Japan's 6 GW lunch break

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Abstract
We developed a website where, for the first time, one can view the entire electricity demand of Japan in real time. One of the unexpected outcomes of this display is the distinct, country-wide, reduction in electricity use during lunch. Every weekday, at about 12:00, electricity demand falls more than 6 GW and then returns to the pre-lunch trend at 13:00. This phenomenon does not appear in major North American or European load shapes. We investigated the causes of Japan's 6 GW lunch break. Industrial users—who are responsible for about one third of Japan's electricity consumption—are not the cause because electricity-intensive industrial processes do not pause for lunch or implement more extensive load-shifting programs. The residential sector is not the cause either because the phenomenon does not occur on weekends or holidays. Instead, a combination of practices and behaviors in the commercial sector appears to be responsible for the drop in electricity use. The Japanese lunch hour is strongly concentrated between 12:00 and 13:00. Japanese office workers have traditionally switched off lights, equipment, and sometimes even air conditioning before they leave for lunch. We estimated that the savings correspond to 75–150 W per person in the commercial sector. These habits form a foundation that may be extended to include new measures at the end of the workday so as to save more electricity or peak demand. Different strategies will be needed to encourage similar behaviors among American office workers, including providing more local controls for energy-using equipment.

Introduction – Electricity demand profiles for Japan and other countries
An increasing number of grid system operators are posting electricity demand on the Internet updated several times each hour. By compiling this information energy planners and researchers can evaluate how social and natural events influence the electricity demand and supply. The demand profiles created with these data streams offer new insights into energy consumption behavior, especially mass or coordinated behaviors. For example, televised football games, popular serials, and even royal weddings in the United Kingdom have caused sharp fluctuations in electrical demand (Carrington 2015). The annual Earth Hour event regularly causes electricity demand dips of over 10 % in regions throughout the world (Olexsak and Meier 2014). These behaviors will require deeper understanding as grids begin to draw upon large amounts of intermittent renewable sources. These load curves, and the knowledge about what causes them, may also point to opportunities for new energy-saving programs. Japan's electricity use, and an unusual dip, illustrates these problems and opportunities. This dip also illustrates the difficulties in identifying the causes of certain changes in electrical demand.

Japanese utilities have been displaying real-time electricity demand since 2004; however, the service was sporadic and limited to only a few utilities. The situation changed dramatically after the Fukushima events because of the shutdown of the entire fleet of nuclear power plants and the possibility of nationwide electricity shortages. All nine major utilities have since then displayed electricity demand in their service areas. In 2014, the data streams were combined and the first display of national electricity demand in real-time was created at http://currentenergy.ucdavis.edu. The grid authorities in other coun-

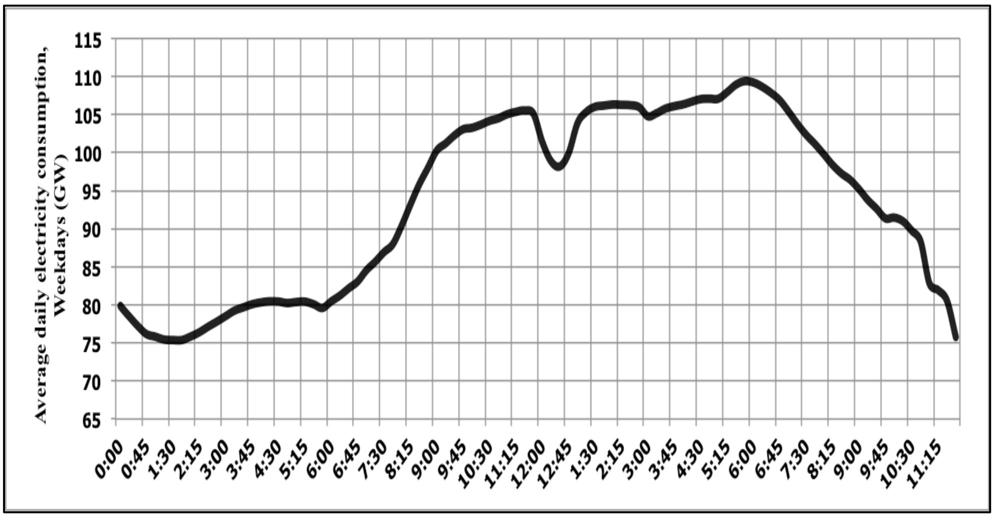

Figure 1. Typical profile of Japan's electricity demand (Sep 26, 2014–Oct 23, 2014). Adapted from currentenergy.ucdavis.edu.

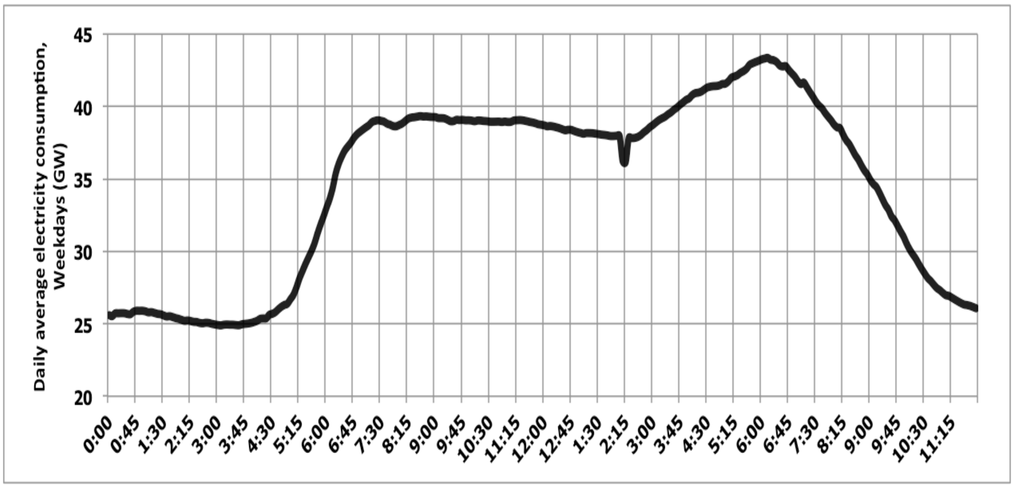

Figure 2. The average daily electricity demand in UK (Sep 26, 2014–Oct 23, 2014). Adapted from currentenergy.ucdavis.edu.

tries, such as South Korea, France, and Italy already report and display national electricity consumption in real time. Figure 1 is a typical profile of Japan's electricity demand. Note that the utilities in the western half of Japan (including Osaka) operate at 60 Hz and the utilities in the eastern half (including Tokyo) operate at 50 Hz. Less than 2 GW is exchanged between the two regions, so there is little practical value of this real-time national display.

Japan's national electricity demand profile revealed – or at least emphasized – several unusual features. The most unusual feature is a regular, sharp dip in demand on most days from 12:00–13:00. The size of this Japan-wide dip is about 6 GW or equal to the output of about six very large power plants (and comparable to the output of the six plants at Fukushima). A 6 GW drop is only about 6 % of total demand in Japan; however, 6 GW represents a huge absolute change and requires substantial resources to service. These fluctuations may become even more difficult to accommodate when electricity supplies are provided by intermittent, renewable sources. It is therefore important to understand the underlying causes of the 6 GW dip and explore strategies to mitigate it in ways that will result in in more economical solutions for both today's generating mix and future generation technologies. We describe below details of the dip in demand and our efforts to explain the behavior causing it.

This dip has been present in some form since the mid-1970s, and was not caused by the Fukushima earthquake and the subsequent nuclear power plant closures. The dip is not caused by a unique regional situation because it appears to a varying extent in the demand profiles of all the utilities. Nevertheless, the phenomenon has not been reported in the literature.

Similar dips are not present in European or North American grids, such as in the UK (Figure 2) or California (Figure 3). The grids in South Korea and Taiwan also have dips at 12:00 – 13:00, though not as large.

It's lunch time

The 6 GW dip in consumption corresponds to lunch time in Japan, so the most obvious explanation is that lunch-related activities (or cessation of activities) are responsible for the dip. But what specific activities cause the change in electricity use? What gets switched off and why? We investigated these questions and explored their implications on managing electricity demand.

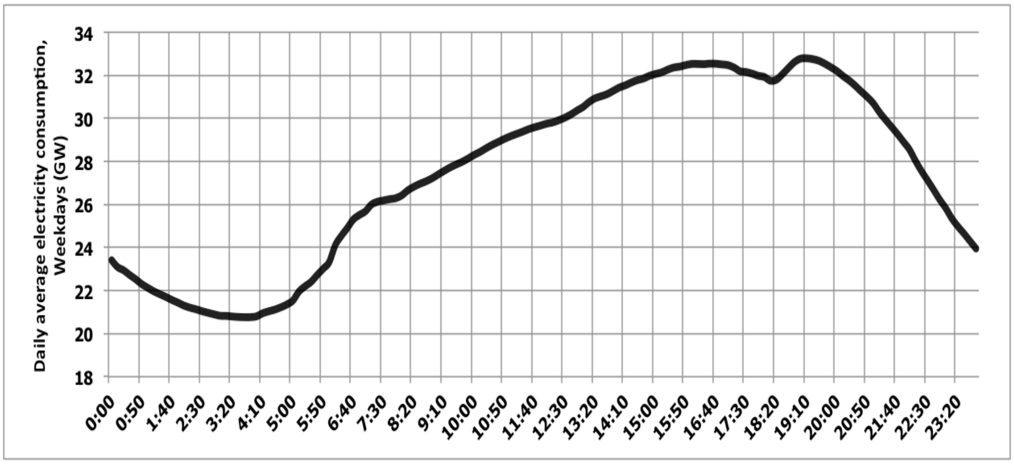

Figure 3. The average daily electricity demand in California (Sep 26, 2014–Oct 23, 2014). Adapted from currentenergy.ucdavis.edu.

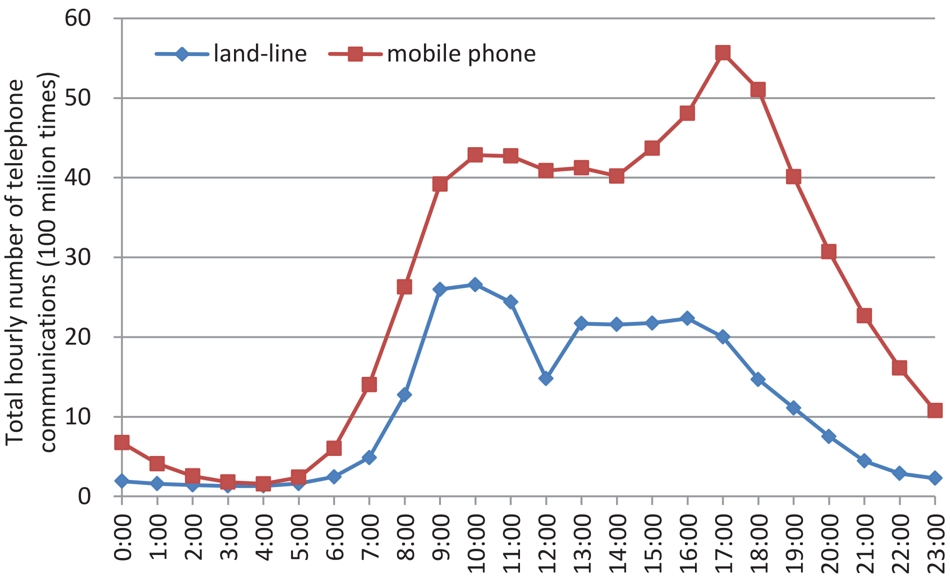

Figure 4. Hourly profiles for land-line and mobile telephone activity (adapted from MIAC 2014).

Who is reducing electricity consumption?

Several clues point towards the commercial sector as the principal source of the drop in demand. (For competitive reasons, Japanese utilities do not make public load data by customer category.) First, the lunchtime dip occurs only on weekdays, not on weekends or holidays. Second, workers in the commercial sector traditionally eat lunch at 12:00–13:00. Japan is a homogeneous culture, so this schedule is widely respected. (After Fukushima, some regional governments tried – unsuccessfully – to shift lunch schedules as a load-leveling measure.)

Third, a Japanese government study of telephone activity revealed differences in usage profiles for land-line and mobile telephones (MIAC 2014). Land-line activity drops almost 40 % from 12:00–13:00 as shown in Figure 4. At the same time, mobile telephone traffic shows no special lunchtime deviation. This behavior is consistent with a hypothesis that employees in commercial establishments will more likely use land-lines for their work calls while mobile calls are personal.

Behavior in other sectors are less clearly linked to the 12:00 dip. Major electricity-intensive industries typically operate non-stop and seek to maintain constant electricity demand. Smaller industries do stop for a lunch break. Schools typically break for lunch from 12:30–13:10.

These observations suggest that the commercial sector is mostly responsible for the reduction in electricity use. There are no data for the commercial sector's contribution to national electricity demand; however it is generally similar to Tokyo's, where it is responsible for about 40 % of peak demand (Tanabe 2015). In Japan, about 40 million people are engaged in the commercial sector. If the commercial sector is fully responsible for the 6 GW drop, then this corresponds to roughly 150 W per person. Small and medium industry is responsible for some of the dip; however, if the commercial sector is responsible for only 3 GW, it still corresponds to 75 W/person. Even a 75 W/person reduction is substantial because it corresponds to each person switching off one piece of electrical equipment or a few lights. For example, 75 W equals about two fluorescent ceiling lights or one desktop PC.

What gets switched off?

The technical explanation for a 6 GW reduction in electricity consumption requires energy savings measures that are both individually significant and widely implemented. Only a few major end uses of electricity are present in the commercial sector: HVAC, lighting, and office equipment are safe to adjust without affecting productivity or safety. Other end uses are present – IT equipment, refrigeration, elevators, miscellaneous – but they tend to operate automatically or are smaller. Broadband traffic is a crude proxy for the automatic energy use by servers, data centers, and data switches, much of which is in the commercial sector. This activity (see Figure 5) is much less sensitive to human intervention (in the short term) and clearly does not exhibit a lunchtime dip in traffic. Broadband traffic seems to follow a completely different schedule uncorrelated to electricity demand.

It appears that switching off equipment during the lunch break is a widespread behavior in commercial buildings. Turning off lights or office equipment during lunch are among the top recommended tips to save energy. (Sometimes the lights are switched off to let employees nap!) The results of one survey conducted for the Japanese Ministry of Environment (Jyukankyo Research Institute 2012) that asked how many offices or organizations switched off lights are summarized in Figure 6.

The Figure shows that in nearly 100 % of government offices, employees switched off lights (though this partly reflects orders from above). These habits are also present in commercial establishments, such as offices, where about ⅔ of them switch off lights. These actions were present even before the Fukushima events but then increased as part of a nationwide effort to conserve electricity. After 2011, more than half of Japanese offices switched off their lights during lunch breaks. In addition, switching PCs and office equipment to sleep mode (or switching off entirely) during lunch is a common behavior.

It is not always clear who initiates and monitors these actions. Large companies have designated persons responsible for energy conservation; however, smaller organizations employ *ad hoc* measures. Whatever the mechanisms, these behaviors have been sustained for over 30 years.

Unique designs of lights and HVAC make it technically feasible – and convenient – for employees to switch off equipment for short periods. In Japanese commercial buildings, employees have easier access to controls for lighting and HVAC equipment than in European and American commercial buildings. For example, lighting is typically zoned. Small to medium-sized commercial buildings are typically serviced with "split system" heating and cooling systems. This means that each office, floor, or zone may have its own heating and cooling system controlled by its own thermostat. It is not uncommon to see a cluster of controls at the entryway to one floor of an office building. This design enables employees to easily control temperatures in their space. In the United States, office computers are typically backed-up during lunch break. Other procedures must be used in Japan if employees are able to shut down their PCs during lunch.

Conclusions

The electrical load profiles for countries and large regions are now becoming widely available and offer new insights into mass or coordinated behaviors. Greater understanding of these behaviors will be required in grids drawing upon large amounts of intermittent, renewable sources. Japan's load profile is an example of such newly-available information. The lunchtime dip

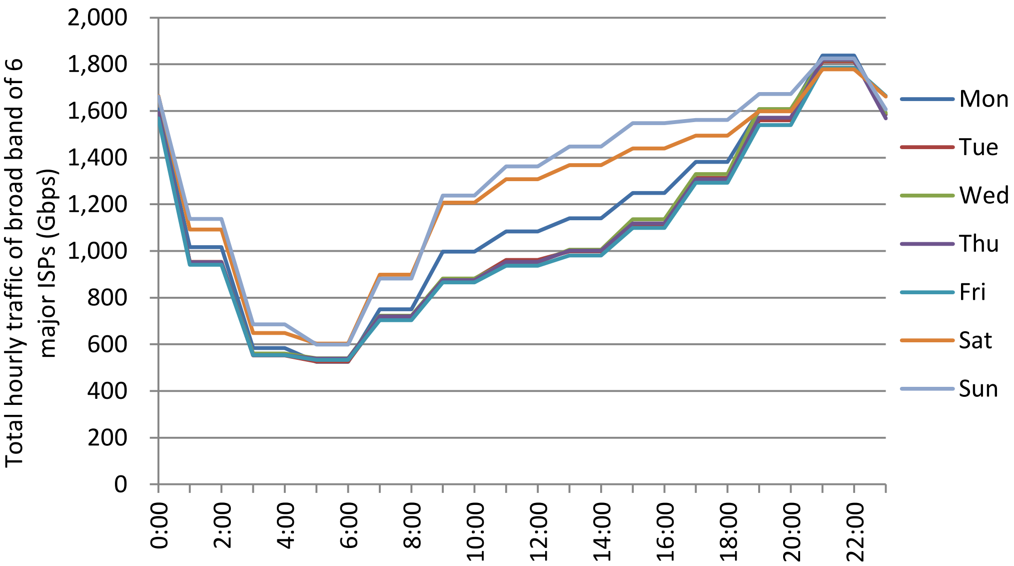

Figure 5. Total hourly traffic of broadband of 6 major ISPs by day of week (adapted from Ministry of Internal Affairs and Communications 2014).

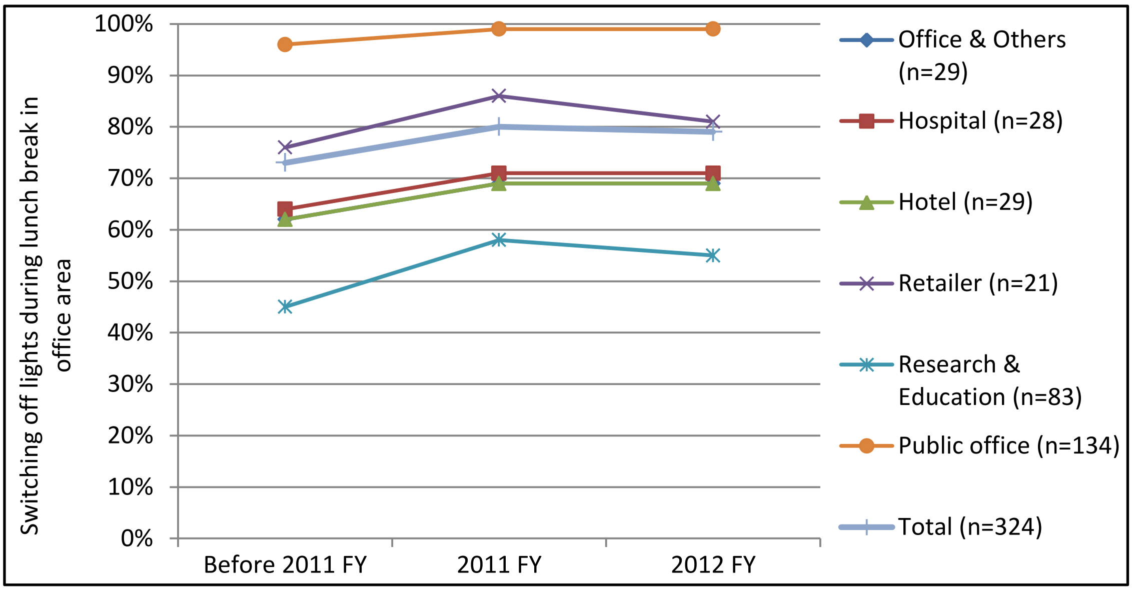

Figure 6. Survey results on switching off lights in Japan (adapted from Jyukankyo Research Institute 2012).

– and its unexpected size of 6 GW – became readily apparent. No similar dip is apparent in European or American grids.

The lunchtime dip appears to have been caused principally by office workers and other workers in the commercial sector. They employ behaviors, such as switching off lights, shutting down computers, and adjusting thermostats to such an extent that they lead to a roughly 6 GW reduction demand, corresponding to 75–150 W per person in the commercial sector. These behaviors have been present for many years but were reinforced by the Fukushima electricity shortages. However, the conclusions of this paper can only be confirmed with the assistance of sectoral load studies conducted by the utilities and in-building surveys of commercial building occupants.

The motivations for these behaviors, and the institutions that have successfully supported them for so long, deserve careful examination. Can they be transferred to other cultures and situations? For Japan, the most important application of these behaviors would be during the summer afternoons, when electricity demand traditionally peaks. For other countries, the ability to respond to fluctuations in renewable generation sources would enhance grid stability and reduce energy costs.

Unique technologies and building infrastructure enable the lunchtime dip. Local controls for lighting and cooling allow individuals (rather than building operators) to implement power-saving measures. Different strategies will be needed to encourage similar behaviors among American office workers, including providing more local controls for energy-using equipment.

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