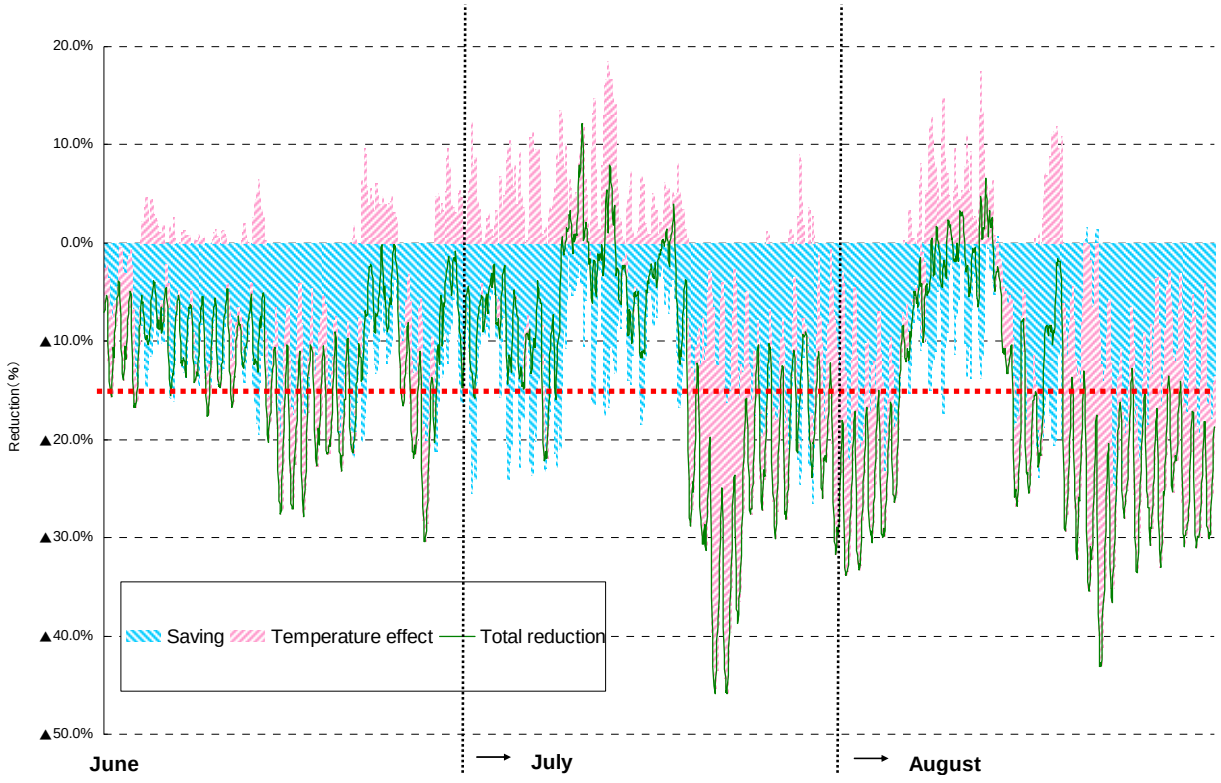
Table 3-2 shows that there are wide differences between the temperature sensitivity level in June and the level in July and August in the service area of Tohoku Electric, too. The reduction rate of electricity demand excluding the effects of temperature changes (electricity saving rate) in the peak hours is estimated at approximately 13% to 18% in June, July and August, indicating that the government's electricity-saving target has mostly been attained. On a monthly basis, the reduction rate in July was slightly lower than the reduction rate in June. That is presumably because round-the-clock

factories that had been shut down in June were restarted in July, leading to a decrease in the reduction rate in off-peak hours, as shown by a sharp decline in the reduction rate in off-peak hours in July compared with June. This suggests that factories damaged by the earthquake disaster are being restored and the people's lives are returning to normal gradually in the service area of Tohoku Electric. Meanwhile, the electricity saving rate in August was far higher than in July. That is presumably due to a year-on-year decrease in the number of people who returned to their hometowns in the Tohoku region during the *bon* holiday season in August, reflecting the impact of the Great East Japan Earthquake. The overall reduction rate of electricity demand that reflects the effects of temperature changes exceeded 15% in the peak hours in July and later, as the temperature remained lower than in the previous year on many days as shown in Figure 2-2.

4. Breakdown of factors

Below, based on the above analysis, we will break the factors behind the hourly electricity demand reduction rate in June, July and August down into temperature factors and other factors, mainly electricity-saving efforts, and analyze the electricity saving efforts in the services areas of TEPCO and Tohoku Electric. Figure 4-1 represents the results of the breakdown of factors regarding the service area of TEPCO.

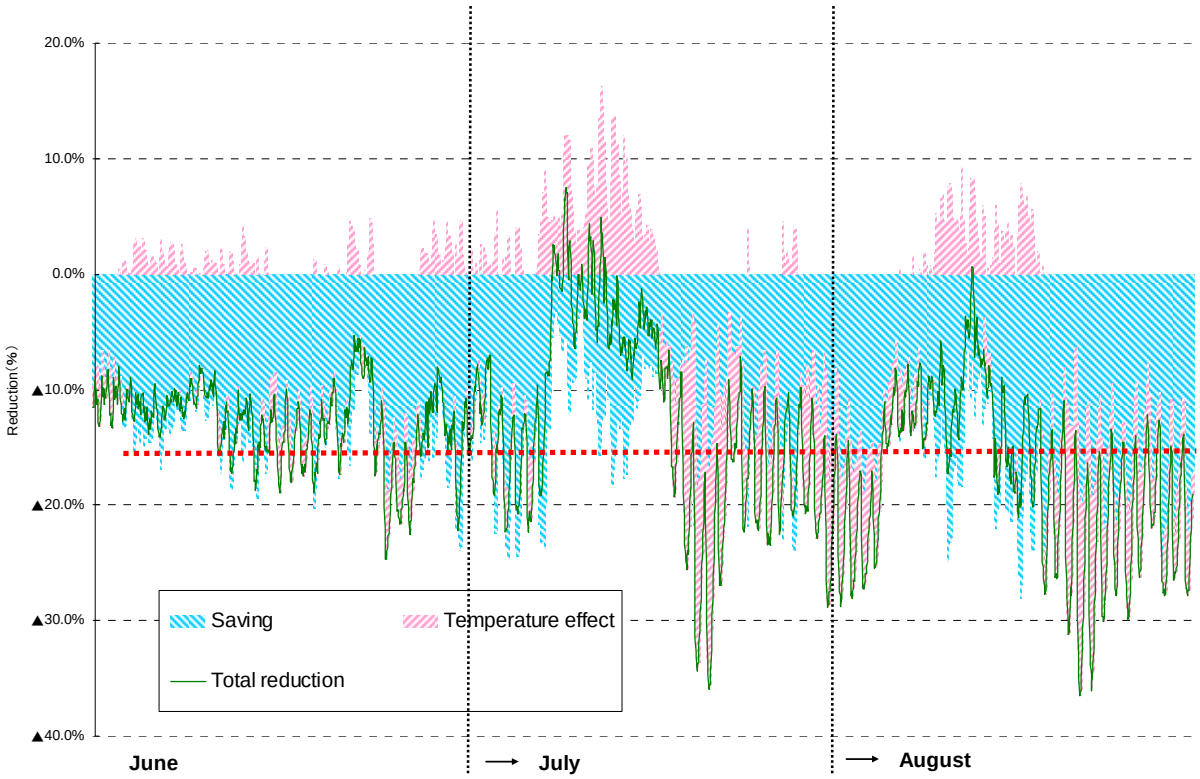
Figure 4-1 The breakdown of factors (TEPCO) (June-August)



Note : The red line in the Figure shows the 15% reduction.

Figure 4-1 shows that the peak-hour electricity-saving rate excluding the effects of temperature changes in the service area of TEPCO is close to the target rate of 15%, indicating that efforts by various relevant parties have yielded results. On the other hand, the figure shows that when the temperature rose sharply, the overall electricity-saving rate declined significantly despite electricity-saving efforts. In particular, when the temperature was high on a holiday, the electricity-saving rate tended to decline. From this, we may presume that considerable electricity-saving effects were achieved on weekdays, with the electricity-saving rate in the commercial sector at a particularly high level.

Figure 4-2 The breakdown of factors (Tohoku Electric) (June-August)



Note : The red line in the Figure shows the 15% reduction.

Figure 4-2 shows that the peak-hour electricity-saving rate excluding the effects of temperature changes in the service area of Tohoku Electric, too, is close to the target rate of 15%. As in the service area of TEPCO, the reduction rate tended to decline when the temperature was high. In the service area of Tohoku Electric, the estimated rate of electricity demand reduction due to electricity-saving efforts was approximately 10% in early June regardless of the time of the day. This apparently reflects the impact of the temporary shutdown of factories that would have operated around the clock in usual years as well as the effects of electricity-saving efforts. In August, the rate of reduction due to electricity-saving efforts exceeded 20% sometimes, particularly during the *bon* holiday season. That is presumably due to a decrease in the number of people who returned to their hometowns in the Tohoku region, which apparently reflects the huge impact of the earthquake disaster.

Figure 4-3 The demand reduction rate by time of day (TEPCO) (June)

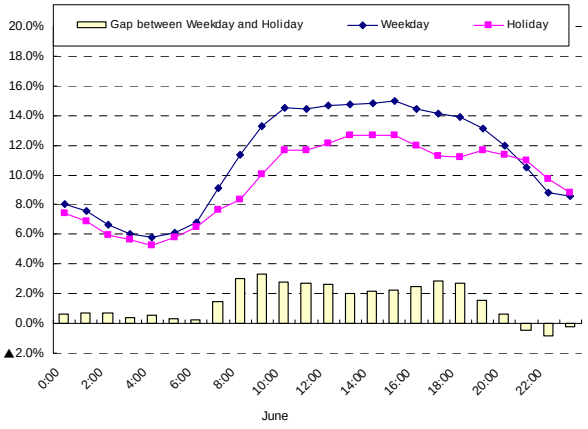


Figure 4-4 The demand reduction rate by time of day (TEPCO) (July)

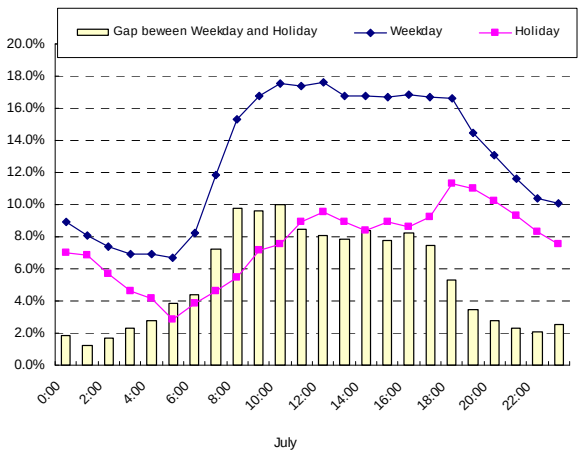


Figure 4-5 The demand reduction rate by time of day (TEPCO) (August)

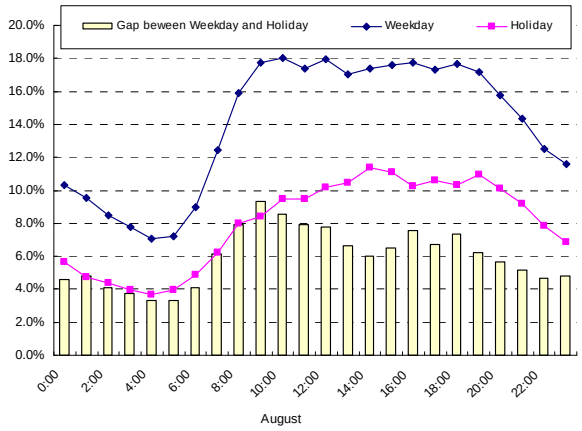


Figure 4-3. 4-4 and 4-5 show that the demand reduction rate in daytime is larger than that in night time. They are also larger in weekday than holiday. They are similar to the load curve of electricity. This results show that the demand reduction rate should have correlation with the amount of electricity demand in each time. There is a huge electricity saving potential in the daytime when many people use much electricity. In daytime, many people were expected to their best to cut the demand. We must analysis the characteristics of energy saving potential in each time and each section and take more effective measures to promote further electricity saving for the future.

5. Conclusion and towards the future

Ahead of September, the Ministry of Economy, Trade and Industry announced that the restriction on electricity usage by large customers, which was imposed under Article 27 of the Electricity Business Act, would be lifted in the disaster-stricken areas on September 2 and in the service area of TEPCO on September 9. This was in response to an improvement in the electricity supply-demand balance in those areas. However, given the possibility of unpredictable emergencies such as an unexpected temperature upsurge and a power plant accident, a reasonable level of electricity-saving efforts should be maintained for the moment. Meanwhile, it deserves high appreciation that the government's electricity-saving target of a 15% reduction in electricity demand for this summer is likely to have mostly been attained through efforts by the government and other relevant parties. In the future, we will conduct a more detailed analysis of sector-by-sector electricity-saving efforts by applying a macro-approach analysis to the electricity demand reduction rate in each sector based on the analysis in this paper.

While the impact of the earthquake disaster is apparently multifaceted, we will be able to acquire useful clues for future energy-saving policies by looking at the electricity-saving efforts made on a massive scale this summer as an example of a major electricity-saving initiative in the Tokyo metropolitan area and by conducting a detailed review and analysis of the processes of drafting of energy-saving plans and implementation of the plans and the impact of the plans on a sector-by-sector basis.

· References

(1) Website of TEPCO: http://www.tepco.co.jp/forecast/html/download-j.html

(2) Website of Tohoku Electric: http://setsuden.tohoku-epco.co.jp/download.html

(3) Website of the Japan Meteorological Agency: http://www.jma.go.jp/jma/index.html

(4) Kenichiro Nishio, "*Setuden wa susundeirunoka? ― Tokyo denryoku kannai ni okeru jyuyogenshouryo no shisan*" ("Are Electricity-Saving Efforts Making Headway? ― Estimate of a Demand Drop in the Service Area of TEPCO") (2011).