Saving Electricity in a Hurry: A Japanese Experience after the Great East Japan Earthquake in 2011

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ABSTRACT

The Great East Japan Earthquake in March 2011 brought about huge power shortage. In order to avoid blackouts, the Japanese society reduced its power demand by 12 % in the summer of 2011. TOKYO and TOHOKU areas, where power shortage was especially severe and mandatory rationing of 15 % was introduced, reduced its power demand by almost 20 %. This paper gives overview of the power saving activities in Japan after the Earthquake, and analyzes how Japanese industry achieved such dramatic demand reduction. Results are based on the questionnaire survey we conducted after the summer 2011. We estimate that more than 70 % the demand reduction in the commercial sector was achieved by limiting use of lighting and air-conditioning, while in large industrial firms 40 % of the demand reduction was by increasing in-house power generation, and 30 % by shifting hour of operation. We also report preliminary findings of the follow-up survey conducted after the summer of 2012, and discuss some implications for persistent savings.

Introduction

Most industrialized nations now have well-developed, reliable power systems. However, there is always a possibility of sudden power shortage. The sources of shortage vary widely. They may be major technical failures, severe weather, or other environmental incidents. Indeed, electricity shortfalls have occurred in almost every part of the world because of various causes (IEA 2005; Meier 2009; Pasquier 2011). When such incidents should happen, regions have to reduce electricity demand in a very short period of time to avoid blackouts.

This paper examines Japanese the experience of power saving activities after the Great East Japan Earthquake that occurred in 11 March 2011. Due to the damages to the power systems, as well as shutdowns of nuclear power plants after the Fukushima Daiichi nuclear disaster, Japan has been facing a severe electricity shortfall. In order to avoid blackouts, the government initiated a power-saving strategy, including an intensive information campaign and a mandatory rationing scheme for large customers in the TOKYO and TOHOKU areas. As a result of those efforts, Japan reduced its power demand by 12 % in summer 2011.

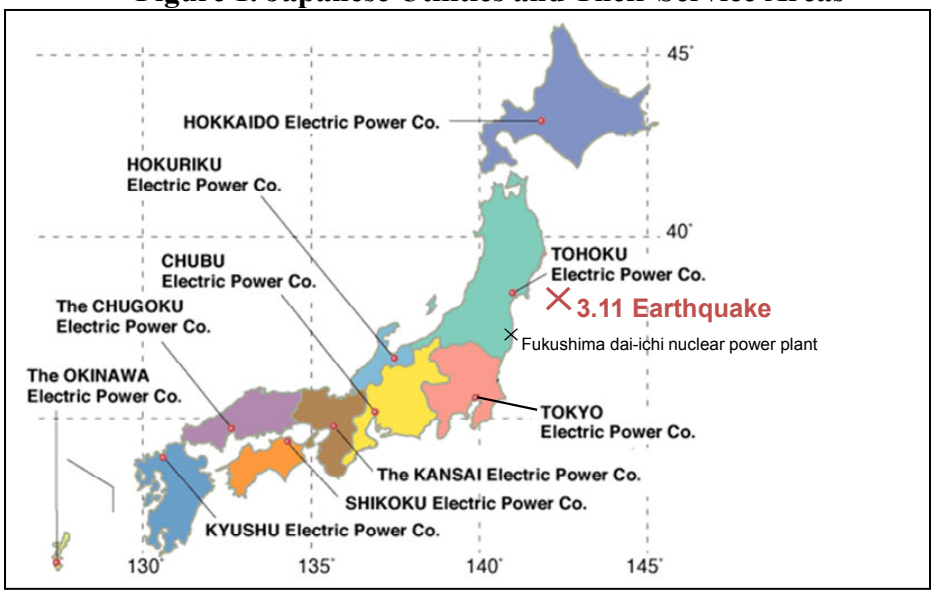
The objective of this paper is to analyze how this large reduction of electricity demand was achieved and to discuss some policy implications. In spite of the great magnitude of the demand reduction and the efforts by the Japanese society, the experience has been rarely reported in the international literature. Since the magnitude of power shortage as well as achieved demand reduction in summer 2011 in Japan is among the largest in the reported cases (IEA 2005; Pasquier 2011), it should have important implications for many countries. The paper focuses on industrial and commercial sectors. Electricity saving activities in residential sector is reported in (Nishio and Ofuji 2012). Based on a questionnaire survey conducted after 2011 summer, the paper investigates achieved demand reduction, implemented measures, and impact

to business activities in the TOKYO and TOHOKU areas. In the last section of the paper preliminary findings of the follow-up survey conducted after summer 2012 is also reported to discuss persistency of power saving activities.

Overview of Power Shortage and Demand Reduction in 2011 Summer

The Earthquake caused extensive damages to power stations and transmission grids along the Pacific coast in service areas of TOHOKU and TOKYO Electric Power Companies (see Figure 1). It was estimated that over 27 GW in the two areas was out of service by 21 March 2011, 10 days after the Earthquake (IEEJ 2011). In the TOKYO area, rolling blackouts were implemented from March 14 for two weeks. In April the situation was eased as the weather became warmer and power supply recovered. Still, it was expected that the TOKYO and TOHOKU areas would be short of their electricity supply by 7 and 10 percent, respectively, in the peak period of summer (Electricity Supply-Demand Emergency Response Headquarters 2011).

Figure 1. Japanese Utilities and Their Service Areas



Source: adopted from (FEPC 2012) with modification.

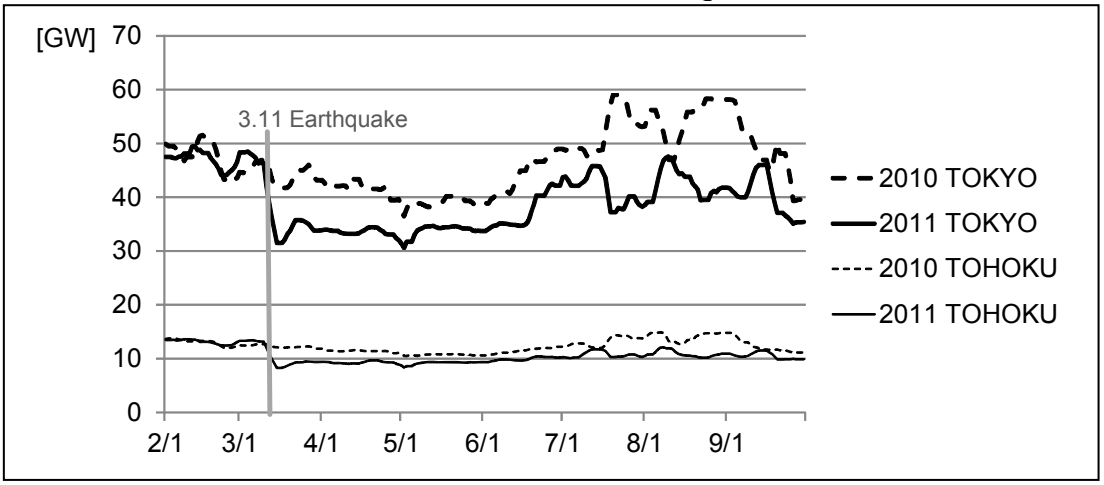
In May 2011 the government established an emergency action plan to save electricity for summer 2011. The numerical targets of demand reduction compared to the 2010 summer level were set as 15 percent for the TOHOKU and TOKYO areas, and 10 percent for the KANSAI area. No target was set for the other areas. While the 10 percent target of the KANSAI area was voluntary, the 15 percent target of the TOHOKU and TOKYO areas was mandatory for large customers with contract demand of more than 500 kW, based on Article 17 of Electricity Business Act (Power Saving Order). Those large firms had to cut electricity demand by 15 percent in the period of 9 am to 8 pm, 1 July to 22 September, compared to the same period of the previous year. In case of intentional non-compliance to the Power Savings Order up to one million JPY (approximately 12,000 USD) would be fined. The government also launched initiatives to raise public awareness and reduce demand of small customers, such as an intensive public campaign, voluntary agreements, and technical assistance (Yamashita 2011).

As a result of extraordinary efforts by all sectors, a remarkable demand reduction was achieved. Electricity demand after the Earthquake through summer 2011 in two regions kept below the level of the previous year by more than 15 percent on average in the TOKYO and TOHOKU areas (Figure 2). Estimation of sectoral demand reduction reveals that not only large customers with mandatory targets but also small customers and households made important contribution in reducing electricity demand (Table 1).

Figure 3 shows how daily and weekly demand curves in TOKYO have changed after the Earthquake. In summer 2011, demand was reduced even in off-peak hours and in weekends, while demand reductions in peak-hours (9 am to 8 pm) and in weekdays was larger than in off-peak hours or in weekends. Although demand shift measures were widely implemented among large industrial plants, as is discussed later in this paper, they were not popular in buildings and households and thus had limited impact at the grid level in TOKYO.

It should be noted that there was basically *no* change of electricity price in 2011, excluding fuel cost adjustments. Only TOKYO Electric Power Company (TEPCO) has raised electricity rates by 17 percent for commercial users since April 2012, and by 8 percent for households since September 2012. Other power companies are still either under governmental screening process or under consideration, as of March 2013.

Figure 2. Trend of Electricity Demand in Weekdays in TOKYO and TOHOKU Areas, Before and After the Earthquake



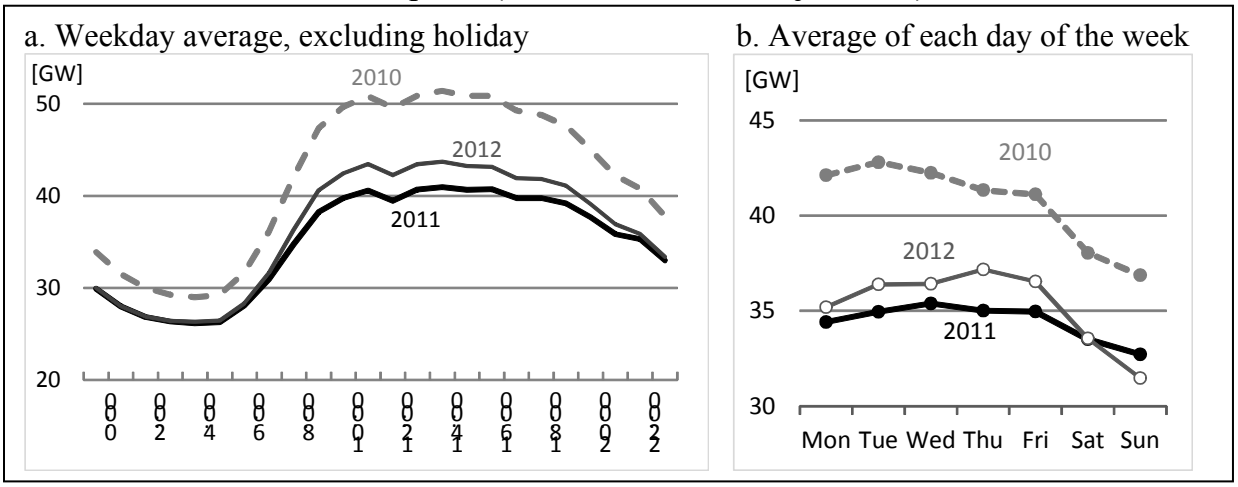
Notes: The lines show moving one-week averages of daily peak demand of weekdays in 2010 and 2011 in TOKYO and TOHOKU areas. Data is from websites of TOKYO and TOHOKU Electric Power Companies.

Table 1. Estimation of Electricity Demand Reduction by Sector in Summer 2011 Compared to 2010 Summer Levels (Weather-Adjusted)

		TOKYO	TOHOKU	KANSAI
Target		- 15 %	- 15 %	- 10 % or more
Results		- 19 %	- 18 %	- 8 %
	Large customers	- 27 %	- 18 %	- 9 %
	Small customers	- 19 %	- 17 %	- 10 %
	Households	- 11 %	- 18 %	- 4 %

Note: Large/small customers mean those with a contract demand of more/less than 500 kW in commercial and industrial sectors. Source: METI (2011).

Figure 3. Average Electricity Demand in TOKYO Area in Summer, Before and After the Earthquake (Without Weather-Adjustment)



Notes: Average demands from July to September in respective years are presented.
Data is from website of TOKYO Electric Power Companies.

Research Questions and Survey Design

Seeing the large demand reduction in summer 2011, it is important to understand how such savings were achieved in detail and to examine what lessons can be learned from the experience. For that purpose we conducted a questionnaire survey to 27,830 firms all over Japan excluding the OKINAWA area (see Figure 1). The survey period was November to December, 2011. The survey was designed so as to answer the research questions that follow.

RQ1: By what measure did firms reduce their electricity demand? The major task of our survey is to understand what measures were implemented to save electricity in summer 2011 in detail. We also conducted interview surveys with more than 20 firms before and after the summer, which revealed that the major part of demand reduction was achieved by a limited number of measures, such as limit of lighting/air-conditioning, shift to off-peak, and increase of in-house power generation. Therefore the survey focuses on those key measures.

RQ2: Were there any progress in energy efficiency activities after the Earthquake? In this paper, *emergency* measures are differentiated from *efficiency* measures (Table 2). An important difference between them is that emergency measures have adverse effects on firms' activities, while efficiency measures not. For example, limiting use of lighting and air-conditioning basically undermines amenity, which may lead to lower productivity. While emergency measures have an indispensable role in saving electricity in a hurry, efficiency measures should also be promoted where possible in order to avoid negative effect. Furthermore, increasing energy efficiency is a requisite in reducing firms' electricity cost and emission of carbon dioxide. Indeed, electricity crisis can provide a good momentum to promote energy efficiency activities from a longer perspective.

RQ3: How negative was the effect of saving electricity? The major objective of saving electricity is to avoid blackouts that would cause huge costs to the society. However, emergency measures also have negative effect as explained above. This fact cannot be neglected, especially

when the electricity shortfall is prolonged as is the case with Japan after the Earthquake. Also, this is relevant because the degree of negative effect would affect the persistency of savings. For example, electricity saving activities that are costly or undermine productivity would not be persisted after the crisis.

Table 2. Measures to Save Electricity

Category	Sub category	Examples
Emergency measures	Reduce use/activity	- Limit use of lighting and air-conditioning. - Reduce production/operation.
	Shift to off-peak	- Shift hours of operation to mid-night, early-morning, or off-peak seasons.
	Fuel switching	- Introduce in-house power generators. - Introduce engine-driven compressors.
Efficiency measures	Improve operation and maintenance	- Optimize operation of equipment. - Housekeeping and maintenance.
	Investment	- Introduce heat recovery systems, inverters etc. - Replace with high-efficiency equipment.

Survey Results: How Firms Cut Electricity Demand in Summer 2011

We received 6,262 responses (22.5 percent response rate), of which 3,658 samples from the TOKYO and TOHOKU areas are analyzed in this section. Full length reports including the complete survey results are available as research reports in Japanese (Kimura et al. 2012; Kimura 2012; Kimura and Nishio 2013).

Estimated Demand Reduction and Its Breakdown by Measure

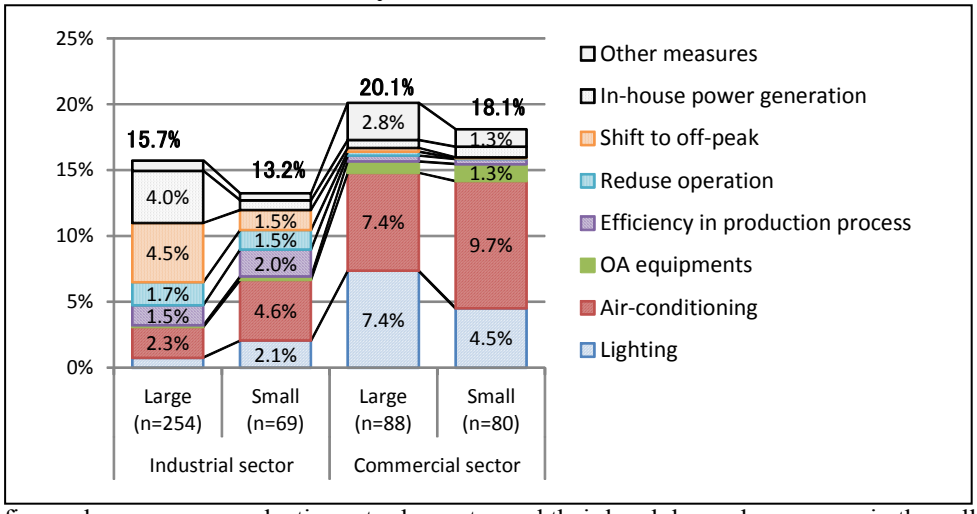
Peak demand reductions of the samples in the TOKYO and TOHOKU areas in summer 2011 were approximately 15 percent in industrial sector and 20 percent in commercial sector (Figure 4). It is estimated that more than 70 percent the demand reduction in the commercial sector was achieved by limiting use of lighting and air-conditioning. This result is consistent with the fact that in offices and stores the major share of electricity consumption is in lighting and air-conditioning. In large industrial firms, 40 percent of the demand reduction was estimated to be achieved by increasing in-house power generation, and 30 percent by shifting hour of operation. Breakdown of demand reduction in small firms showed an intermediate feature between large firms and commercial buildings.

Implemented Measures

Lighting and air-conditioning equipment. Implementation rates of measures that are classified as *emergency* ones were quite high as a whole (Figure 5). Reducing the number of lamps, which is called "thin out lightings" in Japan, became very popular after the Earthquake. Reduction rates of lamps in working areas averaged 17.3 percent in industrial plants, 26.0 percent in office buildings, and 23.6 percent in other commercial facilities. Another popular measure was raising cooling temperature settings. The average temperature setting in office buildings was raised from 26.0 degree C to 27.6 degree C in summer 2011. This is partly because of the success of so-called "Cool-Biz" campaign in Japan, which has been promoted by the government since 2005, advising firms to set cooling temperature at 28 degree C to reduce electricity consumption.

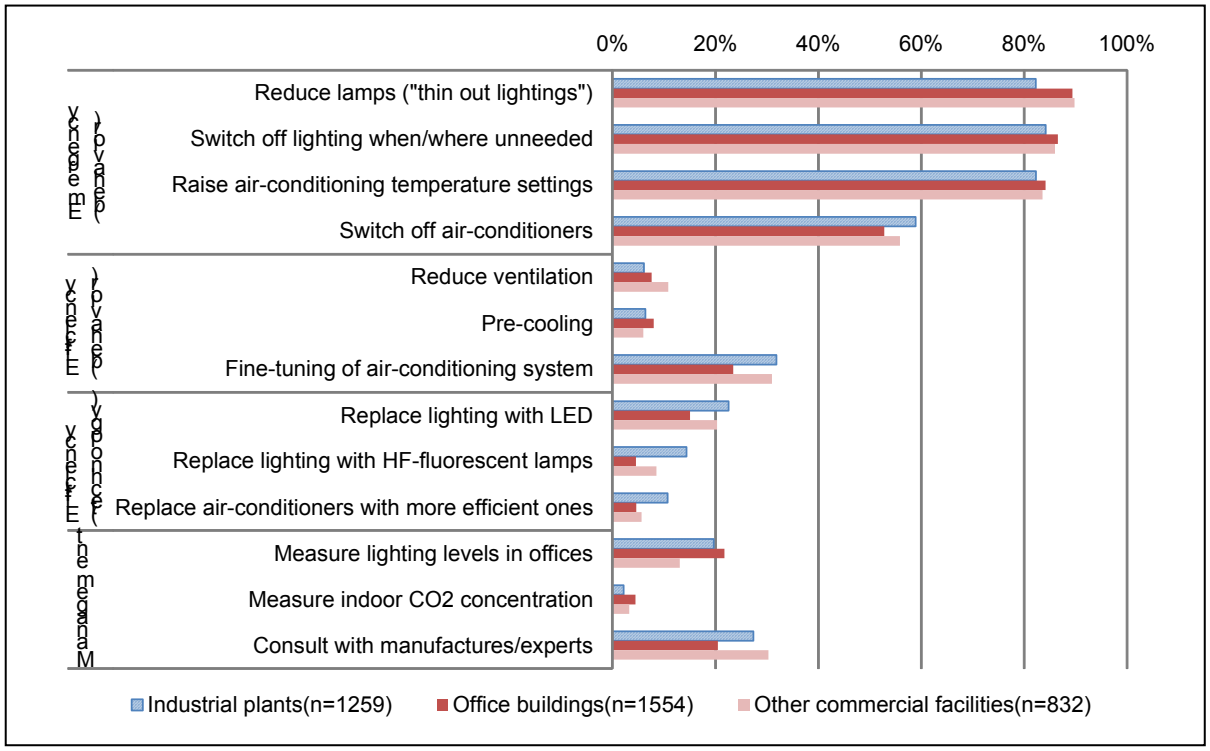
On the other hand, implementation rates of *efficiency* measures were rather low, regardless of whether behavioral or technological. Reducing ventilation is considered to be a very effective measure in reducing air-conditioning demand without compromising amenity because many buildings are over-ventilated because of lack of proper control (Kimura 2011). However, less than 10 percent implemented the measure. Management practices such as measuring lighting levels and indoor CO2 concentration are also important for proper lighting/ventilation controls, but were implemented only in 20 to 30 percent of the samples. These results indicate that efficiency measures and energy management practices received little attention despite the high interest in saving electricity.

Figure 4. Peak Demand Reduction by Measure in the TOKYO and TOHOKU Areas



Notes: The figure shows average reduction rates by sector and their breakdowns by measure in the collected samples. Large/small customers mean those with a contract demand of more/less than 500 kW.

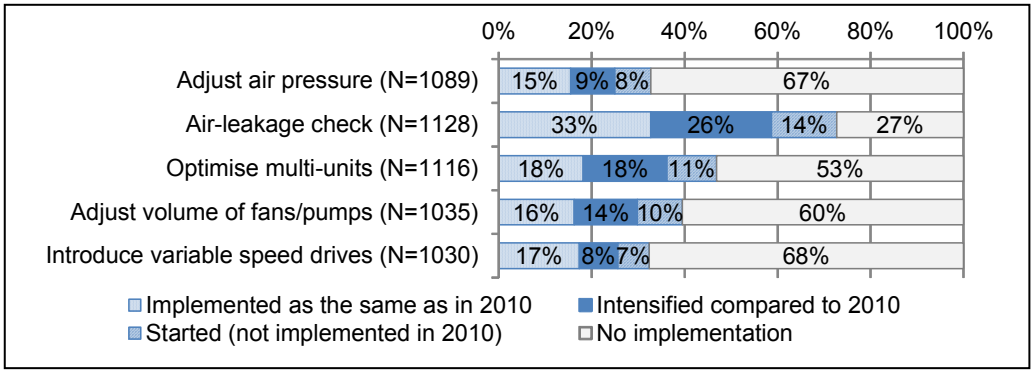
Figure 5. Measures Taken For Lighting and Air-Conditioning Equipment in TOKYO and TOYOKU



Note: Percentage of survey respondents are presented.

Motor-driven equipment in industrial plants. It is difficult to survey electricity saving activities related to production processes because of great heterogeneity. Therefore the survey focused on common conservation measures in fans, pumps and air-compressors. Implementation rates of basic measures of saving electricity were not high, except for air-leakage check (Figure 6). While some 20 to 30 percent intensified those basic measures in summer 2011, more than 50 percent did not implement many of them.

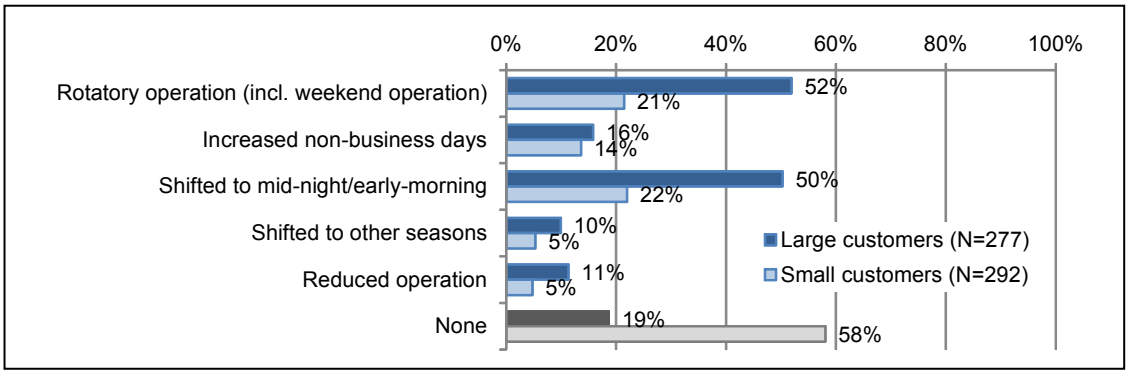
Figure 6. Measures Taken for Motor-Driven Equipment in Industrial Plants in TOKYO and TOYOKU



Shifting operation to off-peak periods. This measure played a very important role in cutting peak demand of large industrial customers in summer 2011, as shown in Figure 3. Popular methods adopted in industrial plants include rotatory operation (52 percent and 21 percent in

large and small industrial customers, respectively) and shifting to mid-night and/or early-morning (50 percent and 22 percent). Much higher implementation rates of those measures by large customers indicate the strong incentive that the mandatory rationing scheme provided. Reduced operation is also listed in Figure 7, showing 5 to 11 percent of implementation.

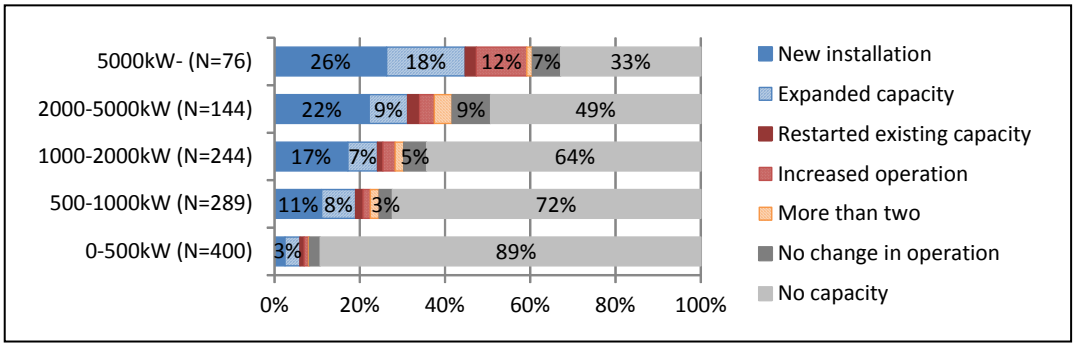
Figure 7. Measures Taken to Shift Operating Hours to Off-Peak in Industrial Sector in TOKYO and TOYOKU



Note: Large/small customers mean those with a contract demand of more/less than 500 kW

Use of in-house power generation. This was another important measure to cut peak demand in large industrial facilities, as shown in Figure 3. Twenty four percent of our samples of industrial facilities used in-house power generators in some ways as a mean to cut electricity demand and to prepare for possible blackouts in summer 2011. Industrial facilities with larger contract demand had higher implementation rates of those measures (Figure 8). This indicates that larger firms had to resort to investing in in-house power generation to meet the 15 percent reduction target. In office buildings and other commercial facilities, those who undertook those measures were 7 percent and 16 percent, respectively.

Figure 8. Use of In-House Power Generation as Response to Electricity Shortage in Industrial Plants According to the Size of Contract Demand, in TOKYO and TOHOKU



Impacts and Costs of Electricity Saving Activities

Both positive and negative impacts of the electricity saving activities were observed. The survey asked about perceived impacts and actual costs incurred to save electricity in summer 2011. As for the positive side, more than 60 percent considered that the activities in summer 2011 increased workers' awareness in saving energy costs. Similarly, 50 percent admitted that

the activities formed the basis of continuous energy improvement within their organization.

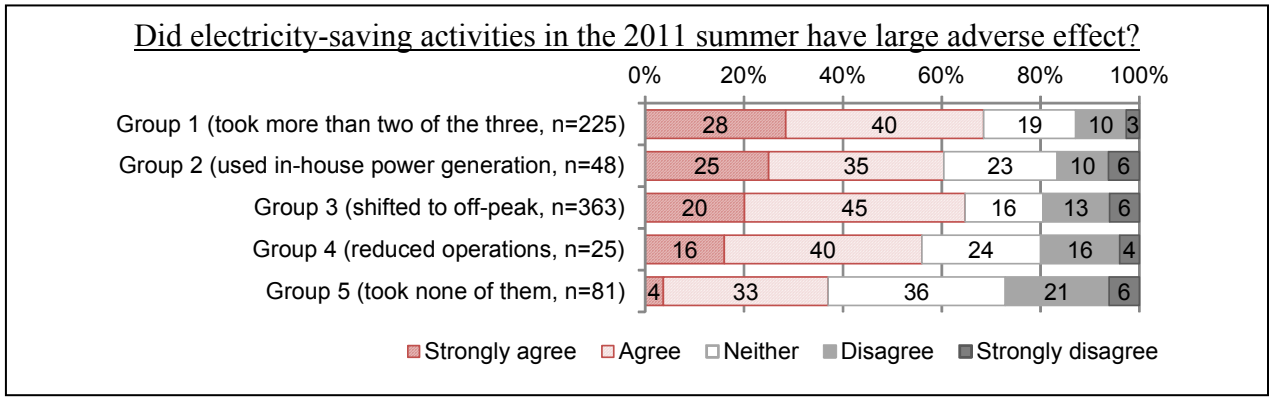
On the other hand, adverse effect of saving electricity was also perceived by respondents. Such perception was particularly strong in large industrial customers. Sixty one percent of the samples of large customers in industrial sector recognized adverse effect of the activities, while 40 percent of large customers in commercial sector did so. As for small customers, only about 30 percent pointed adverse effect.

Three measures turned out to be especially "burdensome", although they are effective in saving electricity: use of in-house power generators, shift to off-peak periods, and reduced operation. We grouped the samples of large industrial customers into five groups according to the implementation status of the three measures (Figure 9). Firms that took none of those burdensome measures (group 5) had a significantly lower perception of the negative impact.

We also asked how much cost was incurred by electricity-saving activities in summer 2011. Average cost incurred at large industrial customers was 15 million JPY, while at other customers 2.4 million JPY. The percentage of respondents who replied that saving electricity incurred no cost was 22 percent in large industrial customers, while it was 61 percent in commercial sector. Furthermore, responses of cost breakdown showed that 47 percent of the cost was incurred for installing and/or operating in-house power generators.

The above results, together with the high rate of shifting to off-peak and using in-house power generators in large industrial customers (see Figure 7 and 8), show that saving electricity was burdensome and costly for large industrial customers, but they had to resort to those measures to comply with the mandatory rationing.

Figure 9. Perception of Large Industrial Customers about the Adverse Effect of Saving-Electricity Activities, According to Their Implementation Status of "Burdensome" Measures



Notes: Group 1 is those who implemented more than two of the three burdensome measures. Group 2 to 4 is those who implemented each of the three measures alone. Group 5 is those who did none of the three measures.

It is also interesting to see that reducing lamps by more than 20 percent on average in commercial facilities was not perceived as very inconvenient. While 20 percent agreed that it had negative impact, only 4 percent chose “strongly agree”. This implies that Japanese offices may have had excessive lighting thus far. This is supported by existing literature (Kimura 2011) and anecdotal evidence from our interview survey in and after the 2011 summer.

Still Continuing? Preliminary Results from a Follow-up Survey in 2012

The electricity crisis in Japan has not been terminated yet in 2013. Suspension of almost all of the nuclear power plants in the country is causing serious supply shortfall. Nevertheless, the supply-demand balance has been a little relaxed, compared to it was in the TOKYO and TOHOKU areas in summer 2011. This is partly due to expanded capacity of thermal power plants and restart of Ohi nuclear power plant in KANSAI area, but also due to persisted savings of electricity.

In May 2012, the government set quantitative targets of demand reduction in KANSAI, KYUSHU, HOKKAIDO, and SHIKOKU as 10 percent, 10 percent, seven percent, and five percent, respectively, for summer 2012. No target was given to the TOKYO and TOHOKU areas because of the increased supply capacity as well as expected demand saving activities. Those decisions were made based on the assessment of the Electricity Supply-Demand Review Committee of the government. Demand reduction achieved in summer 2012 is summarized in Table 3, showing that saving was persisted even without targets that the government set or a mandatory rationing scheme.

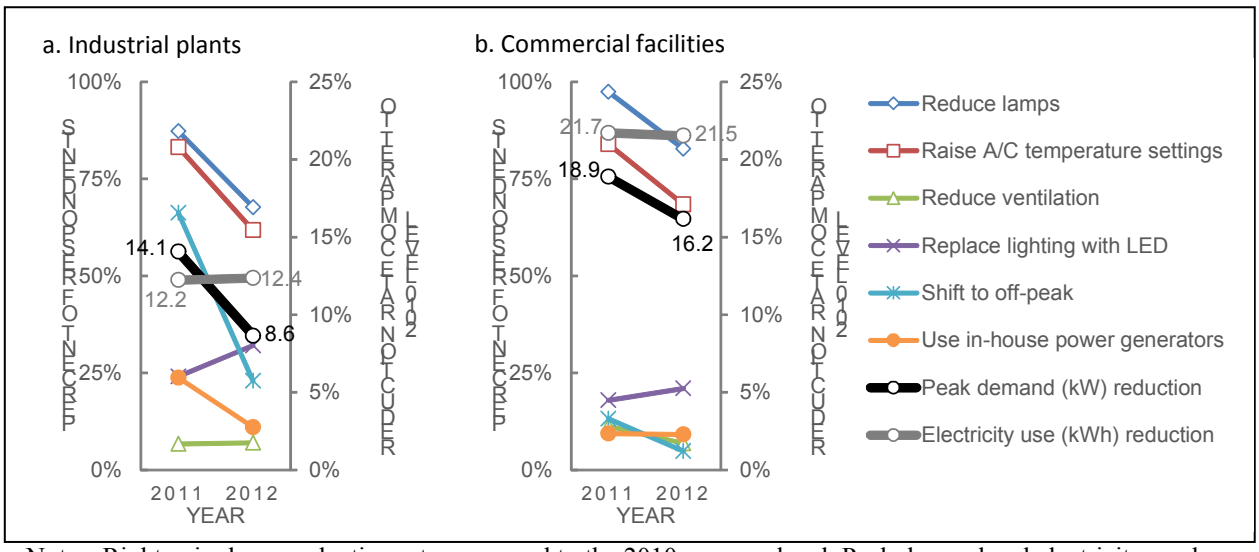
In order to improve our understanding of the persistency of saving activities, we conducted a follow-up survey to the samples of the 2011 survey with valid address, which totaled 5,326. The survey period was from November to December in 2012. We received 2,497 responses. A preliminary result from the TOKYO and TOHOKU areas is summarized in Figure 10.

Table 3. Estimation of Electricity Demand Reduction by Sector in the 2012 Summer Compared to 2010 Summer Levels (Weather-Adjusted)

	TOKYO	TOHOKU	KANSAI	KYUSHU	HOKKAIDO	SHIKOKU
Target	No target	No target	- 10 %	- 10 %	- 7 %	- 5 %
Results	- 12.7 %	- 5.2 %	- 11.1 %	- 9.5 %	- 8.9 %	- 8.6 %
Large customers	n.a.	n.a.	- 13 %	- 8 %	- 15 %	- 9 %
Small customers	n.a.	n.a.	- 11 %	- 9 %	- 11 %	- 9 %
Households	n.a.	n.a.	- 10 %	- 12 %	- 5 %	- 8 %

Notes: Large/small customers mean those with a contract demand of more/less than 500 kW in commercial and industrial sectors. N.a.= data non available. Source: METI (2012).

Figure 10. Implementation Rate of Electricity Saving Measures (Left Axis), and Reduction Rate of Peak Demand and Electricity Use (Right Axis) in TOKYO and TOHOKU Areas in the Summer of 2011 and 2012



Notes: Right axis shows reduction rate compared to the 2010 summer level. Peak demand and electricity use here represent that in summer (July to September) of each year, and that in July of each year, respectively. Reduction rates of peak demand and electricity use are not weather-adjusted.

The reduction of peak demand and electricity use in summer 2012 compared to the 2010 level was either smaller than or around the same level as that in 2011. Still, they maintain a remarkable reduction level: 8 to 12 percent and 16 to 21 percent of reduction were achieved in industrial plants and commercial facilities, respectively. Implementation rates of shift to off-peak and use of in-house power generators dropped significantly in summer 2012, indicating that firms avoided burdensome measures in the absence of a mandatory rationing scheme. *Emergency* behaviors such as reducing lamps and raising air-conditioner temperature settings were also persisting, although the level of each activity was moderated.

As for *efficiency* measures, LED lighting, an example of an efficiency measure by technology, received slightly more attention in 2012 than in 2011. On the other hand, there was no increase in implementation of ventilation control, an example of an efficiency measure by operational improvement. The results indicate that, while higher-efficiency technology will be diffused gradually as the cost decreases and performance increases, promoting operational improvement is more difficult, even in the face of such crisis.

Conclusions

Japan experienced a severe electricity shortfall since March 2011 because of the Great East Japan Earthquake and subsequent shutdown of nuclear power plants. The supply-demand balance was especially severe in the TOKYO and TOHOKU areas in the 2011 summer, which forced the government to introduce mandatory rationing for large customers in those areas.

As a result of intense efforts by households, firms and the government, demand reduction by more than 15 percent compared to the 2010 level was achieved in the two areas in summer 2011. As we discussed in this paper, it should be noted that such a large demand reduction was accompanied by pain, especially in large industrial customers. Cutting 15% of electricity demand

for the entire summer period required many large factories to install in-house power generators and to shift operation to off-peak periods. Those measures turned out to be costly and burdensome. On the other hand, electricity savings in the commercial sector mainly came from limiting use of lighting and air-conditioning, which turned out to be much less burdensome than in the industrial sector. This implies there was excessive electricity consumption in this sector that could be reduced without compromising amenity.

Electricity saving was continuing as of the 2012 summer. Between 5% to 12% reductions from 2010 levels were achieved in the TOKYO and TOHOKU areas. Although implementation rates of major measures were lowered, emergency behaviors such as reducing lamps and raising air-conditioner temperature settings were continued at a relatively high level.

While implementation rates of emergency measures were quite high in the 2011 summer, efficiency measures were not widely adopted. Even in summer 2012 the situation has not changed. This implies that the electricity crisis was not a strong enough stimulus to remove various barriers to increasing energy efficiency. We therefore cannot be too optimistic about the persistence of electricity savings over longer timeframes. In a prolonged electricity shortfall like the Japanese case, it is important to convert emergency efforts from the early stages of crisis into sustainable efficiency efforts.

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