

Analysis of behaviour change due to electricity crisis: Japanese household electricity consumer behaviour since the earthquake

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Abstract

Since the nuclear accident from the March 11, 2011 earthquake, tight electricity supply in Japan continues. After May 2012, when all nuclear plants were off line, two reactors have been restarted. Thus, both changes in energy policy and continued electricity conservation are needed. Just after the disaster there were planned electricity outages, mandatory electricity conservation, and voluntary lighting and air conditioning conservation measures by many public and private facilities and individual households. The household electricity conservation ratio (ECR) for the whole country was 5.1 % just after the disaster, 7.6 % in summer 2011, but fell to 3.3 % in winter 2012. In Tokyo Electric Power Company's (TEPCO) service area, with direct experience of disaster effects, ECRs were 9.5 %, 8.4 %, and 4.3 % for the same periods. In summer 2012, the ECR increased again. Under long-term conditions of tight electricity supply, the ECR varies seasonally and regionally. We evaluate reasons for the changes quantitatively. To analyse the influence of the disaster and subsequent tight electricity supply on household electricity conservation actions and electricity savings, we surveyed post disaster implementation of electricity conservation actions (ECA). We targeted TEPCO's service area in 2011 and all of Japan in winter and summer of 2012. From changes in awareness and implementation status of ECA, we show chronological and regional impacts of the disaster and tight electricity supply on consumer behaviour. Since the disaster, attempts to change Japan's energy policy are on-going. There are

various arguments about providing electricity supply, but it is not easy to meet the 30 % of electricity demand previously met by nuclear power with alternate sources. Encouraging changes in consumer behaviour can play an important role in future energy policy. Evaluating the impact on consumers of long-term electricity supply pressure provides useful data for analysis of changes in consumer behaviour.

Introduction

After the nuclear accident due to the March 11, 2011 Great East Japan Earthquake, tight electricity supply has continued. Immediately after the quake, Tokyo Electric Power Company (TEPCO) and Tohoku Electric Power Company (Tohoku EPCO) over two weeks implemented the first planned rolling blackouts in their service areas since World War II, due to direct earthquake and tsunami damage to generation and transmission equipment. Also, due to the influence of the nuclear accident, when nuclear power plants shut down for routine maintenance, it was not possible to restart them, and from the summer of 2011, wider regional electricity crises have continued. Electricity conservation targets for the summer of 2011 were set at 15 %, 15 % and 10 % reduction compared to 2010, for the service areas of TEPCO, Tohoku EPCO, and Kansai Electric Power Company (KEPCO), respectively. Furthermore, for large customers in TEPCO and Tohoku EPCO service areas contracted for 500 kW or more, the Restriction of Electricity Use (Ministry of Economy, Trade and Industry 2011) was invoked, requiring a 15 % cut in summer peak power, forcing electricity conservation in the industrial and commercial sectors. After that the Restriction of Electricity Use was not used further, for the winter of 2011–2012, in the

service areas of KEPCO and Kyushu Electric Power Company (Kyushu EPCO) conservation targets of 10 % and 5 % respectively were set. For the summer of 2012, various conservation targets of 10 %, 10 %, 7 % and 5 % were set for the service areas of KEPCO, Kyushu EPCO, Hokkaido Electric Power Company (Hokkaido EPCO), and Shikoku Electric Power Company (Shikoku EPCO), respectively. Even though conservation was voluntary, many public facilities, commercial facilities, and households carried out electricity conservation measures.

There are 54 nuclear power reactors in Japan with a total capacity of 48,960 MW. Each reactor is shut down every 13 months for regular inspection. Before the disaster there were 37 units operating, with a maximum output of 34,530 MW. Due to the Fukushima nuclear accident, strict limits were placed on restarting reactors shut down for maintenance, bringing all nuclear power plants to shut down as of May 2012. Since then, only two have been restarted, with a capacity of 2,360 MW. There have been various studies of the pros and cons of restarting Japan's power reactors, but at present, a resolution remains unclear. Amid these conditions, analysis of changes in energy conservation awareness and energy conservation behaviours since the earthquake provides basic information for the design and implementation of future energy efficiency policies. From an international perspective, evaluation of the impact of long term electricity supply pressure on consumers provides useful data for studying change in consumer behaviour.

Existing reports analysing changes in household behaviour and energy conservation effects after the Great East Japan Earthquake include Jyukankyo Research Institute (2011), which addressed conditions in April 2011, and Murakoshi and others (2012), and Nishio and Ofuji (2012), which addressed conditions during the summer of 2011 in the service areas of TEPCO. From these, it is clear that conservation measures for air conditioners and lighting were effective at curbing overall electricity consumption. Also, Yagita and others (2012) studied specific factors linked to energy saving behaviours for multiple regions. However, there have been no studies targeting Japan as a whole. The research described here surveyed household energy conservation implementation activities, awareness, and electricity consumption for the whole country. The goal is to analyse the influence of the earthquake and tight electricity supply on consumer behaviour using time series, seasonal and regional analysis.

Method

For this research we used two types of data, internet questionnaire survey data, and supply data from electric utilities. We carried out an internet survey targeting more than 8,000 households throughout Japan, which represents approximately 0.02 % of all Japanese households. We screened the respondents from online research company's panel by their electric utilities and possibility to obtain electricity usage data. We analysed conditions of household energy conservation activities and awareness of energy conservation, and summer and winter energy conservation effects. An overview of the survey is shown in Table 1. Although the survey targeted all of Japan, Okinawa was excluded because it did not have any nuclear power plants before the disaster and also geographically it was not much affected by the earthquake. Therefore Okinawa was at the same level of power supply as before the earthquake.

We also analysed the relationship between TEPCO's daily peak electricity consumption and outdoor temperature using TEPCO's publicly available data for past electricity demand (TEPCO undated) and the Japan Meteorological Agency's publicly available daily outdoor temperature data for Tokyo (Japan Meteorological Agency undated). To estimate the monthly rate of reduction in electricity consumption by region, we used the Federation of Electric Power Companies' publicly available data on each electric utility's electricity supply data (Federation of Electric Power Companies of Japan undated). We estimated electricity consumption per household by dividing the electricity supplied to households by the number of household contracts. By comparing with the same month in the year before the earthquake, we calculated a reduction rate. Also, to eliminate the influence of yearly variation in temperature, we normalized the electricity consumption data prior to 2011 to have the same cooling and heating degree days as would have occurred with 2012 temperatures.

Change in TEPCO Daily Peak Power

Data for TEPCO's daily peak power versus daily maximum (in summer) or minimum (in winter) temperatures are shown in Figure 1. TEPCO's record daily peak power demand before the earthquake was 61,470 MW in August 2007, followed by 60,890 MW in 2008, and 59,990 MW in July 2010. In contrast, after the quake the 2011 peak was 49,220 MW and the 2012 peak was 50,380 MW, decreases of 18 % and 16 % from the

Table 1. Overview of Questionnaire Survey.

Survey method	Internet questionnaire survey
Survey period	Winter Survey: May 2012 Summer Survey: September 2012
Target	Household customers of Hokkaido, Tohoku, Tokyo, Hokuriku, Kansai, Chugoku, Shikoku, Kyushu (Okinawa is excluded) electric utilities, male or female, age 20 and older, for whom it was possible to obtain electricity usage data for the winter period (Jan. to Feb.) and the summer period (Aug. to Sep.), and who had occupied the current residence for at least a year before the start of the winter period.
Number of Respondents	Winter Survey: 8,241 (valid energy data sample: 7,339) Summer Survey: 8,241 (valid energy data sample: 7,727)
Survey Items	Household type (including respondent's age, sex, family members, building type and floor space), Electricity consumption (electricity usage, bill, days from Jan. to Feb or from Aug. to Sep. in 2011 and 2012), People's awareness about electricity saving, Energy conservation behaviours

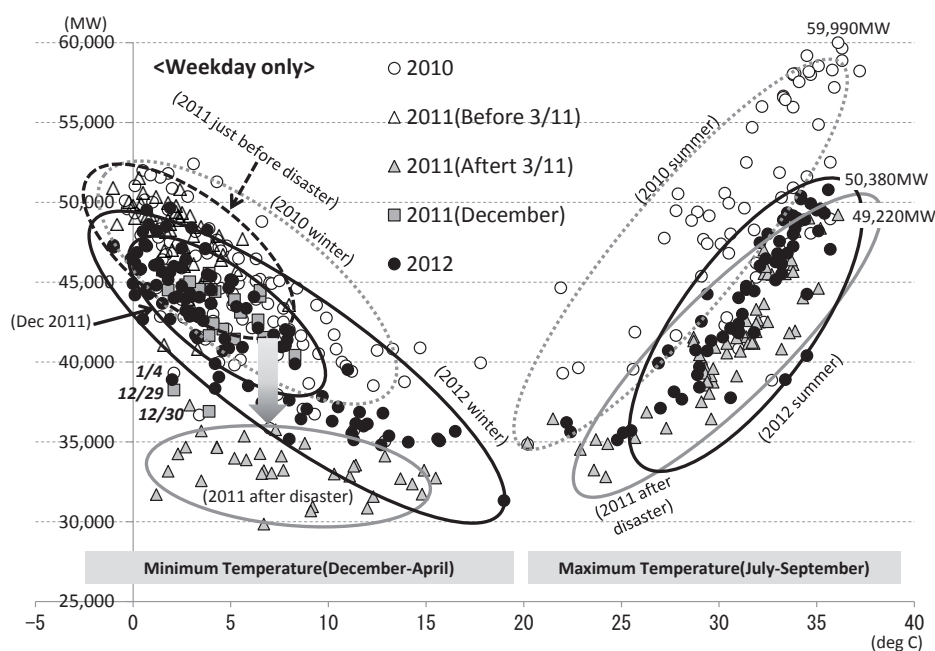


Figure 1. Change in TEPCO daily peak power and temperature.

2010 value, respectively. Tokyo's summer of 2010 was the hottest on record but 2011 was the second hottest. A correlation between the hottest summer day and peak power demand can be seen, but the trend differs greatly before and after the disaster. Compared to the 2010 summer, the post-disaster 2011 and 2012 summers had peak power demands on the hottest days that were clearly lower.

Just after the disaster, there was an electricity supply shortage, and a campaign for public and private entities to conserve electricity was carried out. Comparing daytime peak power before and after the March 11, 2011 earthquake, even under the same weather conditions, the post disaster maximum peak power demand has fallen greatly. In particular, up until the quake, a positive correlation between daily peak power and daily maximum temperature was seen, but just after the quake this relation stopped, and rather than peak power demand being related to temperature, the daily peak power was limited within a certain range. In 2011, due to the trend for electricity demand to increase in the summer period, electricity saving measures were implemented and a decrease in the maximum peak power was clearly seen. However, conditions changed in December 2011. The daily peak power demand returned to about the same level as the winter period before the quake. This may be related to the power demand in winter being smaller than in summer, as well as to some people feeling less anxious about electricity supply due to having made it through the summer electricity crisis even without nuclear power plants operating. This trend continued through the winter of 2012. For the winter period only, except for immediately after the quake, peak electricity demand did not decrease very much. We think that nearly a year post quake, energy conservation awareness suffered a setback. But in the summer of 2012, awareness rebounded, with peak power demand lower than before the quake, returning to the same trend as in 2011, without electricity conservation target.

A large difference was seen in the continuity of energy conservation awareness in summer and winter. In summer, people were more aware of electricity supply shortages, so energy conservation awareness was higher. In contrast, in winter, the total power demand was smaller, but this seems to have led to a decrease in energy conservation awareness. However, tight electricity supply in Japan continues. There is a risk of serious electricity shortages, due to the uncertainties of fossil fuel fired thermal power plant breakdowns.

Conservation Ratio of Household Electricity Consumption

From various direct experiences, including the huge earthquake and power outages due to earthquake and tsunami damage to generation and transmission facilities, electricity conservation awareness for Tokyo and Tohoku increased instantly just after the disaster (Figure 2). Before the quake, about 10 % of households reported that they were acutely aware of electricity conservation, but for Tokyo and Tohoku immediately post quake, in April 2011, this fraction had risen to about half. Furthermore, in other regions also, the fraction of households reporting that they were acutely aware of electricity conservation rose to about 30 %, perhaps because the media covered earthquake, tsunami, and nuclear accident damage from moment to moment for many days. Household electricity conservation awareness for summer 2011 decreased somewhat from just after the quake for the whole country, yet 31 % reporting acute awareness. Notably, the fraction reporting acute awareness in the TEPCO service area stayed high, at about half.

As energy conservation awareness rose, energy consumption also decreased. Based on electric utility data for household electricity supply, we estimated a temperature normalized Electricity Conservation Ratio (ECR- see Glossary), compared with the 2010 fiscal year baseline (Figure 3). The April 2011 ECRs,

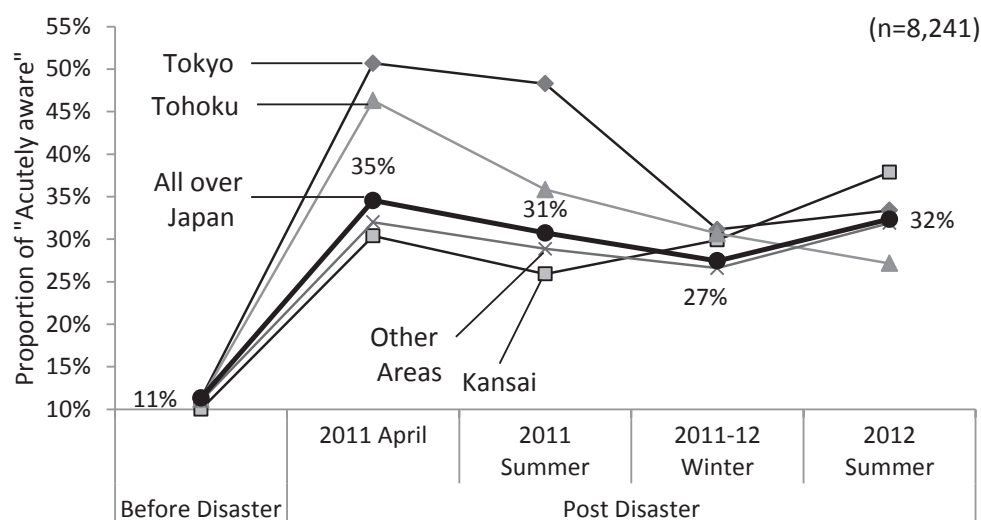


Figure 2. Pre and post disaster change in awareness in saving electricity (%).

just after the disaster (relative to the same month of the previous year), were 9.5 %, 7.8 %, and 5.1 % for TEPCO, Tohoku EPCO, and the whole country, respectively, with other areas also around 5.1 % on average.

The 2011 summer period ECR was an average of 7.6 % for the whole country. By comparison, TEPCO (8.4 %) and Tohoku EPCO (7.9 %) had higher rates of reductions in electricity consumption, because both regions had had target values set at 15 %. Over this period, the media reported not only the weather forecast, but also the electricity forecast made public by the electric utilities (forecasts of power supply, power demand, and the ratio of surplus). Lighting was dim in places such as train stations and lobbies and hallways of public facilities, as well as in workplaces, stores, and leisure facilities, showing the implementation of electricity saving measures impacting peoples' daily lives. This served to heighten the consumer's sense of a crisis regarding electricity shortage. In contrast, the KEPCO ECR, which had been 2.5 % immediately post quake, rose 6.3 points to 8.8 % for the summer period. The KEPCO service area did not receive direct influence from the quake and tsunami, but in July 2011, peak nuclear output fell by half, causing increased concern over electricity supply.

The average whole country ECR for the winter period of 2011–2012 was 3.3 %, a visible decrease from the summer. There was also the case of KEPCO, with a conservation target in place for its service area, which had a 5.3 % ECR, a smaller decrease from its summer value. At the same time, for TEPCO and Tohoku EPCO, the tight electricity supply that had continued since April was mitigated, so there was less reporting about electricity shortages and consumer electricity conservation awareness also decreased somewhat. Except for KEPCO, which had its own electricity savings target, household electricity conservation awareness also fell, with a whole country average of 27 % reporting acute awareness, a 5 point decrease from the summer of 2011.

The average ECR for the year after the disaster (the average for FY2011) is 4.6 % for the whole country. By region the ECR are TEPCO 6.7 %, KEPCO 5.0 %, Tohoku EPCO 4.3 %, while the average for other regions is 3.1 %.

During 2011, in the TEPCO and Tohoku EPCO service areas there was an electricity savings campaign through which consumers could receive prizes for attaining the target reduction of 15 %. However, outside of this period, other than targets set for electricity savings and publicity by government and the media, no other programs for households were implemented. It is very interesting that Japanese households achieved an average electricity savings of about 5 %, only by being provided with information.

More than a year post disaster, summer 2012 ECR (compared to the summer of 2010) were all even higher than for the summer of the previous year, at an average 9.1 % for the whole country, with 11.2 % for TEPCO and 9.2 % for both Tohoku EPCO and KEPCO. Amid continued anxiety about electricity supply, more voluntary electricity savings targets were set: KEPCO, 10 %, Kyushu EPCO, 10 %, Hokkaido EPCO 7 %, and Shikoku EPCO 5 %. Therefore, household electricity conservation awareness reached about the same high levels as in summer 2011, with a whole country average of 32 % reporting acute awareness. In particular, KEPCO, which had set a target value, had a striking 12 point increase in electricity conservation awareness. TEPCO did not set a target value, and did have a decrease in awareness from summer 2011, but still had a higher ECR than other regions.

We surveyed households reporting being acutely aware of electricity conservation during winter 2011–2012 and summer 2012 about the reasons for their awareness. Interestingly, “because our utility bill is cheaper,” (80 % in winter and 90 % in summer) exceeded “because there is an electricity shortage,” (73 % in winter and 75 % in summer) in both periods. In other words, while changes in energy conservation awareness corresponded to changes in calls for conservation due to electricity shortage and changes in the degree of tight supply, people are acutely aware of the effect of reduced utility bills. This is in agreement with analysis by Yagita and others (2012) that among factors contributing to electricity saving behaviours, the most important is evaluation of benefits.

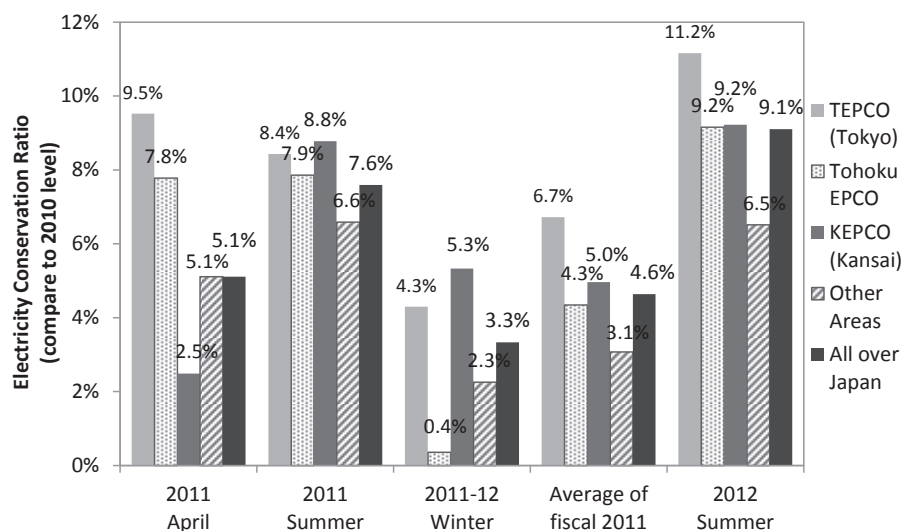


Figure 3. Post disaster household ECR, normalized for temperature, estimated from supplier data.

Table 2. Survey Results for ECR by Region (Normalized for temperature, number of households, and number of family members).

	n	Hokkaido	Tohoku	Tokyo	Chubu	Hokuriku	Kansai	Chugoku	Shikoku	Kyushu	Total
2011-12 Winter	7,610	5.0%	5.8%	6.7%	5.1%	5.0%	7.7%	5.8%	5.3%	5.1%	6.2%
2012 Summer	7,891	2.8%	0.1%	3.7%	3.4%	2.2%	5.2%	2.7%	1.6%	1.5%	3.2%

The average whole country ECR based on the internet survey is 6.2 % for the winter of 2011–2012 (Table 2). This is 3.1 points higher than the 3.3 % estimated from electricity supplier data (Figure 3). Data sought by the questionnaire included electricity usage for the period from January to February 2012, which at the time of the survey was 4~5 months ago, as well as usage from the equivalent period the previous year, which was printed on the customer's meter reading receipt. It is possible that households having this evidence are more methodical than others, so the abovementioned disparity in ECR could be influenced by sample attributes. Also, the summer 2012 whole country ECR from the internet survey data is 3.2 % (Table 2), but it should be noted that the baseline for this ECR is not pre disaster, as it is compared to usage one year earlier (the same period in 2011, which is also post disaster), while the summer 2012 ECR in Figure 3 uses 2010 pre disaster data as its baseline.

Survey of Implementation Status of Electricity Conservation

In the winter 2011–2012 survey, we asked about implementation of energy conservation actions (ECA) before and after the disaster and intentions to continue those activities in future years. The survey included 49 ECA related to heat pump room AC, water heaters, gas and kerosene heaters, electric heaters, TV, lighting, refrigerators, hot water bidet, personal computers, and other equipment. Of the post disaster winter period ECA, those related to room AC took the top three places. It is interesting that even though the fourth and fifth place actions, reducing the use of gas or kerosene fan heaters, and actions to

reduce the quantity of hot water used¹ are not generally actions to reduce electricity use, they had high rates of implementation. In the free response column of the survey, various other actions to reduce gas, kerosene, and water use were mentioned, so it seems that increased electricity conservation awareness influences the use of other energy and water resources as well. When we compare rates of implementing ECA over time for the winter period, overall there is a trend of decreasing implementation from just after the disaster to winter 2011–2012. In particular, just after the disaster, 5.9 % to 6.7 % of households carried out lighting actions, but by the following winter this had decreased to below 5 %. The fraction of households intending to continue ECA carried out in the 2011–2012 winter the next winter and beyond was high. If people do as they said, then we can expect similar rates of implementation for winter 2012–2013 and beyond (Figure 4).

The summer survey included 40 ECA related to heat pump AC, water heaters, TV, lighting, refrigerators, hot water bidet, personal computers, and other equipment. Of the post disaster summer period ECA, those related to heat pump AC took first and second places, and the results showed a similar trend to those seen in the winter period and those Murakoshi and others (2012) found in their study of summer 2011. As was also seen in the winter survey, a high percentage (more than 10 %) reduced the quantity of hot water used. When the rates of implementing ECA in summer 2012 are compared with the winter period, the summer rates are generally higher, and even when compared to summer 2011 rates, we confirmed higher

1. About 20 % of the households in this survey used electric water heaters.

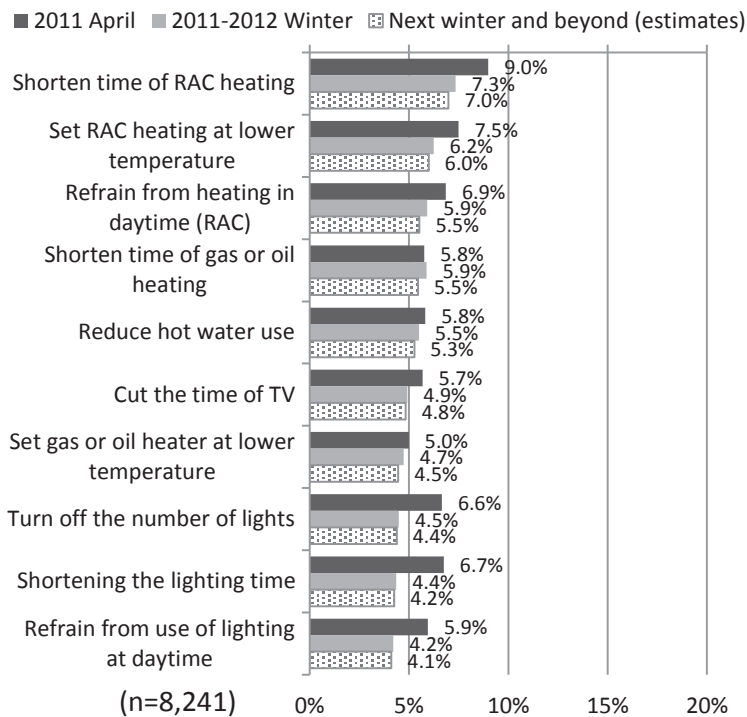


Figure 4. Post disaster rates of implementing ECA (winter survey). The top ten actions are shown, while households doing the actions before the disaster are excluded from the rate.

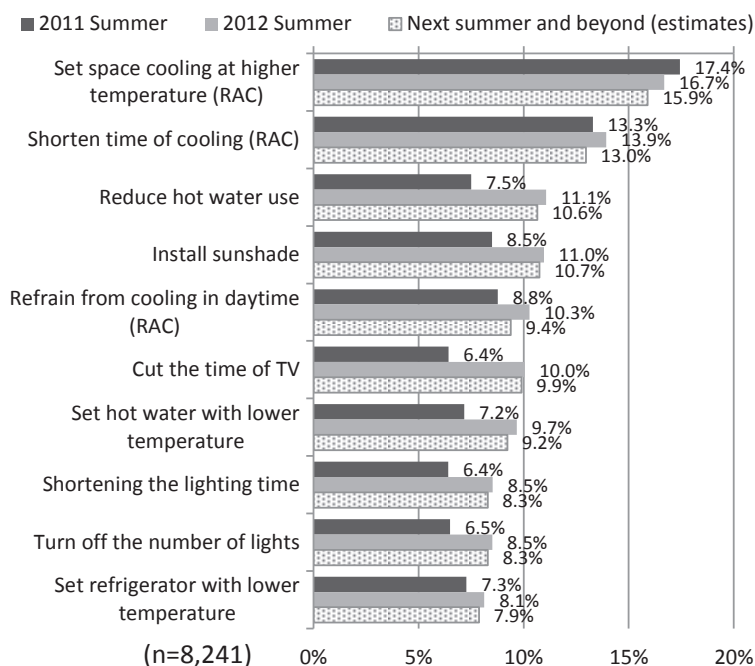


Figure 5. Post disaster rates of implementing ECA (summer survey). The top ten actions are shown, while households doing the actions before the disaster are excluded from the rate.

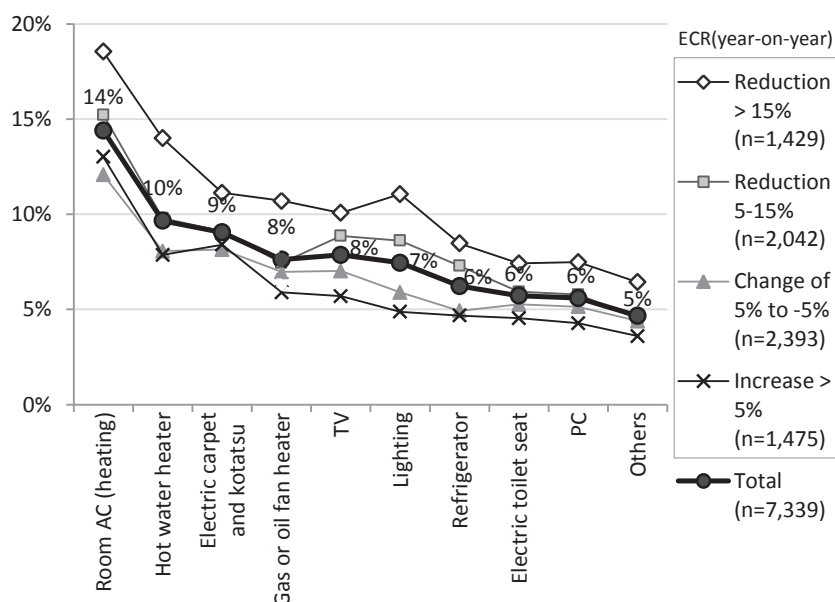


Figure 6. 2011–2012 winter rates of implementing ECA by appliance and by household ECR (winter survey). Households doing the actions from before the disaster are excluded. Year-on-year means that ECR is with reference to the same month in the previous year.

implementation rates for everything except “raising the AC set temperature.” This can be explained by the predominance of households with high electricity conservation awareness in summer 2012, because, as stated above, relative to both the previous summer and winter, there was no margin of excess in electricity supply and demand. The fraction of households intending to continue energy saving actions carried out in summer 2012 the next summer and beyond was also high. The survey results indicate a generally high intention to carry out ECA in the future, but actual behaviours will be affected by energy supply and demand conditions at the time (Figure 5).

In both winter and summer periods, the top ten ECA included many that the government and electric utilities publicized as effective ways to save electricity, such as setting the room AC at a lower or higher temperature and shortening the time lights are on. However, these methods were common knowledge from before the disaster so doubts remain about whether the government and utility publicity effectively led to behaviour change.

The 2011–2012 winter implementation rates by appliance are shown in Figure 6, for the whole sample and by groups of households with various ECR. For the whole sample, room AC was highest at 14 %, followed by water heaters at 10 %, and hot carpet and kotatsu at 9 %. Also, the more electricity the household actually saved, the higher the implementation rate of ECA was. In particular, the group of households achieving more than a 15 % reduction in electricity usage compared with the same month the previous year, had high implementation rates for all appliances. However, even more than 10 % of households exceeding a 5 % increase in electricity usage also took action about heating with room AC, still their top choice. The top most frequently implemented actions followed the same trend, regardless of how much electricity the household conserved. Among these, implementation of lighting actions was

particularly high for households with an ECR above 15 %. And implementation rate of Gas or oil fan heaters is also high for the highest ECR group. But, this seems not to be a major factor that led electricity reduction, because power consumption of fan heaters are small.

The 2012 summer implementation rates by appliance are shown in Figure 7, for the whole sample and by groups of households with various ECR. Just as in winter the appliance with the highest rate of actions is room AC (this time, for cooling) at 31 %, followed by water heaters at 19 %, TV at 16 %, and lighting at 15 %. As stated above, the rates of implementing energy conservation actions overall were higher in summer than in winter. As in winter, the highest ECR group of households (>15 % decrease) had high implementation rates for all appliances, especially lighting, but the differences in implementation rates for all other groups of households (15 % decrease to >5 % increase) were smaller than in winter.

After the disaster 44 % of households switched to energy efficient lamps (Table 3). The most frequent action was to change from incandescent to LED, done by 32 % of households. In an earlier survey of households in TEPCO's service area (Jyukan-kyo Research Institute 2011), 10 % switched to energy efficient lamps just after the disaster. In the summer survey for the same region, 47 % of households switched to energy efficient lamps, showing an increase of more than 35 points over about 1.5 years. Main factors for switching to LED lamps include the progress in price reduction over the past one to two years, so that among all investments in energy efficiency, these have a relatively low unit price, and also the ease of installation, as they fit existing fixtures.

After the disaster, 29 % of households bought new fans or replaced older models with new fans, and 60 % of those answered that the reason for this action was to save energy (Table 4). Also, in the summer survey, of the households who purchased

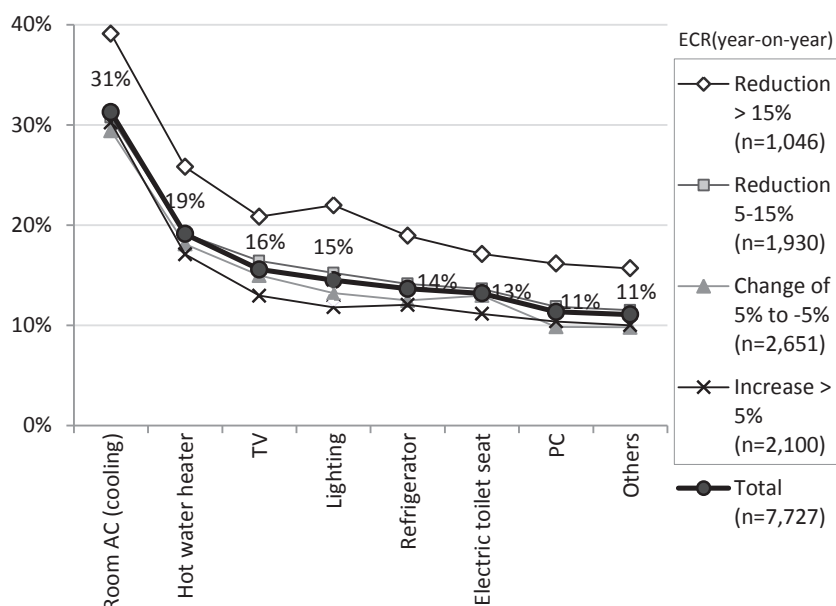


Figure 7. 2012 summer rates of implementing ECA by appliance and by household ECR (summer survey). Households doing the actions from before the disaster are excluded. Year-on-year means that ECR is with reference to the same month in the previous year, summer 2011, which is post disaster.

Table 3. Percentage of households replacing lamps post disaster (summer survey).

	Replaced all lamps	Replaced half of lamps	Replaced part of lamps	Total
Replaced incandescent to LED	4.1%	5.3%	22.7%	32.1%
Replaced incandescent to CFL	2.8%	3.9%	14.5%	21.2%
Replaced CFL to LED	3.0%	3.2%	12.4%	18.7%
Replaced any lamps				44.0%

Table 4. Percentage of households replacing or purchasing new appliances post disaster, and main reason (summer survey).

	Fan	TV	Room AC	Refrigerator	Oil heaters	Electric toilet seat	Gas heaters
Energy conservation	17.4%	4.4%	5.6%	5.4%	3.0%	1.1%	0.6%
Other reasons	11.5%	10.5%	6.2%	5.3%	4.1%	2.9%	0.9%
Total	28.8%	15.0%	11.8%	10.7%	7.1%	4.0%	1.5%

fans to save energy, the percentage saying that they cooled only using AC pre disaster was 38 %, decreasing 30 points to 8 % by summer 2012. We can see that the disaster provided an impetus for more households to use fans as an alternative means for cooling besides AC.

Family Type and Implementation Status of Energy Conservation Actions

Looking at ECR for different family types, in the winter study, singles had the highest ECR, followed by couples, parents with children, and three-generation families and others, showing a trend for smaller scale households to have higher ECR. Also, within the same family type, those headed by seniors, ages 60 and older, had higher ECR than those with young to middle aged

heads of household, ages 20 to 50. In the winter survey, single elderly people and three-generation households implemented the highest number of conservation measures, while young and middle aged singles implemented the fewest (Figure 8).

The trend for smaller scale households with older heads to have higher ECR was also seen in summer (Figure 9). But in summer singles had lower ECR than couples and we did not see a difference in the age of the single householder (Figure 9). The trend for singles have lower ECR than couples agrees with previous reports studying reduction rates in summer 2011 (Murakoshi and others, 2012, Nishio and Ofuji, 2012). The number of measures implemented in the summer survey was higher for elderly parents with children, elderly couples, and elderly singles, while just as in the winter survey, young and middle aged singles carried out the fewest measures.

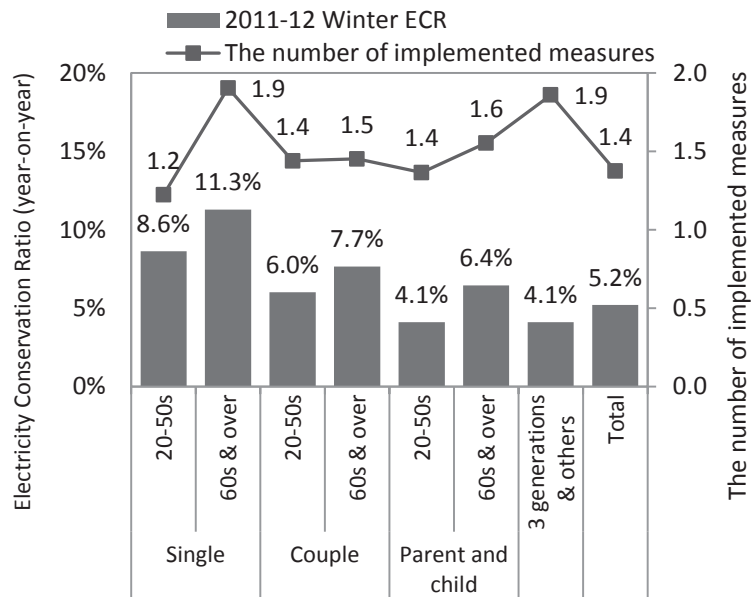


Figure 8. ECR by family type and average number of ECA implemented (winter survey). Temperature normalized. Single, couple, parent and child have been divided by age of head of household.

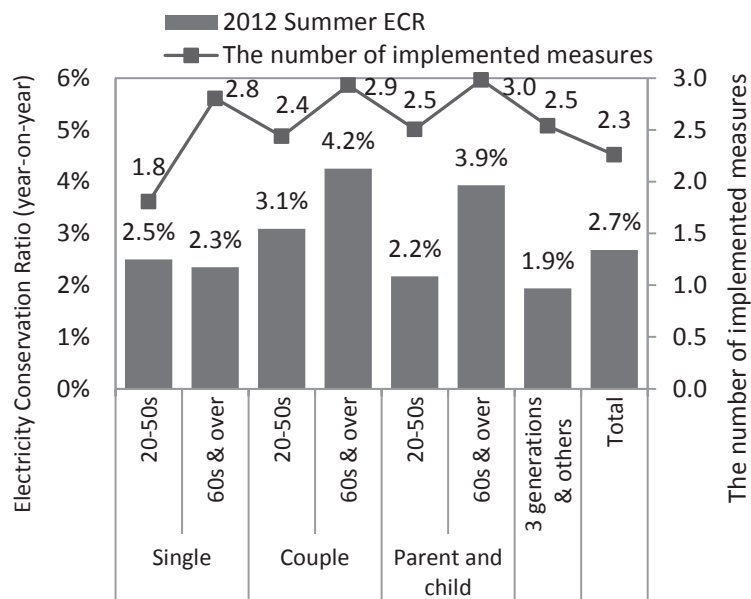


Figure 9. ECR by family type and average number of ECA implemented (summer survey). Temperature normalized. Single, couple, parent and child have been divided by age of head of household.

There are two possible factors leading to differences in ECR by household size. First, families with more members may have more barriers to taking actions. For example, in order to shorten the hours of AC use, in households with two or more members all family members must agree, or it is not an energy conservation action at the household level. Furthermore, the more family members there are, the more difficult it is to reach agreement. Second, the share of each appliance in total energy use differs. For smaller households the consumption of a single AC or refrigerator is a large fraction of the total. But as the household size increases, the types and numbers of household appliances also increase, while the fraction of appliances that are subject to ECA may decrease. Even if the same number of ECA are carried out, the ECR will be higher for small households. This can be seen in Figures 8 and 9, where, couples and parents with children implemented similar numbers of energy conservation actions, but couples had higher ECR.

Possible factors causing older households to have higher ECR, even within the same family type, include differences in numbers of energy conservation actions carried out, and differences in the degree to which there is room for energy conservation. No matter the family type, older households implemented more actions, and this trend is more pronounced in the summer (Figure 9). From the survey responses, the fraction of households buying energy efficient appliances and lighting was higher for older households than for younger ones. Also, in general, a high proportion of older singles and couples are home all day on weekdays, and when they are home they use heating or cooling, and lighting. In contrast, younger households have a lower occupancy rate during the day and use less energy overall, so there is less room for decreasing consumption by conservation. For these reasons, older households had higher ECR than young and middle aged households.

Conclusions

The goal of this research was to understand energy conservation effects, household awareness of energy conservation, and conditions of implementing energy conservation actions, after the Great East Japan Earthquake. To do so, we analysed publicly available supply data from electric utility companies and data from a nationwide internet survey of households, and we have made actual conditions clear.

Compared with TEPCO's system wide peak power recorded in 2010, the year before the earthquake, the 2011 peak was 18 % smaller and the 2012 peak was 16 % smaller. Comparing the seasonal daily peak power, the summer peak has clearly decreased since the disaster. However, except for immediately after the disaster, the winter daily peak power has not decreased very much. This seasonal difference can be explained by consumers having higher energy conservation awareness due to tight electricity supply in summer, because TEPCO's maximum peak power consumption occurs during summer, while energy conservation awareness recedes in winter as the overall electric power demand decreases.

Residential ECR for the whole country (compared with the same period in the year before the disaster) was 5.1 % just after the disaster, 7.6 % in summer 2011, 3.3 % in winter 2011–2012, and 9.1 % in summer 2012. Electricity consumption the year after the disaster decreased by 4.6 %. By region, the TEPCO

and Tohoku EPCO service areas, which were directly impacted by earthquake and tsunami damage, had high ECR. In summer 2011, in addition to TEPCO and Tohoku EPCO, KEPCO, which had also set an electricity savings target, had a high rate of electricity conservation. In winter 2011–2012, because the tight electricity supply eased the whole country ECR decreased, but in summer 2012, even in the KEPCO service area electricity supply tightened, due to nuclear power plants being off line, and nationwide, energy conservation awareness increased again, with the ECR yet.

The appliance most often chosen for implementation of household ECA is the room AC, in winter for heating and summer for cooling. The second most frequent appliance was the water heater. In winter the third and fourth most frequent were electric carpet or kotatsu, and gas or kerosene fan heaters. The overall rate of implementing ECA was higher in summer than in winter. This seasonal difference in implementation rates is consistent with seasonal differences in energy conservation awareness seen in the survey and with ECR results estimated from electric utility supplier data. Also, we found high overall rates of consumers intending to continue their energy conservation actions. If they follow through on their survey responses, the reductions in household energy consumption can be expected to continue into 2013 and beyond. But, considering that energy conservation actions are motivated by awareness of energy conservation, when electricity supply shortages resolve and consumer awareness wanes we cannot refute the possibility that energy conservation actions will return to their pre disaster levels.

The energy efficient equipment most often purchased post disaster was LED lamps, purchased by 32 % of households, followed by fans, at 29 %. Factors encouraging LED purchase include decreased prices and the ease of installation. Of the respondents who purchased fans, 60 % said they did so “to contribute to saving energy.” In other words, fans are being used to complement AC, as an alternative means of cooling.

We analysed ECR by family type, and found that smaller households, singles and couples, had higher ECR. Also, for the same family type, elderly households, those with heads age 60 and older, had higher ECR. The difference in ECR with household size is likely due to an increase in barriers to taking actions households with more family members, and also due to different share of household energy use held by a single appliance. Factors contributing to elderly households having higher ECR include differences in the numbers of energy conserving actions implemented, and also having more of a margin for energy conservation.

The tight electricity supply and demand since the Great East Japan Earthquake has been ridden out, through the summer of 2012, due to efforts to conserve electricity in each sector, industry, business, and household. However, it is unknown whether this will continue or will stop as a temporary phenomenon, so the risk of electricity shortages has not been resolved. Investigations are on-going about whether nuclear power generation in Japan should be continued or abolished, but the direction is uncertain. Having lost its stable energy supply foundation, it has become necessary to revisit Japanese energy policy as a whole. With the change in ruling administration from the December 2012 election, these investigations and discussions will proceed. For Japan, household electrical appliances have already

become highly energy efficient, but on the other hand, there is room for improvement in thermal insulation performance of housing. Moreover, feedback programs have hardly diffused into the market at all. That electricity conservation progressed amid this backdrop was due to the large shock of the triple disaster and to the continuing tight electricity supply. How this trend will continue or change will need to be carefully surveyed in the future. However, to enable behaviour change to permeate society, establishment of social systems, such as implementation of feedback programs and diffusion of smart homes is needed. It will be necessary to use the change in environment brought about by the pain of the disaster, to provide policies to furnish the social environment for such developments.

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Glossary

ECA (energy conservation actions): actions taken (here, by households) with intent to decrease energy consumption.

ECR (electricity conservation ratio): percentage of reduction in electricity consumption for a given period, relative to a baseline period. In this report, the baseline could be the same period in the year before the Great East Japan Earthquake, or it could be the same period in the prior calendar year. These cases are distinguished in the text and figures.

Great East Japan Earthquake: This magnitude 9.0 quake occurred on the afternoon of March 11, 2011 off the Pacific coast of Japan's Tohoku region. It was soon followed by tsunami, which led to a nuclear accident at TEPCO's Fukushima Daiichi nuclear power plant. It is often referred to as 3.11, and sometimes as the triple disaster.

KEPCO (Kansai Electric Power Company): One of ten electric utility companies in Japan, in the Kansai region, around Osaka.

kotatsu: a heating appliance attached to the underside of a low table. The table is covered by a quilt, around which people sit on cushions, with legs under the quilt. An alternative to a kotatsu is a hot carpet, or electric carpet, which heats people who sit on it.

TEPCO (Tokyo Electric Power Company): One of ten electric utility companies in Japan, in the Kanto region, around Tokyo.

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