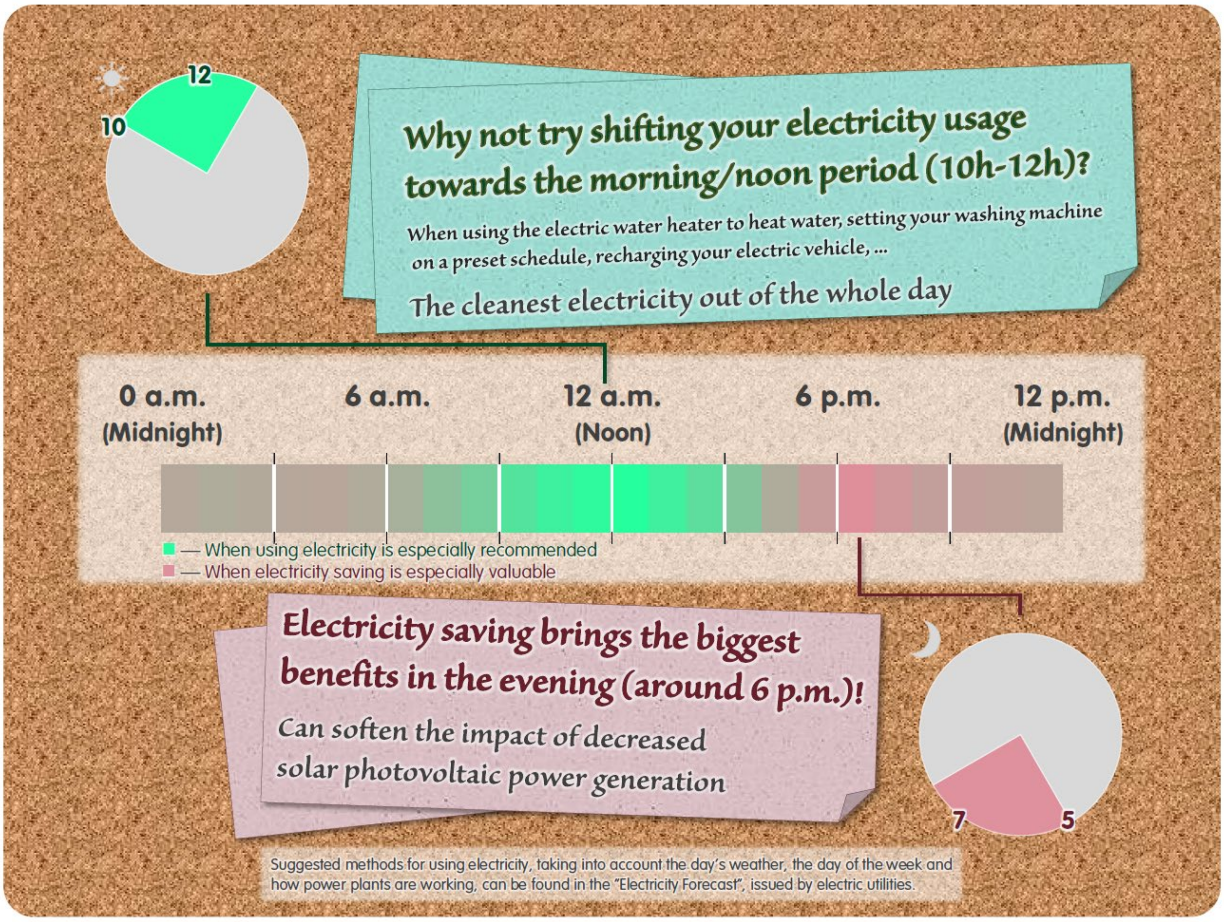
Bringing about both low-carbonisation and a stable power supply by shifting electricity usage to the morning/noon period!

The value of electricity saving is especially high in the evening

YANAGISAWA Akira
Executive Economist, The Energy Data and Modelling Center, The Institute of Energy Economics, Japan



Why not try shifting your electricity usage towards the morning/noon period (10h-12h)?

When using the electric water heater to heat water, setting your washing machine on a preset schedule, recharging your electric vehicle, ...

The cleanest electricity out of the whole day

Electricity saving brings the biggest benefits in the evening (around 6 p.m.)!

Can soften the impact of decreased solar photovoltaic power generation

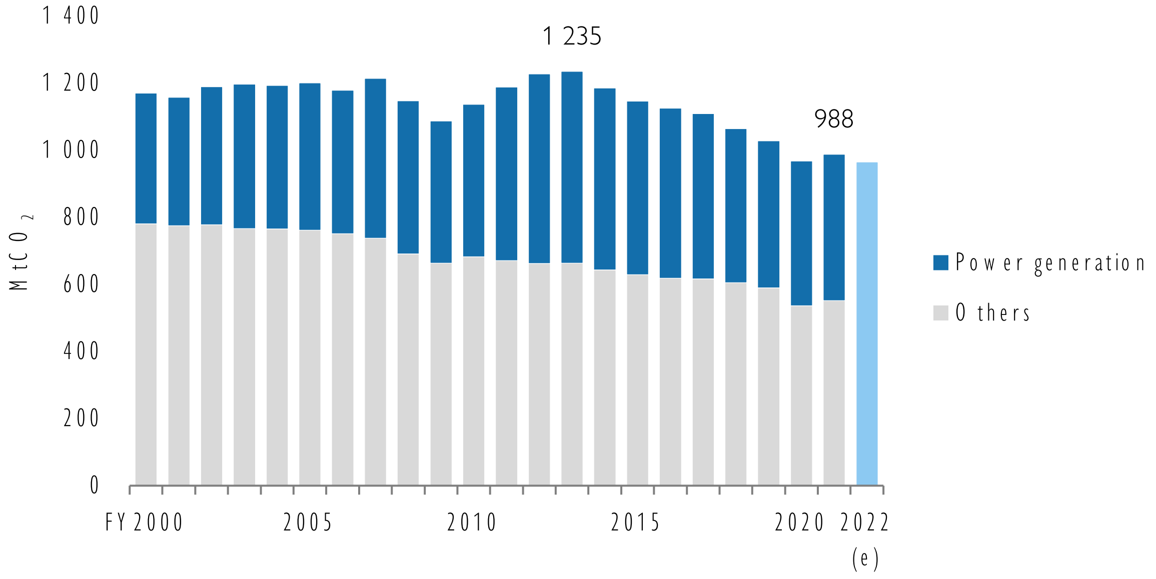
Suggested methods for using electricity, taking into account the day's weather, the day of the week and how power plants are working, can be found in the "Electricity Forecast", issued by electric utilities.

Keywords: Electricity, low-carbonisation, power supply stabilisation, carbon intensity, monthly, hourly

Expectations for energy low-carbonisation and reality

Energy-related carbon dioxide (CO_2) emissions in Japan have been on a downward trend since peaking in FY2013 (Figure 1). Although FY2021 saw emissions rising year-on-year for the first time in eight years due to the gradual recovery of socio-economic activities following the Covid-19 pandemic, from mid-FY2022 onwards emissions began to gradually decrease once again. This declining trend has come about due to decreasing emissions from the power generation sector following a sharp increase in such emissions in the years leading up to FY2013, as well as due to a steady decrease in emissions from sectors other than power generation.

Figure 1 | Energy-related CO_2 emissions



Note: Direct emission basis
Sources: Compiled from Agency for Natural Resources and Energy (ANRE) “Comprehensive Energy Statistics” (https://www.enecho.meti.go.jp/statistics/total_energy/, accessed on 18 September 2023), and The Institute of Energy Economics, Japan (IEEJ) “EDMC Energy Trend” [FY2022]

This reduction in CO_2 emissions outside the power generation sector has been supported exclusively by energy conservation efforts. Meanwhile, reduction measures in the power generation sector (the biggest emitter of all sectors[1]) include suppressing the volume of electricity generated (that is, demand suppression) and improving power generation efficiency. It, however, is generally believed that low-carbonising the energy sources used (i.e. inputs) through the use of renewable energy and nuclear, etc. plays a much larger role. Indeed, we are witnessing the enormous impact that low-carbonisation in power generation can have.

However, it cannot yet be stated that energy low-carbonisation in Japanese power generation has fully played its role in CO_2 emission reduction. This is because, in fact, the decrease in emissions seen in the recent past represents nothing more than a gradual return to the previous levels of emissions that jumped due to the stagnation of nuclear power generation following the Great East Japan Earthquake of 2011. For example, when the current situation is compared with FY2000, energy low-carbonisation not only continues to make no contribution to decreasing emissions, but in fact, has contributed to an increase of 80 Mt in FY2021 (Figure 2). The key factor in the decrease in emissions witnessed over the past two decades has been a continued fall in the volume of electricity generated per unit of gross domestic product (GDP)—that is to say, electricity saving.

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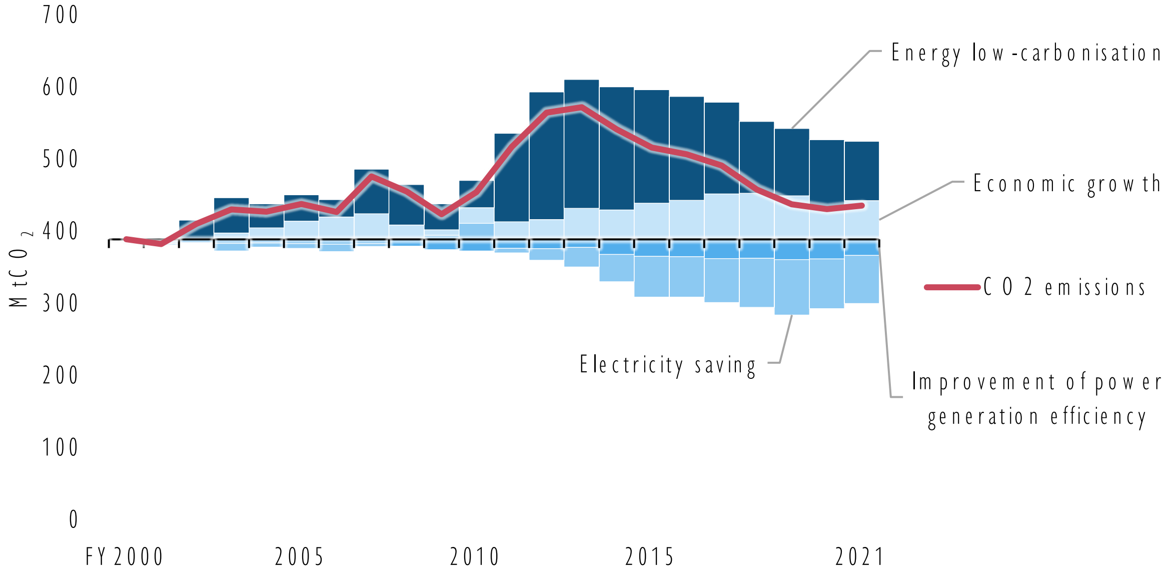
[1] Direct emission basis

Figure 2 | Contributing factors behind increases/decreases in CO_2 emissions from the power generation sector (compared with FY2000)



Notes: Direct emission basis. The contributing factors were calculated based on: CO_2 emissions from power generation sector = GDP × Electricity generated per unit of GDP × Energy consumption (inputs) per unit of electricity generated × CO_2 emissions per unit of energy consumption in power generation sector. “Energy low-carbonisation” refers to the contribution of the decrease in the CO_2 emissions per unit of energy consumption in power generation sector; “Economic growth” refers to the contribution of the increase in GDP; “Improvement of power generation efficiency” refers to the contribution of the decrease in the energy consumption per unit of electricity generated; “Electricity saving” refers to the decrease in electricity generated per unit of GDP.

Sources: Compiled from ANRE “Comprehensive Energy Statistics” (https://www.enecho.meti.go.jp/statistics/total_energy/, accessed on 18 September 2023), and Economic and Social Research Institute, Cabinet Office “National Accounts of Japan” (https://www.esri.cao.go.jp/jp/sna/menu.html, accessed on 19 September 2023)

Growing usage of output control in solar PV power generation

Japan has set out a goal of achieving carbon neutrality by 2050, implying the reduction of total emissions of greenhouse gases (GHGs), of which energy-related CO_2 accounts for a large portion, to net zero, and for the intervening period has also set a goal of reducing GHGs to 46% of FY2013 levels by FY2030 as its Nationally Determined Contribution (NDC). There are high expectations of low-carbonisation of the energy used in power generation as a means for achieving this. However, the power generation mix that is obtained by simply extending a line from the current situation, in which Japan has still not even succeeded in offsetting the increase in CO_2 emissions that occurred following the Great East Japan Earthquake, will not be sufficient for attaining these targets.

Meanwhile, even in the current situation in which solar photovoltaic (PV) power generation makes up a mere 8.3%[2] of total annual electricity generated, an impediment to its utilisation is already apparent. This impediment is the difficulty of human-controlled adjustment of intermittent renewable energy sources such as solar PVs and wind. If the supply-demand balance for electricity breaks down and becomes unstable, this can cause power outages and damage to electrical equipment[3]. As more solar PV power generation has been introduced, oversupply of electricity, in which supply (the generation volume) greatly exceeds demand at certain times, is becoming a problem. Measures adopted to counter this include suppression of thermal power generation, transmission of electricity to other areas, and creating extra electricity demand by using electricity up as water-pumping power[4]; however, when oversupply cannot be resolved through such means, "output suppression" or "output control" is used to suppress generation of some of the solar PVs or wind. Having already been carried out in places such as the Kyushu area where solar PVs have been introduced on a scale that are large compared with electricity demand in the area, output control was carried out in the Kansai and the Chubu areas for the first time in 2023. Even in areas, where regions with such high electricity demand such as the Kinki and the Chukyo located, and the problem of excess power generation was thought to be less likely to manifest, steps have needed to be taken to put output control measures in place due to the considerable progress made with the introduction of solar PVs.

Making efficient use of renewables—and ultimately, using it in larger amounts—requires more than simply laying out solar PV panels, and building more wind turbines in an unplanned manner. The use of the electricity generated also needs to be handled appropriately[5]. New methods for doing this will include large-scale augmentation of the interregional power grid and the introduction of large numbers of storage facilities; however, it is evident that the costs of introducing grid equipment and storage facilities in Japan (where the electric current frequency differs between East and West Japan) will be high. In addition to these "hardware-related" or supply-side measures, the supply-demand balance can also be controlled through "software-related" or demand-side measures—that is, by bringing about temporal shifts in electricity demand by shifting the timing when electricity is used[6].

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[2] In FY2021. ANRE "Comprehensive Energy Statistics" (https://www.enecho.meti.go.jp/statistics/total_energy/, accessed on 18 September 2023)

[3] Supply of electricity is an extreme example of the "just in time" approach, being required to match demand at all times. Not only supply shortages but also oversupplies can destabilise the power grid. In Japan, public awareness of the issue of supply shortages was shared widely following the Great East Japan Earthquake, yet there is still little understanding of the problem of oversupply.

[4] In pumped-storage hydro (PSH) power generation, one method of hydro power generation, water which has been allowed to descend in the course of generation is then pumped back up to an upper reservoir using electric pumps, where it can then be used for more generation. This system thus provides an energy storage function in the form of the gravitational potential energy of water. The electricity consumed in powering the pumps which move the water is referred to as "water-pumping power". Pumped-storage hydro power generation began as an operational method in which pumped water can be used to augment the supply of electricity for short periods of time, whilst the water is pumped at times when there is slack in the electricity supply. In recent years, it has begun to play a crucial role in proactively creating extra electricity demand, because it offers a way to use up electricity as water-pumping power during times of electricity oversupply.

[5] This does not mean that solar PVs will not be suppressed by one kWh whatsoever.

[6] In addition, experiments are also being made with the use of renewable electricity to produce hydrogen by using electrolysis to split water, the hydrogen then being used to generate electricity at the appropriate timing, which could enable the supply of and demand for electricity to be shifted by month or season.

Electricity becomes low-carbon in spring

In the 2000s, discussions began on the estimation of the season and hourly carbon emission factors for electricity, with the aim of reducing CO_2 emissions by making use of relatively low-carbon electricity. For example, the Three-Year Plan for Promotion of Regulatory Reform (Revised) (Cabinet Resolution, 2008), states the following:

Providing incentives for consumers to shift their electricity consumption from daytime to nighttime hours would be an effective means for reducing emissions of CO_2 generated from Japan's power generation plants (However, this would be the case only in situations where a daytime to nighttime shift causes CO_2 emissions to fall. Conversely, in some cases, usage will need to be shifted from nighttime to daytime hours.) In addition, providing incentives to the user to select electric utilities for each timeslot after taking into account the emissions of CO_2 generated by electricity consumption by the consumer's company may also be effective. To enable this, discussions must include the adoption of "average seasonal emission factors" and conclusions reached on this matter.

However, given the recognition that (1) carbon emission factors for electricity did not necessarily show fixed seasonal trends, (2) differences between daytime and nighttime hours were limited[7], and (3) accurate estimation of seasonal and hourly values was a difficult task, seasonal carbon emission factors were not adopted in the end. In recent times, however, Japan has experienced electricity oversupplies and demand shortfalls in the spring as demand for air-conditioning falls even while solar PV power generation rises, while at the same time, low-carbon energy is forming an increasing share of Japan's power generation.

At the national level hereafter, the carbon intensity of Japan's electricity (CO_2 emissions per unit of electricity generated)[8], considered one indicator for measuring the level of electricity low-carbonisation), exhibits unstable trends (Figure 3-(1)). However, if the trend-cycle component alone is displayed as in Figure 3-(2) with the aim of analysing the overall trend, there is a general downward trend in carbon intensity as a result of the growing introduction of solar PV power generation and the increased biomass-fired power generation. Or, if we display only the seasonal component as shown in Figure 3-(3), it is apparent that the size of the cyclical fluctuations by season—lowest in May and peaking in January—has grown greater over the years. The magnitude of these fluctuations grew from just over 80 gCO_2/kWh in FY2016 to just under 110 gCO_2/kWh in FY2022, and is projected to grow still further in the years ahead in line with the increase in solar PV power generation.

There seems little reason not to make effective use of the low-carbon electricity that is available on a cyclical basis and is predictable in nature. Bringing about a shift in demand for electricity by suppressing consumption of the relatively high-carbon electricity of winter months and proactively using the lower-carbon electricity available in the spring would be helpful for encouraging efficient energy low-carbonisation.

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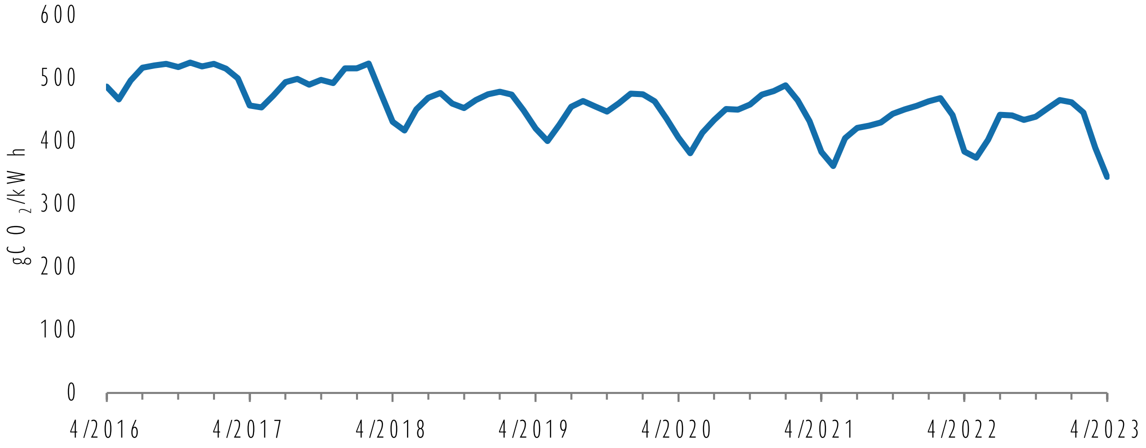
[7] Against a 24-hour average of 453 gCO_2/kWh in FY2007, the average for daytime hours (8h-22h) was 462 gCO_2/kWh, while that for nighttime hours (22h-8h) was 435 gCO_2/kWh. Secretariat, Study Group on Methods of Calculating a Utility-Specific Emission Factor Based on the Act on Promotion of Global Warming Countermeasures, Ministry of the Environment "Introduction of an average seasonal emission factor" (https://ghg-santeikohyo.env.go.jp/files/calc/kento_j04/mat04.pdf, accessed on 18 September 2023)

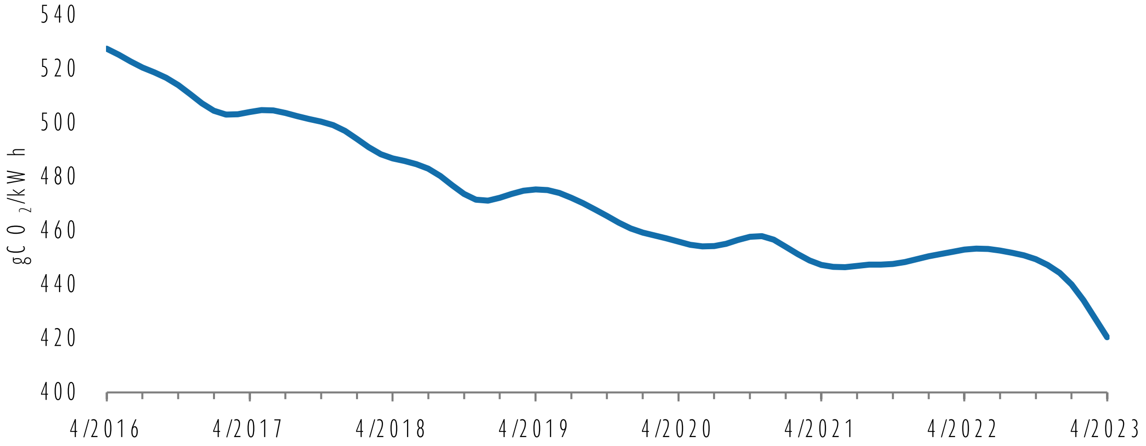
[8] Estimated from "Electric Power Statistics" and from standard calorific values and carbon emission factors. In addition, volumes of other heavy fuel oil are divided into heavy fuel oil A and heavy fuel oil C proportionately according to their consumption ratio, mixed gas are divided into coke oven gas, blast furnace gas, and converter gas proportionately according to their consumption ratio, other gas is treated in the same manner as city gas, and carbon emission factors of others are set at 0. For electricity received from entities other than electric utilities, the carbon intensity of electricity by thermal power generation is set at the same level as that of generation at electricity utilities. Credits for GHGs are not taken into account.

Figure 3 | The monthly carbon intensity of electricity supplied by utilities, the trend-cycle component and the seasonal component

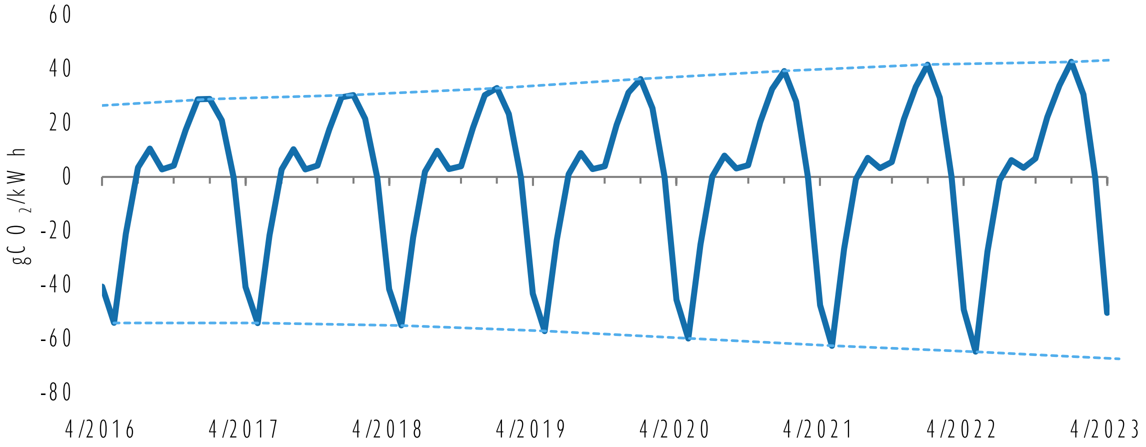
(1) Original series



(2) Trend-cycle component



(3) Seasonal component



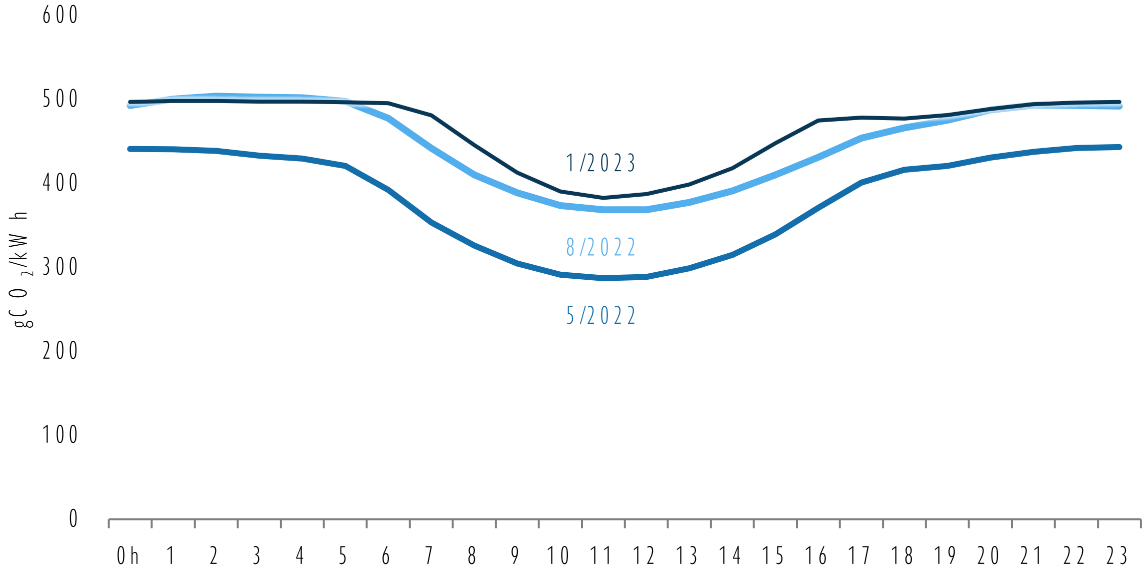
Source: Estimated based on Ministry of Economy, Trade and Industry "Electric Power Statistics", and other sources.

Daytime electricity is lower-carbon than nighttime electricity

However, shifting the timing of electricity usage by month or season is often challenging or offers limited scope. This means we should also consider shifting usage on an hour-by-hour basis, which poses fewer hurdles.

It may be surmised that the carbon intensity of electricity varies from hour to hour as well. It, however, is difficult to estimate such values accurately since data relating to the power generation/fuel consumption status for each type of generation in each timeslot is not publicly available. This paper therefore greatly simplifies the picture based on the actual data available for use, by creating an approximate estimate for the carbon intensity of electricity for each hour based on the assumption that the hourly carbon intensity for thermal power generation for any given month remains constant at the values obtained in the previous section (Figure 4)[9].

Figure 4 | Example of the hourly carbon intensity of grid electricity



Note: The carbon intensity of thermal power generation does not vary by hour within any given month, and is represented by the values shown in Figure 3-(1).
Source: Estimated based on the actual supply-demand data for general electricity transmission and distribution utilities

Electricity grows lower-carbon as time moves from midnight to daytime hours; it then grows higher-carbon once again as time moves from daytime towards midnight. It is possible to observe seasonal trends for the 12h noon timeslot, the 18h evening timeslot, and the 0h midnight timeslot, from the monthly shifts in carbon intensity for each timeslot (Figure 5). Looking at the trend-cycle component, it is the carbon intensity of the 12h timeslot (a time when solar PVs are highly active) that has seen the most dramatic decline in carbon intensity over the years. Turning to the time series where both the trend-cycle component and the seasonal component have been added (that is, the series that is easiest to predict), it can be seen that although the 12h timeslot does see a somewhat larger rise than the others around the New Year, it constantly remains at a level lower than the 0h timeslot, unlike in earlier years[10]. In other words, it looks as though shifting electricity demand from the nighttime to daytime hours would be effective from the perspective of making use of lower-carbon electricity. In addition, as the 18h timeslot occupies a slightly lower level than the 0h timeslot, a shift from nighttime to evening would also be effective to a

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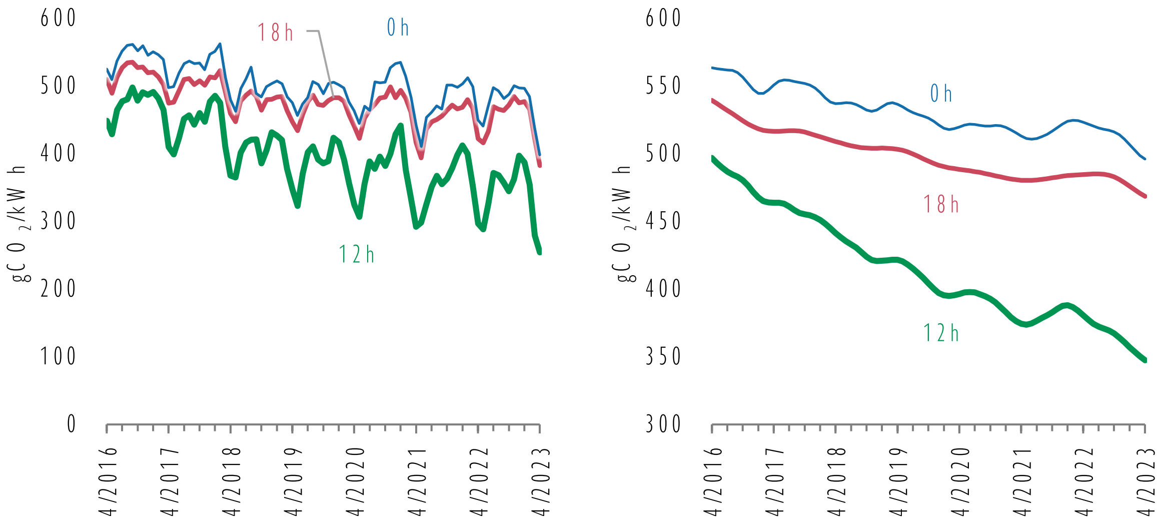
[9] Estimated based on the actual supply-demand data for general electricity transmission and distribution utilities and on "Electric Power Statistics". Values for each timeslot are the average for the month in question.

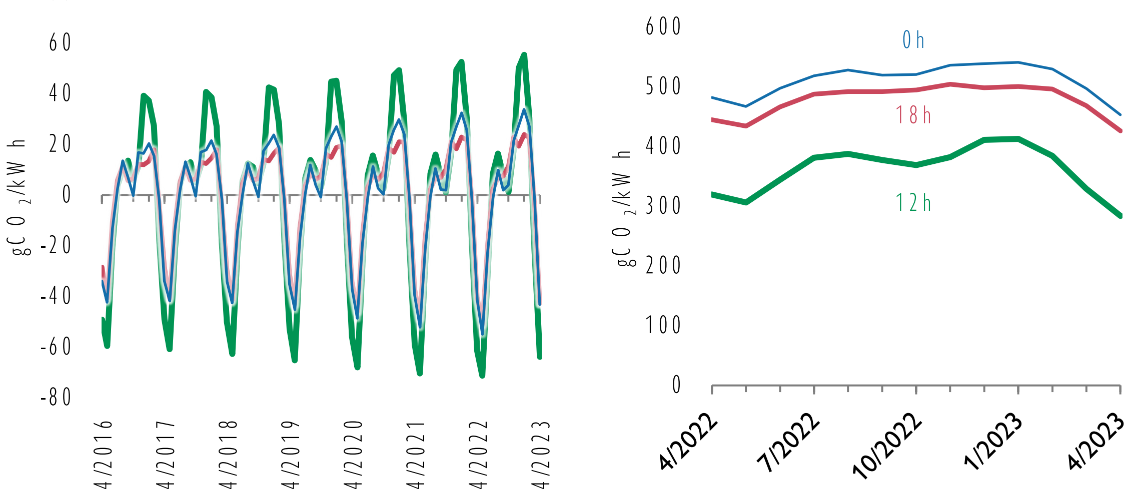
[10] For example, at the time of the discussions for the Three-Year Plan for Promotion of Regulatory Reform (Revised) (Cabinet Resolution, 2008), there was a general perception that electricity was lower carbon in the nighttime hours when the share of nuclear formed a higher share of electricity generated, because these discussions preceded the Great East Japan Earthquake and the introduction of the Feed-in Tariff (FIT) system (in 2012), which triggered the introduction of solar PVs on a huge scale.

certain extent. This, however, cannot be treated as a conclusion to this matter.

Figure 5 | Hourly carbon intensity of grid electricity (0h midnight timeslot, 12h noon timeslot, 18h evening timeslot), trend-cycle component, seasonal component and trend-cycle component + seasonal component


(1) Original series

(2) Trend-cycle component


(3) Seasonal component

(4) Trend-cycle component + Seasonal component

Note: The carbon intensity of thermal power generation does not vary by hour within any given month, and is represented by the values shown in Figure 3-(1).
Source: Estimated based on the actual supply-demand data for general electricity transmission and distribution utilities

The pitfall of focusing exclusively on CO_2 must be avoided

There are risks in using low-carbonisation alone as the standard when shifting electricity demand. In some cases, such an exclusive emphasis can result in grid instability. In recent times, the danger of electricity supply shortages has been experienced more frequently in seasons of high demand (summer and winter). Then pumped-storage hydro power generation and delivering water-pumping power are being used as a barometer for tight or slack supply-demand situations[11]. With pumped-storage hydro power generation, different timeslots exhibit different monthly/seasonal fluctuation patterns for the volumes that are generated, unlike the patterns seen for carbon intensity (Figure 6)[12].

This fact can serve as a source for analysing monthly shifts in the value for each timeslot as carbon intensity, in order to evaluate shifts in electricity demand from the perspective of supply stability. At the 12h timeslot, large volumes of electricity are used for water pumping from winter through spring. Meanwhile, in summer, there is a gradual change from electricity generation during the high-load period to electricity consumption for water pumping. At the 0h timeslot, electricity is generally being used as water-pumping power, although the volume is usually lower than at 12h. Conversely, at the 18h timeslot, electricity generation is always carried out regardless of month or season. This suggests that overemphasis on a single perspective could potentially result in the 18h timeslot experiencing shortages of electricity supply against demand all year round[13]. If electricity supply stability is used as the evaluation criterion, a shift in electricity demand towards the evening hours would actually need to be avoided, a very different conclusion to that reached when low-carbonisation is treated as the yardstick. When supply stability is the criterion, the most favourable period to which to shift demand is the period from 10h to 12h, where there is a need to create more demand or there is relatively ample slack in the supply capacity, regardless of the season.

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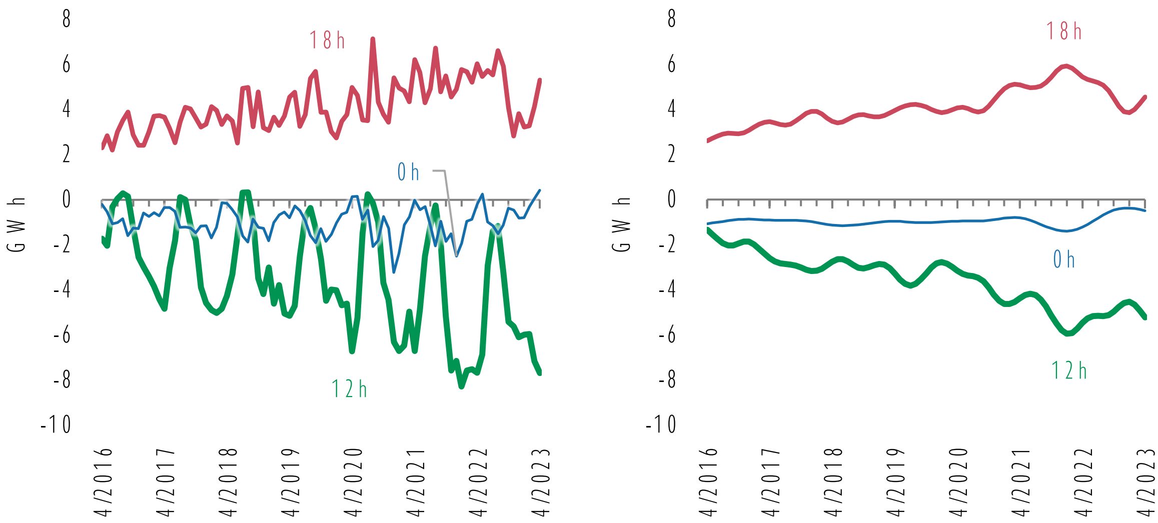
[11] Pumped-storage hydro power generation requires the water that will provide the hydroelectric power sources to be pumped into an upper reservoir. This pumping of the water consumes electricity. In recent years, a strong tendency has developed for this kind of pumping to be used to proactively create extra demand for electricity in order to use up the excess electricity generated by solar PVs. Whichever way these systems are viewed, it is fair to assume that the pumping of water will take place at times when there is relative slack in the electricity supply. Conversely, although the pumped-storage hydro power generation itself may sometimes be undertaken with the aim of disposing of water from reservoirs that have filled to capacity, as a general principle it is carried out at times where additional electricity supply is needed. Therefore, Pumped-storage hydro power generation and water-pumping power are here used as simple proxy indicators for the electricity supply-demand balance.

[12] Values for each timeslot are the average for the month in question.

[13] This is the time period corresponding to the head of the duck suggested by the so-called “duck curve”.

Figure 6 | Hourly pumped-storage hydro power generation (0h midnight timeslot, 12h noon timeslot, 18h evening timeslot), trend-cycle component, seasonal component and trend-cycle component + seasonal component

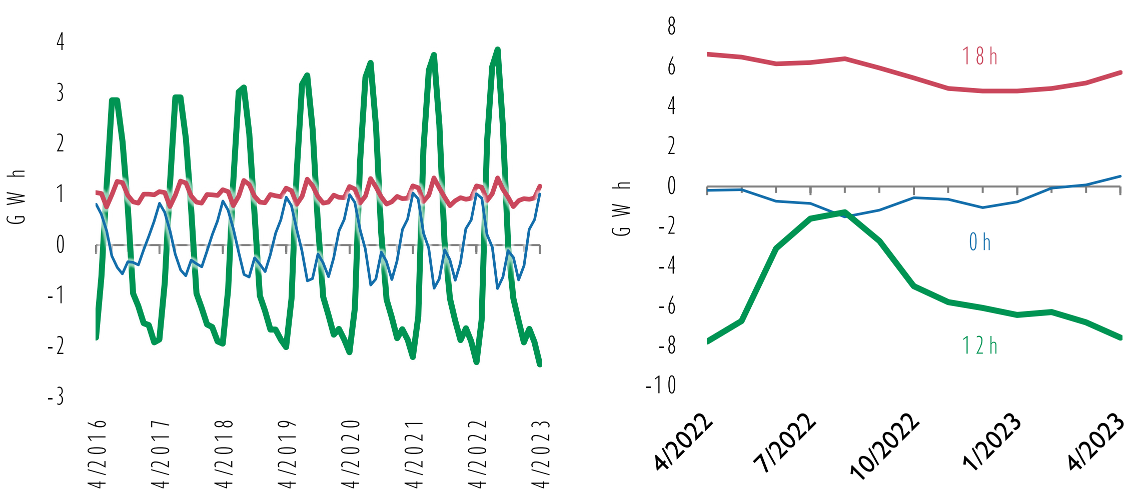


(1) Original series

(2) Trend-cycle component

(3) Seasonal component

(4) Trend-cycle component + Seasonal component

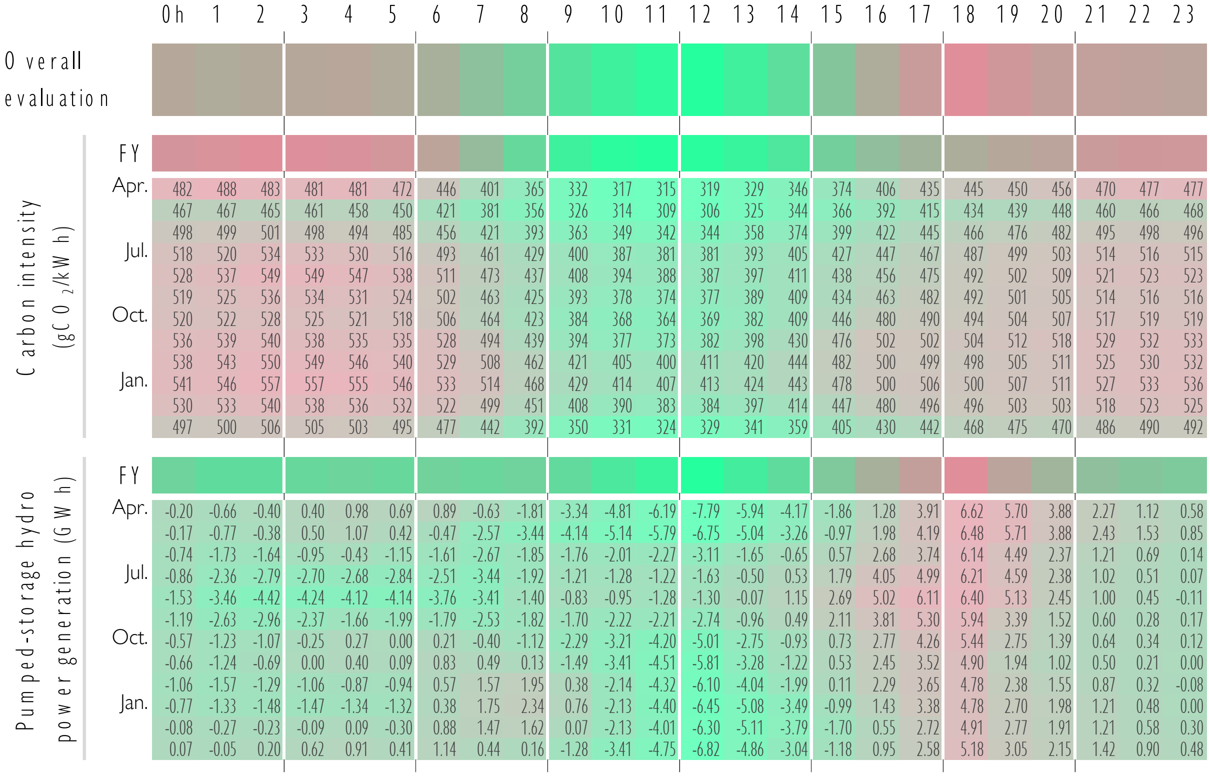


Notes: Values for each timeslot are the average for the month in question. Negative values indicate the consumption of electricity for water pumping.
Source: Estimated from actual supply-demand data for general electricity transmission and distribution utilities

Using electricity over the 10h to 12h period: Helping to achieve a balance between promoting low-carbonisation and ensuring a stable supply

The above discussion suggests that, in general, shifting nighttime electricity demand towards the morning/noon period (10h through 12h) would be beneficial for both low-carbonisation and supply stabilisation (Figure 7)[14]. Conversely, the timeslot to which shifting demand should most be avoided (or, to put it another way, where shifting demand away from the timeslot in question is the most important) is around 18h.

Figure 7 | Evaluation of different timeslots as destinations for shifted demand of grid electricity



Carbon intensity (gCO_2/kWh)

	0h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Apr.	482	488	483	481	481	472	446	401	365	332	317	315	319	329	346	374	406	435	445	450	456	470	477	477
	467	467	465	461	458	450	421	381	356	326	314	309	306	325	344	366	392	415	434	439	448	460	466	468
	498	499	501	498	494	485	456	421	393	363	349	342	344	358	374	399	422	445	466	476	482	495	498	496
Jul.	518	520	534	533	530	516	493	461	429	400	387	381	381	393	405	427	447	467	487	499	503	514	516	515
	528	537	549	549	547	538	511	473	437	408	394	388	387	397	411	438	456	475	492	502	509	521	523	523
	519	525	536	534	531	524	502	463	425	393	378	374	377	389	409	434	463	482	492	501	505	514	516	516
Oct.	520	522	528	525	521	518	506	464	423	384	368	364	369	382	409	446	480	490	494	504	507	517	519	519
	536	539	540	538	535	535	528	494	439	394	377	373	382	398	430	476	502	502	504	512	518	529	532	533
	538	543	550	549	546	540	529	508	462	421	405	400	411	420	444	482	500	499	498	505	511	525	530	532
Jan.	541	546	557	557	555	546	533	514	468	429	414	407	413	424	443	478	500	506	500	507	511	527	533	536
	530	533	540	538	536	532	522	499	451	408	390	383	384	397	414	447	480	496	496	503	503	518	523	525
	497	500	506	505	503	495	477	442	392	350	331	324	329	341	359	405	430	442	468	475	470	486	490	492

Pumped-storage hydro power generation (GWh)

	0h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Apr.	-0.20	-0.66	-0.40	0.40	0.98	0.69	0.89	-0.63	-1.81	-3.34	-4.81	-6.19	-7.79	-5.94	-4.17	-1.86	1.28	3.91	6.62	5.70	3.88	2.27	1.12	0.58
	-0.17	-0.77	-0.38	0.50	1.07	0.42	-0.47	-2.57	-3.44	-4.14	-5.14	-5.79	-6.75	-5.04	-3.26	-0.97	1.98	4.19	6.48	5.71	3.88	2.43	1.53	0.85
	-0.74	-1.73	-1.64	-0.95	-0.43	-1.15	-1.61	-2.67	-1.85	-1.76	-2.01	-2.27	-3.11	-1.65	-0.65	0.57	2.68	3.74	6.14	4.49	2.37	1.21	0.69	0.14
Jul.	-0.86	-2.36	-2.79	-2.70	-2.68	-2.84	-2.51	-3.44	-1.92	-1.21	-1.28	-1.22	-1.63	-0.50	0.53	1.79	4.05	4.99	6.21	4.59	2.38	1.02	0.51	0.07
	-1.53	-3.46	-4.42	-4.24	-4.12	-4.14	-3.76	-3.41	-1.40	-0.83	-0.95	-1.28	-1.30	-0.07	1.15	2.69	5.02	6.11	6.40	5.13	2.45	1.00	0.45	-0.11
	-1.19	-2.63	-2.96	-2.37	-1.66	-1.99	-1.79	-2.53	-1.82	-1.70	-2.22	-2.21	-2.74	-0.96	0.49	2.11	3.81	5.30	5.94	3.39	1.52	0.60	0.28	0.17
Oct.	-0.57	-1.23	-1.07	-0.25	0.27	0.00	0.21	-0.40	-1.12	-2.29	-3.21	-4.20	-5.01	-2.75	-0.93	0.73	2.77	4.26	5.44	2.75	1.39	0.64	0.34	0.12
	-0.66	-1.24	-0.69	0.00	0.40	0.09	0.83	0.49	0.13	-1.49	-3.41	-4.51	-5.81	-3.28	-1.22	0.53	2.45	3.52	4.90	1.94	1.02	0.50	0.21	0.00
	-1.06	-1.57	-1.29	-1.06	-0.87	-0.94	0.57	1.57	1.95	0.38	-2.14	-4.32	-6.10	-4.04	-1.99	0.11	2.29	3.65	4.78	2.38	1.55	0.87	0.32	-0.08
Jan.	-0.77	-1.33	-1.48	-1.47	-1.34	-1.32	0.38	1.75	2.34	0.76	-2.13	-4.40	-6.45	-5.08	-3.49	-0.99	1.43	3.38	4.78	2.70	1.98	1.21	0.48	0.00
	-0.08	-0.27	-0.23	-0.09	0.09	-0.30	0.88	1.47	1.62	0.07	-2.13	-4.01	-6.30	-5.11	-3.79	-1.70	0.55	2.72	4.91	2.77	1.91	1.21	0.58	0.30
	0.07	-0.05	0.20	0.62	0.91	0.41	1.14	0.44	0.16	-1.28	-3.41	-4.75	-6.82	-4.86	-3.04	-1.18	0.95	2.58	5.18	3.05	2.15	1.42	0.90	0.48

Notes: 🟩 indicates favourable times to shift demand towards; 🟥 indicates those that are not favourable. Both the values for carbon intensity and those for pumped-storage hydro power generation reflect the trend-cycle component + seasonal component (FY2022 values). The negative values for pumped-storage hydro power generation represent the electricity consumed by water pumping.

Source: Estimated from actual supply-demand data for general electricity transmission and distribution utilities

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[14] However, a different set of recommendations would probably be required if the perspective were that of load-levelling at power supply facilities.

Promoting widespread behavioural changes

The notion of temporal shifts in electricity demand has been in existence for a long time. There are price menus which provide economic incentives to encourage these, including cheaper electricity at nighttime or higher prices in the summer. In recent years, demand response systems have been put together which proactively engage with consumers in the immediate term, aiming to increase the economic efficiency of the electricity supply and stabilise the supply-demand balance. However, in systems which aim to encourage shifts in electricity demand through economic incentives alone, the costs of such inducements must be provided on a reasonable scale to operate the system, and the electricity supply-demand balance must be forecast accurately in order to ensure such costs are not wasted. Yet forecasting supply and demand accurately in advance is no easy task. Furthermore, it is surmised that one of the reasons why seasonal carbon emission factors were not ultimately adopted in the past was the insufficient rigour to form part of a system such as the systems for estimating, reporting and publicly announcing GHG.

The discussion hitherto has been developed by setting out quantitative estimations, and is not intended to give any actual suggestions as to day-to-day operational methods for the electricity supply. Neither is it intended to serve as a detailed guide for electricity saving or shifting electricity demand, which varies according to daily conditions including region, days of the week, weather, temperature, the operational/malfunction status of power plants, and the like. Information of this kind is what the various utilities issue in the form of their "Electricity Forecasts". Rather, what this paper stresses is the importance of ensuring that as many people as possible recognise the kind of typical cyclical patterns that can be predicted in advance, as set out above. As the spread of this kind of awareness leads electricity consumers to voluntarily and habitually change their actions and behaviours, it will promote low-carbonisation of electricity and a more stable electricity supply whilst minimising dependence on high-cost hardware and systems.

One example where the actions and behaviours of electricity consumers can have an impact is water heating by electricity. Previously, electricity during nighttime hours was considered lower-carbon than that in the daytime. For that reason, a strategy of water heating with heat pump water heaters using nighttime electricity was adopted as a measure for effective CO_2 reduction in addition to the high energy efficiency of heat pumps., In recent times, however, daytime electricity has become lower-carbon than nighttime, regardless of the month or season. Getting consumers to alter the time settings for water-heating from nighttime to daytime in line with this change in the situation can boost the CO_2 reduction effects of electric water heaters with no need for additional investment. Turning to the supply-demand balance side, meanwhile, using daytime electricity to heat water is also helpful for stabilising the electricity supply, by creating extra demand for electricity during the times when oversupply is apt to occur. Furthermore, using nighttime electricity to heat water is no longer favoured in the way it once was. This is because the reduction in nuclear power generation following the Great East Japan Earthquake has resulted in a decrease in (low-carbon) baseload power sources operated on a stable basis during the night.

Similar to electric water-heaters, yet in fact predicted to be far more important, are electric vehicles (EVs) and plug-in hybrid vehicles. When EVs are recharged using standard charging methods which require leaving them plugged in for long periods, it should be possible to use the functions of the EV system to ensure that the actual recharging itself takes place automatically during those times that are most favourable from the perspectives of low-carbonisation and supply stabilisation of electricity. However, with fast charging (which charges the vehicle in a short space of time), the actual time that the vehicle is plugged in is inherently short. Given that consumers are typically making use of fast charging at times such as when returning home in the evening, fast charging is not only of limited effectiveness in terms of contributing towards low-carbonisation and supply stabilisation even if the most optimal time within this limited period of time is chosen, but in fact could potentially have negative effects on both aspects. In other words, whether these technologies have positive or negative effects will depend greatly on whether EV owners have at least a vague awareness of what times are generally most favourable for recharging, and whether they habitually put this into practice or not. EV consumes considerable amounts of electric energy (kWh), and fast charging exerts impacts in electric power of the range of tens of kW or still higher, incomparably large when compared with electric water-heater.

Spreading appropriate understanding of this issue is the key to gently inducing changes in actions and behaviours among large numbers of electricity consumers at the mass level. To do this, it is essential that accurate information be provided in clear formats. In other words, rather than issuing highly detailed information specialised for particular regions and days/times that users will need to receive and update frequently, it is best to provide succinct information that has been consolidated and set out in an organised way and which aims to foster awareness of “what the overall picture is”. Care should be taken with this point, as overemphasising rigour and precision can lead to communications becoming excessively complex and lengthy, which may make it harder to develop wider understanding[15].

In addition, when information is to be shared across a wide sphere, it is generally thought best to do so earlier. As EVs are starting to be adopted on a wide scale, such information needs to be rolled out as soon as possible. Once misconceptions or outdated information that are no longer appropriate has spread—for example, that EVs do not cause any CO_2 to be emitted, or that top-up charging is harmful[16]—trying to overturn such myths is no easy task. Incorrect ideas, once lodged in consumers’ minds, can harm efforts to low-carbonise and stabilise the electricity supply.

Although electricity and other forms of energy are essential for socio-economic activities and our daily lives, the understanding of electricity (of the kind that is often seen in relation to infrastructure) has not permeated society to any great depth. For example, calls for electricity saving on the grounds of power shortages have been frequently heard in recent times; unfortunately, however, it is highly dubious whether the contents of the requests themselves—should users avoid using electricity at peak times? Should they reduce their total electricity usage during some periods?—are being conveyed correctly. Needless to say, efforts are underway to improve situations like this where such information is only known among a select few, but what is needed is guidance that will help consumers naturally act in the right way, without relying on too much detail or specialised theories. If the need for high-cost hardware and systems can be reduced as a result of this, the advantages of such guidance will be considerable.

Contact: report@tky.ieej.or.jp

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[15] For example, the values for carbon intensity discussed in this paper are average values, and are not marginal values that indicate changes that occur when shifts have occurred in electricity demand. However, marginal values cannot be obtained from the statistics, and can be greatly differing values since the types of power supply that increase or decrease vary depending on the situation. Having numerous combinations of presupposed conditions and suggested responses (“Do A in the case of X”, “Do B in the case of Y”, etc.) is not ideal when information needs to be presented succinctly.

[16] The idea that top-up charging is harmful comes from discussions about nickel-cadmium batteries and nickel-metal hydride batteries which are subject to the memory effect, and does not apply to lithium-ion batteries.