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Japan's Approach to Reducing Greenhouse Gas Emissions from Data Centers

Takao SHIINO

Nomura Research Institute

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Japan's approach to addressing climate change involves the use of a synergistic effect generated by the efforts of multiple concerned parties to achieve greater reductions in carbon dioxide (CO_2) emissions.

A data center refers to either a dedicated space or building that houses anywhere from a few hundred to several tens of thousands of computers. Recently, we have been facing the problem of rapidly increasing electricity consumption by data centers, which is attributable to growing information processing volume caused by the increased use of the Internet and computers for everything from information processing for business applications to the viewing of videos by individuals. Nevertheless, the increase in the absolute volume of information processing means that data centers are contributing to greater efficiency in social activities. Accordingly, while accepting this increase, we must strive to improve energy efficiency.

In the U.S., power usage effectiveness (PUE) has been adopted as an energy efficiency metric for data centers. While this metric reflects the energy-saving performance of support facilities in a data center such as air conditioning and power supply equipment, it does not measure that of the information technology (IT) equipment.

In Japan, a new metric known as a Data Center Performance Per Energy (DPPE) and four sub metrics constituting DPPE have been developed; this metric is being promoted internationally. The DPPE metric takes into account the energy efficiency of both the IT equipment and support infrastructure of a data center.

Japan's thinking behind DPPE is that if all the parties involved with a data center, including computer users, IT equipment suppliers and data center builders, strive to improve each sub-metric for which they are responsible, the overall synergistic effect will lead to major reductions in Greenhouse Gas emissions.

I Data Center Performance per Energy (DPPE) Metric Proposed by Japan

Japan's strength resides in its concept of substantially reducing carbon dioxide (CO_2) emissions by integrating the efforts of all the different parties concerned that are aimed at addressing climate change.

As a member of the Study Committee on the Trends in Energy Efficiency Improvement Measures for Data Centers, Etc. organized by the Ministry of Economy, Trade and Industry, the author participated in a Data Center Energy Efficiency Workshop where representatives from Japan, the US and Europe met on February 2, 2010, in San Jose, California, in the US. At this workshop, Japan's ideas on the Data Center Performance Per Energy (DPPE) metric were presented and were well received and endorsed by the US and European representatives.

A feature of the DPPE metric being proposed by Japan is that it clarifies the role of each party involved in the building and operation of data centers such as data center builders, computer manufacturers, computer operators and data center owners in improving energy efficiency. The identified roles are then expressed as indices. This initiative aims to promote the reduction of Greenhouse Gas emissions from data centers by combining all of the efforts contributed by each party.

While the idea of setting energy efficiency indices for data center facilities has already been considered in the US and Europe, little thought has been given to the effects and the practical application of the indices that cover all related elements.

II Climate Change and Data Centers

In fiscal 2008, Japan entered the first commitment period of the Kyoto Protocol. Japan's commitment was to reduce CO_2 and other Greenhouse Gas emissions on average by 6 percent below the 1990 level by fiscal 2012. However, with a 1.9-percent increase in fiscal 2008, it is clear that major cuts will be required if this target is to be reached. A more ambitious post-2012 target was set by the then Hatoyama cabinet that is reducing Japan's Greenhouse Gas emissions by 25 percent below the 1990 level by 2020. The biggest obstacle to achieving this target is that as of now, CO_2 emissions from the commercial sector such as offices and stores have actually increased by 41.7 percent. To cope with this situation, the Law on the Rational Use of Energy (known as the Energy Conservation Law) was amended in fiscal 2009 to go beyond energy conservation in factories, and to cover the commercial sector as well. The revised law requires energy conservation efforts for each company (including offices and stores) and covers a wider range of companies and facilities as its targets. Within this commercial sector, energy consumption by data centers has been growing rapidly.

By "Data Center," we mean a dedicated space or a building containing anywhere between hundreds or several tens of thousands of large-scale computers, with a total floor space of between several thousands to several tens of thousands of square meters. The largest data center extends over four or five stories—exceeding a large supermarket in size.

Computers housed in these data centers are used for various kinds of data processing with which we are very familiar such as bank deposit and withdrawal processing, airline reservations and weather forecasting. In addition, they are also used for sophisticated work such as the design of automobiles. In recent years, Internet-based processing has been increasing. E-mail messages and web pages have migrated from monochrome to color, and users have come to commonly exchange photos and videos. As a result, the amount of information that is stored and exchanged within data centers has increased rapidly. As for videos, not only those produced by broadcasting stations, but also those created by consumers, are now being transmitted and stored in data centers. Accordingly, the amount of information that is stored and exchanged within data centers has been further increasing at an exponential rate.

In addition, with the goal of achieving a low-carbon society and conserving energy, a large number of sensors have been installed to improve energy efficiency in a wide range of fields including factories, offices, homes, roads and transportation. Information acquired through such sensors is collected at data centers, where it is processed and controlled by computers. The increasing efforts throughout society to reduce Greenhouse Gas emissions have also led to a growing demand for data centers.

1 Background of problems presented by data centers in efforts to address climate change

As explained above, while the increase in power consumption by data centers presents problems in any efforts to address climate change, it is also true that society is making even greater demands for data centers. In an ordinary office building, the installation of the most up-to-date equipment usually improves energy efficiency and reduces the absolute amount of energy consumption. In the case of a data center, however, the latest equipment that is installed to improve processing capacity becomes smaller and has a higher level of performance year by year. Each time such equipment is installed, therefore, the absolute amount of energy consumption per unit floor area increases. This factor has led to a sharp increase in data center energy consumption. As a result, if we look at the annual change in the energy consumption of buildings in the commercial sector, we find that most buildings that are ranked high in terms of greater energy consumption are data center buildings. Table 1 lists the 20 buildings in Tokyo with larger rates of increased energy consumption, which were announced by the Tokyo Metropolitan Government. The first-ranked S Building on Table 1 nearly tripled its power consumption in two years, from 2005 to 2007, with an increase of about 175 percent. Most of the top 20 buildings in terms of the rate of increase are data center buildings, which present problems in controlling overall CO_2 emissions.

2 EPA report was first in giving warning

The US Environmental Protection Agency (EPA) was first in making full-scale efforts to analyze the issue of increasing energy consumption by data centers. In August 2007, the EPA submitted its report on the results of a study in response to a request from the US Congress. According to this report, data centers consumed about 61 billion kilowatt-hours (kWh) in 2006, or 1.5 percent of total US electricity consumption. The energy consumption in 2006 is estimated to be more than double that consumed for this purpose in 2000, or at an average annual increase rate of 12 percent. This increasing trend is expected to further accelerate. If the current trends in efficiency remain the same, energy consumption by data centers could nearly double again in five years, i.e., by 2011. To address this issue, US IT companies such as Intel, Microsoft, IBM and Dell organized the Green Grid to improve the energy efficiency of data centers. This consortium is dedicated to conducting research on new energy-saving practices and promoting the adoption of these practices. The Green Grid proposed the use of Power Usage Effectiveness (PUE) in 2007, which is the metric that enables data center operators to measure the energy efficiency of their data centers. After two years, PUE has received broad adoption all over the world. PUE is the ratio obtained by dividing all power consumption in a data center by the electricity consumed by the IT equipment within the data center, and is expressed by the following formula.

$$\text{PUE} = \frac{\text{Total Data Center Power Consumption}}{\text{Electricity consumed by IT equipment}}$$

It should be noted that data centers defined by the EPA report include not only large stand-alone buildings as listed in the materials published by the Tokyo Metropolitan Government (see Table 1), but also one floor or one room of a building that is used as a computer room housing servers and other IT equipment. Because of this, the electricity consumed by relatively small, inexpensive servers known as volume servers accounted for 34 percent

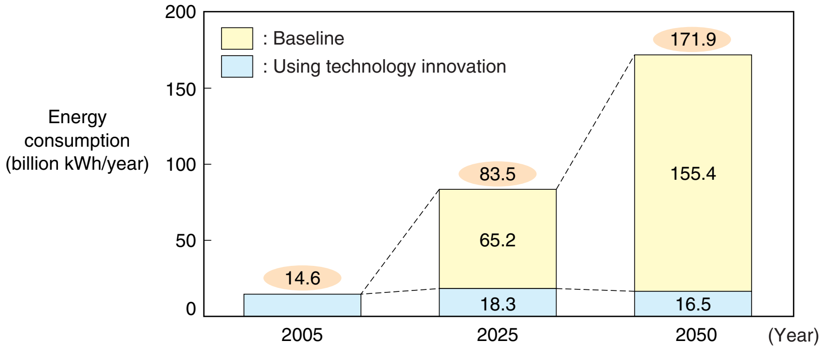
Table 1. Buildings with larger rates of increased power consumption in Tokyo (in the commercial sector)

(Unit: CO_2-ton)

	Increase in 2 years (%)		Name of building	Name of company	2005 (base year)	2006	2007
1	174.6	DC	S Building	@ Tokyo	20,903	38,176	57,407
2	112.9	DC	Shiohama Building	KVH	9,539	14,003	20,309
3	106.8	DC	Shibuya Technical Center	KDDI	8,076	12,946	16,705
4	91.6		Sumitomo Fudosan Nishi-Shinjuku Building No. 4	Sumitomo Realty & Development	2,402	2,922	4,602
5	70.7	DC	NTT DATA Omori Sanno Building	NTT DATA	5,985	6,441	10,217
6	67.1	DC	NTT Building 1100	NTT East	4,896	6,665	8,180
7	66.9	DC	SOFTBANK MOBILE Shinsuna Center	SOFTBANK MOBILE	14,206	20,224	23,706
8	48.5	DC	Bank of Tokyo-Mitsubishi UFJ Tama Business Center	The Bank of Tokyo-Mitsubishi UFJ	20,884	23,916	31,013
9	44.8		Toyo Ekimae Building	Sumitomo Realty & Development	2,406	3,037	3,483
10	41.5	DC	Tokyo Shinjuku Data Center	IDC Frontier	4,997	5,521	7,069
11	37.4	DC	NTT Communications 0925	NTT Communications	5,298	6,699	7,280
12	35.0	DC	NAS Center (Nikkei Minamisuna Bekkan)	Nikkei Advanced Systems	12,771	14,360	17,240
13	34.2		Tennoz First Tower	Tennoz Management	3,126	3,800	4,194
14	32.2	DC	TIS Tokyo Center	TIS	15,099	17,341	19,958
15	31.8	DC	TIS Tokyo Center III	TIS	5,757	6,328	7,587
16	31.5		Shinsei Bank Meguro Production Center	Shinsei Bank	6,111	6,693	8,036
17	30.1		Bank of Tokyo-Mitsubishi UFJ Aobadai Bunkan	The Bank of Tokyo-Mitsubishi UFJ	1,059	1,219	1,378
18	28.8		JTB Foresta Nishikan	JTB ESTATE	3,737	4,395	4,815
19	28.5	DC	NTT DATA Kasai Techno Building	NTT DATA	10,637	12,001	13,665
20	28.5	DC	Marubeni Tama Center	Marubeni	5,014	5,820	6,441

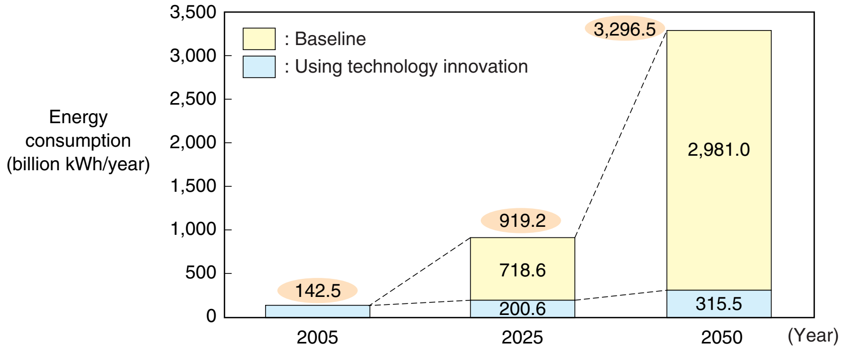
Note: DC = data center.
Source: Compiled based on materials published by the Tokyo Metropolitan Government.

Figure 1. Forecast for data center energy consumption in Japan



Source: Compiled based on "2008 Report of the Survey and Evaluation Committee of the Green IT Promotion Council," published in June 2009.

Figure 2. Forecast for worldwide data center energy consumption



Source: Compiled based on "2008 Report of the Survey and Evaluation Committee of the Green IT Promotion Council," published in June 2009.

of all electricity consumed in data centers. This type of server was responsible for the majority (68 percent) of the electricity used by all US servers in 2006. Among all server classes, volume servers also experienced the greatest growth in energy consumption at an annual growth rate of 17 percent.

As such, data centers defined in the EPA report refer to the locations of all servers within the US. These locations are considered as data centers regardless of their floor area or the format of the building where the IT equipment is installed. Based on such definitions, the EPA report warns of an increase in power consumption by data centers.

3 Forecast for electricity consumed by Data Centers in Japan

In 2008, the Green IT Promotion Council was established in Japan to promote energy conservation in IT-related industries. The council conducted studies on savings in energy consumption by IT equipment and energy conservation in society through the use of IT[1].

In fiscal 2008, the Green IT Promotion Council used a similar method as that adopted in the EPA report to forecast the amount of electricity consumed by data centers in 2005, 2025 and 2050. The report estimates that the annual power consumption by data centers in Japan that was 14.6 billion kWh in 2005 will increase about 6-fold to 83.5 billion kWh in 2025 and about 12-fold to 171.9 billion kWh in 2050 if the current energy efficiency trends remain the same (baseline in Figure 1). With leading-edge technology innovation occurring in the future, however, the report predicts that annual power consumption could be kept at the level close to that of 2005, i.e., 18.3 billion kWh in 2025 and 16.5 billion kWh in 2050 (using the technology innovation as shown in Figure 1). In other words, the council aims to control energy consumption by data centers by improving energy efficiency around 5-fold in 20 years and around 10-fold in 45 years.

The Green IT Promotion Council also forecasted power consumption by data centers all over the world. According to these projections, the annual worldwide data center power consumption that was 142.5 billion kWh in 2005 is expected to increase to 919.2 billion kWh in 2025 and 3,296.5 billion kWh in 2050 (baseline in Figure 2). If leading-edge innovative technologies are applied, the report estimates that it could be controlled to about twice the level in 2005, i.e., in 200.6 billion kWh, in 2025 and 315.5 billion kWh, and in 2050 (using the technology innovation as shown in Figure 2).

III Trends in Data Center Energy-Efficiency Regulations

As described in Chapter II, moves are seen in Japan, the US and Europe to control ever increasing data center energy consumption. Because large data centers are often stand-alone buildings, energy-efficiency regulations similar to those applied to large commercial buildings are considered to be imposed. The regulatory approaches can be broadly divided into the following two methods:

(1) Rating and qualifying data center buildings with high energy efficiency
(2) Imposing regulations including penalties on energy consumed by data center buildings

In the US, where environmental regulations are generally lenient, the rating and qualifying method (Item (1)) is adopted. In Europe, where strict regulations are applied, penalties (Item (2)) are starting to be imposed. In Japan, in a similar way as in Europe, the Tokyo Metropolitan Government launched a strict control scheme on total CO_2 emissions.

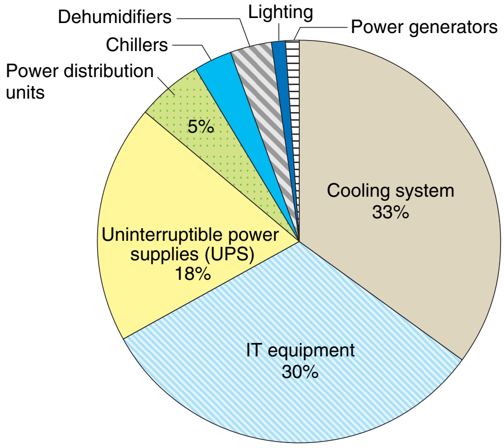
1 Trends in regulations on data centers in the US

In the US, the program in which the energy performance of data centers is rated and those in the top 25 percent of efficiencies will be able to apply for the Energy Star mark is scheduled to be launched in June 2010. In the past, energy efficiencies of about 100,000 buildings including commercial facilities such as offices and hotels as well as public facilities such as schools have already been reported. For ordinary commercial buildings, annual energy use per unit floor area is measured, and is then compared with other similar types of facilities on a scale of 1 – 100. Buildings that achieve a score of 75 or higher are eligible for the Energy Star mark and certificate. As of February 2010, there are more than 8,000 Energy Star qualified buildings. Plaques with the Energy Star mark can be seen at the entrances of hotels, etc.

In rating the energy performance of ordinary commercial buildings, energy consumption per unit floor area was considered an appropriate index and adopted for the measurement of energy efficiency. However, as described in Chapter II, at data centers, every year servers are becoming smaller and smaller while having a higher level of performance, improving processing capacity per unit floor area. This has caused power consumption per unit floor area to increase. Consequently, this index was no longer appropriate for data centers. Accordingly, in October 2007, the EPA started to conduct studies on appropriate energy efficiency metrics for data centers and collect related data. Based on these studies, the EPA developed a new rating program suitable for data centers, which will be launched in June 2010.

In examining the energy efficiency of a data center, the EPA adopted the PUE metric proposed by the Green Grid, as explained in Chapter II.

Figure 3. Ratio of electricity consumed by components in a data center



Source: The Green Grid.

The PUE is a ratio that expresses the proportion of electricity used by IT equipment to total data center power consumption. “PUE = 1.0” means a status where nothing other than IT equipment requires electricity. Actually, however, devices such as cooling equipment and power supply equipment also consume large amounts of electricity, as shown in Figure 3. In the case of the status assumed by Figure 3 where IT equipment is responsible for 30 percent of total data center power consumption, the PUE value is 3.3 (1/0.3).

To rate the energy performance of data centers in the US, the PUE values and incidental information for 150 data centers within the US were collected and analyzed. As shown in Figure 4, the PUE values of these data centers are distributed anywhere between 1.26 and 3.25, with the average PUE value being 1.91. The largest number of data centers fall within the range of 1.51 to 1.75.

Relationships with the ambient temperature, reliability/availability and scale of a data center were also analyzed. With respect to ambient temperature, the EPA examined monthly changes in energy consumption in 10 data centers in low-temperature areas and that of 10 data centers in high-temperature areas. As a result, the EPA concluded that no major changes were observed in energy consumption during summer and winter, and that no significant correlation exists between PUE value and ambient temperature.

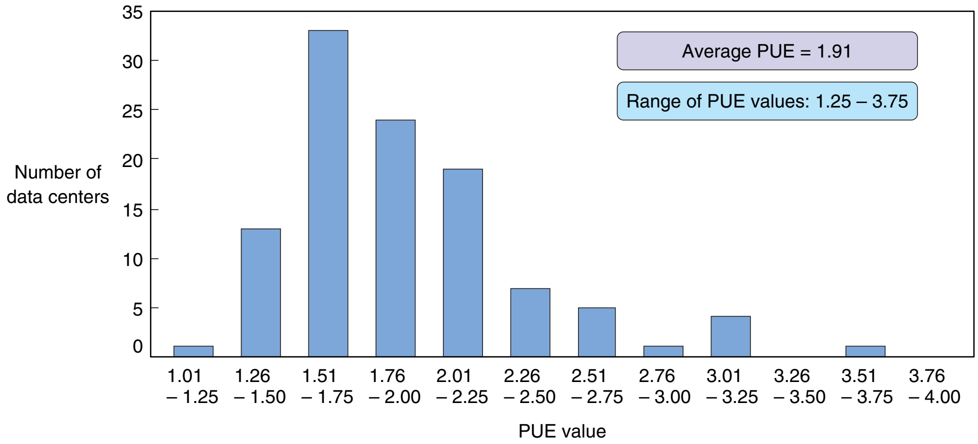
As for the reliability/availability standards of data centers, the Uptime Institute of the US created the Tier Classification System. This system defines four distinct Tier performance criteria—Tier I to Tier IV. The Tiers are progressive and each incorporates the requirements of all the lower Tiers. There are greater requirements in the order from Tier I to Tier IV such as those for redundancy for air-conditioning, power supply and IT equipment. The EPA also analyzed the relationships between Tier levels and energy consumption, and found no significant correlation between Tier levels and PUE values. Theoretically, data centers at the levels of Tier III and Tier IV in which redundant power supply and air handling systems are provided are considered to present less efficient energy performance and greater PUE values. Actually, however, because these data centers are usually built by companies specializing in data centers and managed by professional operators, leading-edge technologies are applied to improve efficiency. These efforts are considered to contribute to little differences in energy efficiency between data centers at Tier I and Tier II levels and at Tier III and Tier IV levels.

However, the EPA recognizes a significant correlation between data center size and PUE value. According to EPA analyses, as shown in Figure 5, the larger the total power consumption by IT equipment within a data center, that is, the larger the size of a data center, the smaller the PUE value and the greater the energy efficiency achieved by benefiting from economies of scale. Based on this data, the EPA developed a regression equation that expresses the relationship between the size of a data center and PUE value, and calculates the predicted PUE value based on the size (total IT equipment energy consumption) of a data center. The EPA rating system uses the energy efficiency ratio that is obtained by dividing the actual PUE value by the predicted PUE value. In the top 25 percent of data centers in terms of energy efficiency, this ratio was improved by 14 percent or more.

Accordingly, data centers with an actual PUE value that is greater than the predicted PUE value by 14 percent or more may be eligible for the Energy Star mark. Because the larger the size of a data center, the smaller the predicted PUE value, a data center will not be able to earn the Energy Star mark unless it can achieve an actual PUE value that is less than the predicted PUE value. Actually, as we can see in the linear regression line shown in Figure 5, the predicted PUE value for a mid-scale data center with a total energy consumption of around 200 million Btu is about 1.9. This data center can earn the mark even if its actual PUE value is about 1.6. However, because the predicted PUE value of a large-scale data center with a total energy consumption of around 600 million Btu is about 1.7, this data center will not be eligible for the mark unless its actual PUE value is less than about 1.5. Therefore, not all data centers achieving an actual PUE value of 1.6 are necessarily eligible for the Energy Star mark (Figure 6).

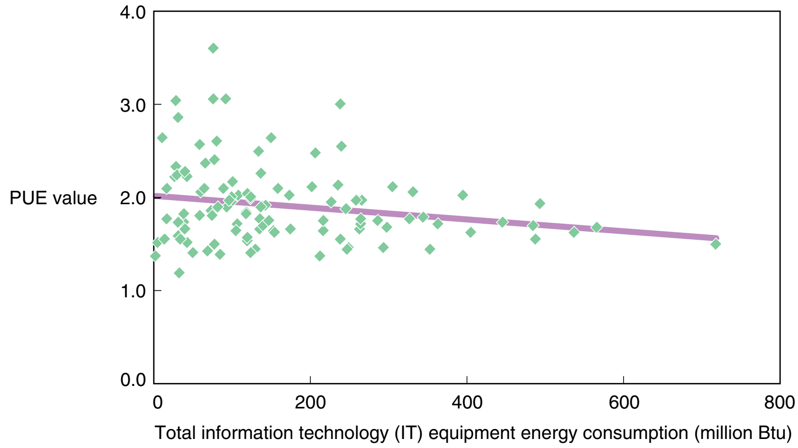
Thus, the Energy Star mark will be issued to about one-fourth of the data centers that register their PUE

Figure 4. Distribution of PUE values of data centers in the US



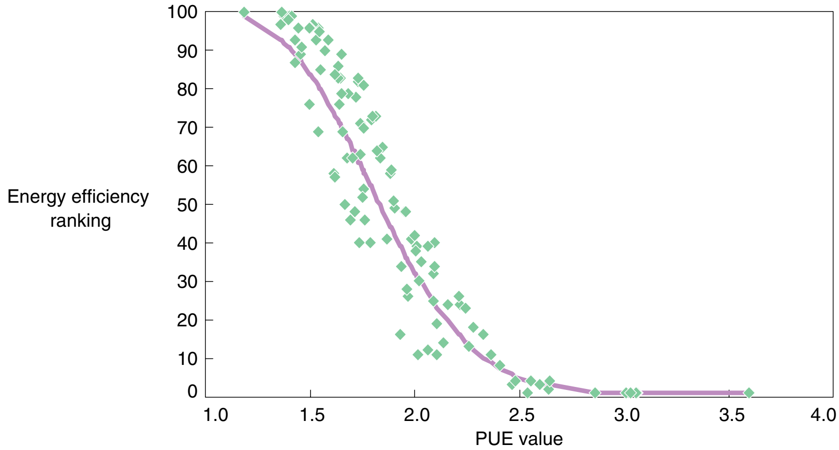
Note: PUE = Power Usage Effectiveness.
Source: Compiled based on materials published by the US Environmental Protection Agency (EPA).

Figure 5. Relationship between PUE value and size of data centers in the US



Source: Compiled based on materials published by the US Environmental Protection Agency (EPA) .

Figure 6. Relationship between PUE value and energy efficiency ranking of data centers in the US



Source: Compiled based on materials published by the US Environmental Protection Agency (EPA) .

values with the EPA after such values are verified by a licensed agency. This program is designed to encourage the efforts of data center owners and operators to improve their PUE values.

2 Regulatory trends of data centers in the EU and UK

The key legislation of the European Union (EU) covering ordinary buildings is the Directive on Energy Performance of Buildings. After December 2006, this directive requires the issuance and presentation of "energy performance certificates (EPCs)" that express the theoretical energy performance of buildings when buildings are constructed, sold or rented. An EPC certifies only the energy performance, and is neither a reduction goal nor a certificate that takes special characteristics of data centers into account. For data centers, in November 2008, the Code of Conduct for Data Centers was launched by the EU Director General to present the criteria for energy efficient data centers. This code is a voluntary program aimed at data center owners and operators. Companies signing the code are expected to set their targets and make efforts to meet these criteria.

At the same time, the EU set a series of climate and energy targets to be met by 2020, which are known as the 20-20-20 targets. Specifically, these include: a 20 percent reduction in CO_2 emissions below 1990 levels; use of more than a 20 percent share of renewable energy; and a 20 percent reduction in energy consumption through improved energy efficiency. In order to meet these targets in the remaining ten years, compulsory measures are beginning to be adopted.

In April 2010, the UK started a mandatory climate change and energy saving scheme, which is known as the CRC (carbon reduction commitment) energy efficiency scheme. In pursuit of overall targets of reducing Greenhouse Gas emissions by 2050 by at least 80 percent compared to the 1990 baseline, the CRC scheme sets caps on total energy consumption by large-scale buildings. Owners of large-scale buildings that have used more than 6,000 MWh per year in all buildings that one owner has are obliged to participate in CRC. The scheme is expected to apply to around 5,000 buildings. In April each year, the owners of these buildings purchase allowances based on the CO_2 emissions predicted for that year (allowances are priced at £12 per CO_2-ton at the maximum). Subsequently, efforts by relevant organizations to reduce energy consumption are evaluated in terms of absolute amount and rate of reduction, and their energy saving performance is made known. The owners of buildings achieving good performance will receive bonuses; those having poor performance will have to pay penalties.

Unlike ordinary buildings, energy used by data centers is increasing year after year, making it unlikely for data centers to record good performance and instead likely to pay penalties. It appears unreasonable to apply such an absolute target scheme to data centers, whose production output increases more and more in response to growing social demand. Rather, an intensity target scheme that aims to improve energy efficiency would be more appropriate.

3 Trends in environment-related regulations adopted by the Tokyo Metropolitan Government

In April 2010, the Tokyo Metropolitan Government launched Japan's first mandatory program that caps total energy consumption and applies to large-scale buildings including data centers.

The Ordinance on Environmental Preservation to Secure the Health and Safety of Citizens of Tokyo (Environmental Security Ordinance) adopted by the Tokyo Metropolitan Government applies to about 1,400 large-scale buildings that consumed the crude oil equivalent of more than 1,500 kiloliters of energy in the preceding fiscal year (Table 2). These buildings are required to cut their CO_2 emissions over the fiscal 2010 – 2014

Table 2. Overview of Tokyo Metropolitan Environmental Security Ordinance

Subject buildings	Buildings that consumed the crude oil equivalent of more than 1,500 kiloliters of energy in the preceding fiscal year
Buildings subject to reduction obligation	Buildings that consumed the crude oil equivalent of more than 1,500 kiloliters of energy in three consecutive years
Reduction plan phases	1st plan phase: Fiscal 2010 – 2014 2nd plan phase: Fiscal 2015 – 2019
Base-year level	In principle, the average emission level over a period of any three consecutive years between fiscal 2002 and 2007
Obligated reduction rate	1st plan phase: By 6 percent to 8 percent from the base-year level 2nd plan phase: By 17 percent from the base-year level
Top-level buildings	Top-level buildings: The obligated rate of reduction is reduced to 1/2 Near top-level buildings: The obligated reduction rate is reduced to 3/4
Tenants	All tenants must cooperate with a building owner; specified tenants are required to submit their own emission reduction plans
Implementation of reduction obligation	If the required level cannot be attained through a building owner's own efforts, a cap and trade system can be used
Penalties	A violator will be ordered to cut emissions by 1.3 times the amount it fails to reduce; the names of violators are published and the expenses incurred are billed by the governor

Source: Compiled based on materials published by the Tokyo Metropolitan Government.

period (the first plan phase) by 8 percent on average, and by 17 percent on average over the fiscal 2015 – 2019 period (the second plan phase) from base-year levels that are calculated from average emissions over a period of any three consecutive years between fiscal 2002 and 2007. Any such building that is unable to meet the target level can purchase carbon credits from other entities that have reduced their CO_2 emissions by more than the obligated levels in a cap and trade system. Any building that still fails to achieve its reduction target will be subject to penalties, which include publishing the names of violators and billing by the governor for the expenses incurred to purchase the necessary amount of carbon credits. In fiscal 2010, which is the first year of this program, subject buildings are required to report their base-year levels and to measure the actual amount of emissions during the fiscal year.

In the same way as in the UK, Tokyo's program also sets absolute-based emission caps. However, the program includes a rule that a data center, where center facilities are clearly augmented (6% or more) and production capacity is expanded due to an increase in the number of customers and demand, can increase its base-year level by the proportion of such increase. This rule incorporates a concept similar to the intensity target scheme.

4 Trends in environment-related regulations at the national level

When we look at regulatory trends at the national level, the revised Law on the Rational Use of Energy was enforced in April 2010. Under the revised law, reduction obligations that were based on the energy consumption by each building (including a factory) in the past, and they are now based on the energy use by a company as a whole. An entire company is required to endeavor to save energy and achieve the improvement of energy efficiency by an annual average of 1 percent. Because of this revision, data centers located within an office building and small-scale data centers that were not covered in the past are now subject to reduction obligations. However, because the revised law adopts intensity-based emission caps by aiming to improve energy efficiency rather than absolute-based emission caps, this scheme is appropriate for data centers that increase production output in response to growing social demand.

IV Contribution of Data Centers to the Environment

1 Concentrating overall social needs for data processing in data centers

As was previously discussed in this paper, increased attention is being paid to data centers whose energy consumption has been rapidly increasing. Most countries have started to take action to control such increases. Nevertheless, what we must first acknowledge is that the use of computers at data centers essentially aims to provide greater efficiency in business activities and administrative services and increases quality of life, and that we should not regard the increasing data processing volume itself as a problem.

Data processed at data centers are contributing to the environmental improvement of overall society in forms such as improved logistics efficiency, paperless workflow and telecommuting[1]. However, it is obvious that such contributions cannot justify the increase in energy consumption simply in proportion to the increase in data processing volume. For data processing that society expects data centers to handle, measures must be taken to process data by using highly energy-efficient methods. To this end, the following two approaches should be considered.

(1) Concentrating the overall social demand for data processing in data centers and improving the efficiency of data processing
(2) Further improving the energy efficiency of data centers so that concentrated data processing can be handled by using highly energy-efficient methods

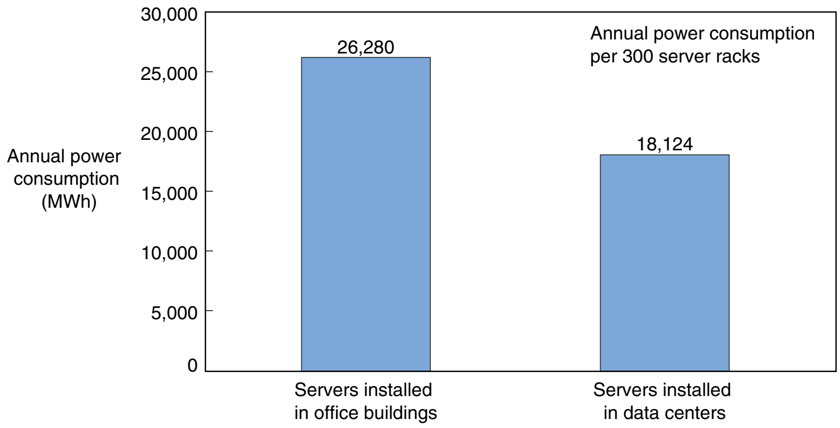
From the perspective of overall society, as indicated in the previously mentioned EPA report, many small servers are dispersed on office building floors and in computer rooms. With respect to Approach (1), i.e., concentrating dispersed servers in data centers, a report published by the Japan Data Center Council indicates the effect of reducing energy consumption by 30 percent, as shown in Figure 7.

Specifically, small servers used by companies are usually located either in ordinary office buildings or in server rooms within office buildings. However, IT equipment that locally generates high temperatures compromises the efficiency of an air-conditioning system. Relocating IT equipment to data centers that are equipped with the latest air-conditioning system suitable for IT devices and that employ the technologies to properly operate and manage these devices substantially reduces power consumption. Another report indicates slashing energy consumption by 40 percent by reducing the number of concentrated server units by means of technologies such as virtualization, as shown in Figure 8.

In light of these achievements, if absolute-based emission caps are applied to large-scale data centers (large-scale buildings) unconditionally, there is a possibility that servers might be dispersed in small data centers or office buildings that are not subject to regulation, causing the overall energy efficiency of society to be downgraded. Accordingly, applying emissions caps should be considered from the perspective of improving energy efficiency related to data processing in society as a whole.

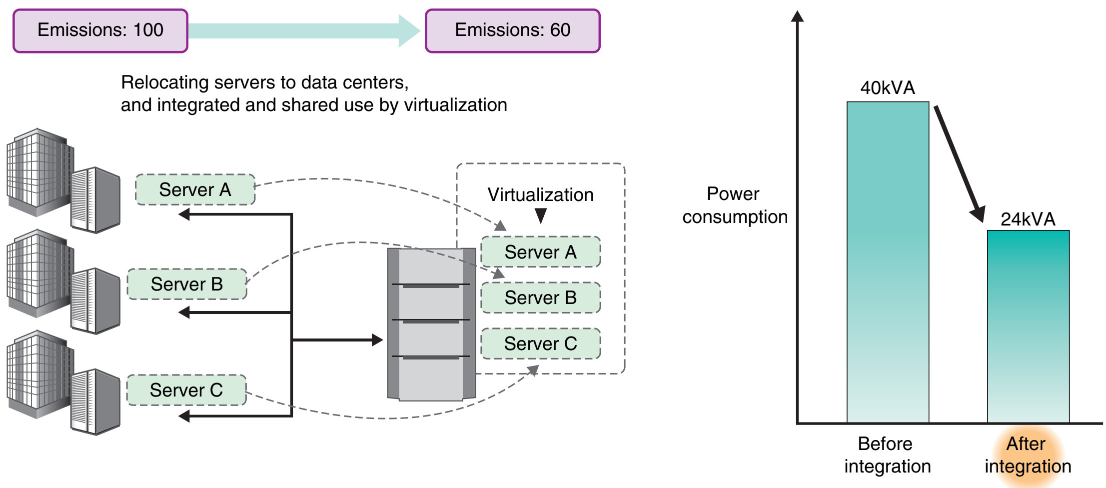
As for Approach (2), improving the energy efficiency of concentrated data processing in data centers, many

Figure 7. Comparison of electricity consumed by servers in data centers and office buildings



Source: Materials published by the Japan Data Center Council.

Figure 8. Improving server energy efficiency through virtualization (reducing CO_2 emissions)



Source: Materials published by Nippon Telegraph and Telephone Corporation.

methods are available, as described in the following section.

2 Improving the Energy Efficiency of Data Centers themselves

Reducing the energy consumed by and the amount of CO_2 emitted by data centers as a whole, involves the following three areas (Table 3):

(1) Reducing the amount of electricity consumed by IT equipment used in a data center
(2) Improving the energy efficiency of support facilities such as air-conditioning and power supply systems that are necessary for data center operation
(3) Changing energy used in data centers to green energy that produces no (fewer) CO_2 emissions

(1) Reducing the amount of electricity consumed by IT equipment

The methods available to reduce power consumed by IT equipment used in a data center include:

(1) Replacing servers with energy-saving servers equipped with an up-to-date CPU such as a quad core CPU (a microprocessor that contains four central processing units in a single package)
(2) Reducing power consumption by using smaller hard disks
(3) Reducing the number of server and storage (external memory) units by employing virtualization technology
(4) Cutting power consumption in idle mode by using server energy management software

In terms of the ratio of electricity consumed by a server, the CPU is responsible for about 30 percent of total electricity consumption, and the remaining 70 percent is used by hard disk drives, power supplies, fans, etc. Therefore, to reduce total power consumption, it is effective to improve the efficiency of these devices or to share these devices. Furthermore, because it is known that a server CPU is in idle mode for more than 70 percent of the time, the integration of servers to increase the rate of operation is an effective means of improving energy efficiency.

The integration of servers means that one large-scale server is divided into multiple virtual servers by virtualization technology, and the existing application software is operated on these virtual servers. Because when the number of small servers to be procured is determined, the predicted load of each server at peak time is usually assumed to determine the required overall capacity. Therefore, the rate of operation during normal operating time is often around 10 to 15 percent. By integrating the servers to increase the average rate of operation, overall efficiency can be improved. Because servers sometimes consume about 30 percent of electricity even in idle mode

Table 3. Methods for reducing CO2 emissions from data centers

Area	Concept	Specific examples
(1) Reducing electricity consumed by IT equipment	Reducing CPU power consumption	• Using energy-saving servers equipped with quad core CPUs • Using energy-saving servers equipped with CPU power control software
	Reducing power consumption by integrating servers	• Reducing the number of servers and improving the rate of operation through virtualization
	Reducing power consumption of storage (external memory) devices	• Using smaller hard disks • Reducing the number and improving the operating rate of storage devices by virtualization
	Improving server cooling system	• Improving rack cooling efficiency by using a rear-door heat exchanger or enclosed rack systems
(2) Reducing electricity consumed by data centers (facilities) housing IT equipment	Improving airflow efficiency (cool air supply and waste heat recovery)	• Optimizing the flow of cool air by preventing heat accumulation and air leakage • Removing objects blocking airflow on and under the floor • Separating hot (heat exhaustion) and cold (cooling air) aisles
	Improving efficiency of air conditioners	• Using inverter-controlled energy-efficient air conditioners • Using a nighttime cold heat storage system
	DC power supply	• Using DC power supplies for routers and servers to reduce power loss during AC-DC power conversion
	Reducing power consumption of cooling devices	• Using free cooling (outdoor air cooling)
(3) Changing to green energy	Using photovoltaic power generation	(• Usage depends on the available space surrounding a data center)
	Using hydropower generation	(• Usage depends on the location of a data center)
	Using cogeneration (combined heat and power)	(• Usage depends on the surrounding environment)

Note: Quad-core CPU = a microprocessor that contains four central processing units in one package.

as compared to that used during peak time, such integration is effective. Similarly, moves have already been started to use virtualization technology for storage devices. The integration of storage devices is also effective.

(2) Reducing electricity consumed by data centers (facilities) housing IT equipment

To promote the saving of overall data center energy, consideration should then be given to data center facilities. The energy efficiency of data center facilities related to cooling, power transformation and distribution, etc. should be improved.

Among these facilities, the largest amount of electricity is used for cooling. A method that requires no additional investment is to remove any unused cabling, piping and equipment under the data center floor to improve airflow (cool air supply and waste heat recovery) so that the existing cooling systems can operate in a better environment. An effective investment for this purpose is to replace the existing equipment with highly energy-efficient equipment such as adopting Inverter controlled air conditioners in cooling systems. Free cooling is an economic method in which lower outdoor air temperatures are used for cooling. In Japan, this method can be employed during the winter half. Studies are also being done on using underground's cooler air and colder water by building a data center under the ground.

(3) Changing to green energy

Changing energy used in data centers to low-carbon renewable energy is also effective in reducing CO_2 emissions. In this area of renewable energy sources, the use of photovoltaic power generation, wind power generation and hydropower generation have already begun. In the future, small nuclear power generation systems might become available.

V Data Center Energy Efficiency Metrics

A well-known saying states that "we can't manage what we can't measure." To promote energy management and reduce energy consumption in order to improve the energy efficiency of data centers, it is first necessary to determine what to measure and how to measure the identified objects. For this purpose, metrics for measuring the energy efficiency of data centers must be defined and applied.

As shown in Figure 2, the energy consumption of data centers in Japan is expected to increase by around six times in the 20 years between 2005 and 2025. However, if the energy efficiency of those centers could be improved by a factor of five, energy consumption could be held to no more than 1.1 times its 2005 value. To ensure achievement of this goal, we first have to verify what measures should be taken to attain this five-fold improvement. To this end, it is necessary to define data center energy efficiency. Based on the definition, any improvement should be measured and verified on an annual basis.

1 Previously proposed Energy Efficiency Metric: PUE

Currently, the most commonly known metric to indicate the energy efficiency of a data center is the PUE, which was adopted by the EPA as explained in Chapter II. The PUE metric focuses on the efficiency of support facilities such as those to cool and supply power to IT equipment.

In a data center, the devices that perform core data processing functions such as computers and network equipment generate large amounts of heat, necessitating high-capacity air-conditioning systems to dissipate the heat. To maintain an interior temperature of around 24°C, therefore, air-conditioners consume large amounts of power. In the US example introduced in Chapter III, the power consumed by air-conditioning and other devices is greater than that consumed by the computers, which is actually about twice as much (Figure 3). In this case, the PUE value is "(1 + 2)/1," that is, about 3. Because of such substantial amounts of power consumed by support structures, attention is paid to the PUE metric in an attempt to reduce their power consumption.

In the domestic air conditioner market, those products that have incorporated inverter technology can offer a high level of energy-saving performance, being eligible for four or five "Star Marks," which are intended to encourage consumers to purchase these types when replacing their old units. As explained in Chapter IV, Japanese data centers have replaced their air-conditioning equipment with units offering greater energy efficiency and that draw in colder outdoor air during the winter (free air cooling). As a result, it is assumed that the current average PUE value has become around 2.0. This PUE value indicates that the power consumption of cooling and other support facilities now equals that of computers.

According to the 2009 EPA report, the average PUE value for 150 data centers in the US was 1.9, which is similar to that of Japan. The PUE value of Japan's state of the art data centers has now dropped to around 1.5, with support facilities consuming only half as much power as the computers. Compared to the era when the PUE value was 3.0, the power consumption of support facilities is now only 25 percent of the level at that time.

In Europe and the US, it appears that the PUE metric is to become a standard index of data center energy efficiency. If we focus only on the PUE value, however, especially now that the power consumption of support facilities is less than that of IT equipment, we miss the opportunity to manage a major aspect of power consumption.

Figure 9. Data Center Performance Per Energy (DPPE) metric and its sub-metrics

$$\text{Data center energy efficiency} = \frac{\text{Data center output}}{\text{Total data center energy consumption}} \qquad \text{Formula (1)}$$

$$\text{DPPE} = \frac{\text{IT equipment utilization factor} \times \text{Total IT equipment capacity}}{\text{Total data center energy consumption - Green energy}} \qquad \text{Formula (2)}$$

$$\text{PUE} = \frac{\text{Total data center energy consumption}}{\text{Total IT equipment energy consumption}} \qquad \text{Formula (3)}$$

$$\text{DPPE} = \text{IT equipment utilization factor} \times \frac{\text{Total IT equipment capacity}}{\text{Total IT equipment energy consumption}} \times \frac{\text{Total IT equipment energy consumption}}{\text{Total data center energy consumption}} \times \frac{1}{\left(1 - \text{Green energy} / \text{Total data center energy consumption}\right)} \qquad \text{Formula (4)}$$

IT equipment utilization factor = ITEU (IT Equipment Utilization)

$$\frac{\text{Total IT equipment capacity}}{\text{Total IT equipment energy consumption}} = \text{ITEE (IT Equipment Energy Efficiency)}$$

$$\frac{\text{Total data center power consumption}}{\text{Total IT equipment power consumption}} = \text{PUE (Power Usage Effectiveness)}$$

$$\frac{\text{Green energy}}{\text{Total data center energy consumption}} = \text{GEC (Green Energy Coefficient)}$$

$$\text{DPPE} = \text{ITEU} \times \text{ITEE} \times 1/\text{PUE} \times 1/(1 - \text{GEC}) \qquad \text{Formula (5)}$$

2 Newly proposed comprehensive energy efficiency metric: DPPE

Despite the fact that power consumption on the IT equipment side has become relatively large, unfortunately, there are no metrics to measure the power efficiency of this equipment. If we only consider the PUE value, the older the computer models are then the poorer are the energy efficiency, and the larger the power consumption of the IT equipment (the denominator of the PUE calculation formula), which resulting in a smaller PUE value.

Given this fact, Japan's Green IT Promotion Council has proposed to the US and Europe and now to the Asia, comprehensive energy efficiency metric that also considers saving IT equipment power consumption and using green energy in addition to the PUE metric that is designed to measure the efficiency of support facilities. This comprehensive efficiency metric is referred to as "DPPE"[5] (the Data Center Performance Per Energy). The DPPE metric is designed to measure and verify the improvement of energy efficiency for each element and promote the reduction of Greenhouse Gas emissions by a data center as a whole.

The energy efficiency of a data center, as based on the amount of information that is processed, is given by Formula (1) in Figure 9. In establishing this formula, considerable discussion was held as to how to measure the value of the output of a data center. When a server processes information, it is argued that the value of the processed data differs between a billion-yen financial transaction and a simple greeting sent by e-mail. Be that as it may, the value of the output produced by data center servers cannot be controlled by its operators, nor can those operators do anything to enhance the value of the output.

In addition, if we consider how processing by a single data center changes over time, we can measure and compare the energy consumption needed to produce data output of the same value. However, when we attempt to make a comparison with other data centers, we find that the value attached to the same e-mail and financial transactions varies depending on a company and social conditions at the time of processing. Therefore, the output of a data center is measured simply as the amount of data processing that is performed by computers, with no consideration given to the value of the output.

The processing capacity of IT equipment such as computers, storage and network equipment is described in the manufacturers' catalogs, and varies within a given range. Therefore, we believe that the actual amount of information processing can be obtained by multiplying the maximum processing capacity by the average IT equipment utilization factor. For a data center's total energy consumption (which is the denominator of Formula (1) in Figure 9), when we consider reductions in CO_2 emissions as a means of preventing global warming, we can deduct any energy sources that do not produce

Table 4. Four sub-metrics constituting the DPPE metric

Sub-metric	Formula	Corresponding area as shown in Table 3
ITEU	= IT equipment utilization factor in a data center	(1) Reducing electricity consumed by IT equipment
ITEE	= Total rated capacity of IT equipment / total rated energy consumption of IT equipment	(1) Reducing electricity consumed by IT equipment
PUE	= Total energy consumption of data center / total energy consumption of IT equipment	(2) Reducing electricity consumed by data centers (support infrastructure) housing IT equipment
GEC	= Green energy / total energy consumption of data center	(3) Changing to green energy

CO_2 emissions when these energy sources are produced and used, such as solar power generation. That is, the energy efficiency in a low-carbon society should be calculated by identifying how much grid power (public utility power) that generates CO_2 emissions is consumed. Based on this concept, the DPPE metric that indicates comprehensive data center energy efficiency is defined as expressed in Formula (2) in Figure 9.

To date, the PUE metric has already been widely used as the data center energy efficiency index, and is calculated by dividing total data center energy consumption by total IT equipment energy consumption, as explained in Chapter II. Therefore, by combining Formulas (2) and (3) in Figure 9, the DPPE metric can be defined as indicated in Formula (4).

Here, we have assigned a name to each item as described below, and each of these items is separately calculated as a sub-metric constituting the DPPE metric. Formula (5) was created by combining these sub-metrics to obtain the DPPE value.

In this way, the comprehensive data center energy efficiency metric, as proposed by Japan, is derived by breaking down the original Formula (2) into four elements (sub-metrics) (Table 4).

The goal behind creating these four sub-metrics is to reflect the efforts made by parties (enterprises) related to data centers in the four areas to reduce energy consumption in each sub-metric. Japan's approach is based on the concept that overall data center energy conservation can be achieved only when energy saving is attained by both IT equipment such as computers and support facilities that cool IT equipment.

To achieve energy saving in IT equipment such as computers, efforts by both manufacturers and users are necessary, as represented by energy-saving household appliances, which are selling well thanks to Japan's unique "Eco-Point" consumer rebate system. Specifically, (1) highly energy-efficient equipment must be developed and introduced (manufacturer efforts), and (2) users who purchased such equipment must use it in such a way that the energy-saving effects are maximized (user efforts).

With respect to support infrastructure, as indicated by the PUE metric described above and by using highly energy-efficient equipment, (3) it is important to reduce as far as possible the power consumption of the cooling and power supply equipment (equipment supplier efforts). At the same time, (4) it is also important to generate power through carbon-neutral methods such as solar and wind power (green energy) so as to reduce CO2 emissions. As discussed in the next chapter, the manufacturer efforts described in (1) above are reflected in the IT Equipment Energy Efficiency (ITEE) sub metric, user efforts (2) in the IT Equipment Utilization (ITEU) sub-metric, equipment supplier efforts (3) in the PUE sub-metric, and green energy usage (4) in the Green Energy Coefficient (GEC). In each area, efforts are being made to improve the value of the corresponding sub metric.

Specifically, for the introduction of high energy-saving performance IT equipment as described in manufacturer efforts (1), Japan proposes the ITEE sub-metric that is defined as the value obtained by dividing the total capacity of IT equipment by the total rated power of that IT equipment. ITEE is the weighted average efficiency of the energy-saving performance that is stipulated under the Law on the Rational Use of Energy and published in catalogs and on websites. However, because the energy-saving performance of computers, storage and network equipment is measured by using different units, an appropriate factor must be multiplied to obtain an average.

Japan is going ahead of other countries in that its Law on the Rational Use of Energy stipulates the indicators for the energy-saving performance of such equipment, and these indicators are published in catalogs and on websites. In fact, the US has only just introduced a means of indicating the energy-saving performance of computers, with storage and network equipment yet to be addressed. Japan aims to promote the worldwide spread of the concept of using the weighted average efficiency of the energy-saving performance that is indicated in the catalogs of IT equipment as the metric. While the energy-saving performance of individual devices is to be calculated by using Japan's standardized methods for the time being, these methods could be replaced in the future with International Standards when such standards are established.

To promote the optimum use of energy-efficient equipment, which corresponds to user efforts (2), Japan proposed the ITEU sub-metric, which was endorsed by the US. Even when only turned on, the power consumption of IT equipment is as much as 10 to 30 percent of peak power consumption. Therefore, it is important to turn off the power of equipments when not in use or under-utilized, equipment so as to maintain the most energy-efficient utilization of the entire system. The ITEU sub-metric is used to indicate whether the system is being used anywhere near its optimum level. IT service companies are currently promoting the improvement of efficiency by integrating multiple servers into a single server. Such integration provides an effective means of reducing operating costs as well as maintenance costs, while at the same time reducing energy consumption.

Regarding (3), i.e., the efficiency of data center facilities, Japan and Europe agreed on the adoption of the PUE that was proposed by the Green Grid; the US EPA will also use this metric starting in 2010.

For (4), i.e., the use of green energy, the ratio of green energy generated by a data center relative to overall energy consumption is expressed by GEC.

As mentioned above, since 2008, the Green IT Promotion Council has been promoting the study of its own data center energy efficiency indices, which are integrated into the DPPE metric. In developing this metric, the council adopted the approach by focusing on the following factors:

- The metric must be easy to calculate or measure.
- It must enable the comparison of data centers on a par with each other.
- It must enable the comparison of annual energy-saving effects on a consecutive basis.

In the future, the council plans to collect the DPPE and its sub-metric values from a greater number of data centers, thereby clarifying any problem related to the measurement of these metrics and identifying measures to improve the values and the effects of such measures. Once the values of these four sub-metrics can be collected from many domestic and overseas data centers, it becomes possible to establish the criteria for energy-saving methods that are appropriate for the usage characteristics and locations of data centers. In addition, the analyses of these collected values will lead to improved accuracy based on which we move towards 2025 to achieve improved energy efficiency in data centers.

VI Possibilities of Improving the Efficiency of Data Centers

In this chapter, consideration is given to what extent a leading-edge data center can improve energy efficiency, say, five years from now based on the possible improvement of each sub-metric at the current stage and the combined efforts made by all parties concerned.

1 Possibilities of improving the ITEE sub metric

Because the ITEE sub-metric indicates the energy-saving performance of each item of IT equipment, the obvious strategy would involve replacing the equipment with units offering better energy efficiency. Essentially, the best servers would be those that are configured with CPUs that offer the best energy-saving performance. As already mentioned, however, the CPU draws only about 30 percent of the total power consumption of a server, with other associated hardware components such as memory and hard disks, not to mention the power supply and cooling fans, drawing a greater amount of power. Therefore, while continuing to use the same CPU, ITEE can be improved by selecting equipment that has higher energy-saving performance for the power supply and is more efficient in terms of internal cooling.

In Japan, Top Runner standards are typical standards that are applied to the evaluation of ITEE. (Japan's Top Runner program sets the efficiency standards for a wide variety of products. Regularly, products are tested to determine the most efficient model in each category of products, and the level of efficiency of this model is regarded as the new baseline. This program provides incentives for developing even more energy-efficient product models to compete.) The possibilities of improving ITEE can be inferred from the rate at which the energy efficiency of IT equipment has been improved based on these Top Runner standards. The Top Runner standard for servers is the ratio of power consumption (kW) to composite theoretical performance (MTOPS, Millions of Theoretical Operations Per Second, which is one of the CPU performance indicators), where a smaller value indicates higher energy-saving performance. Taking the average energy-saving performance based on the number of units shipped, the value 0.012 in fiscal 2001 fell to 0.0023 in fiscal 2007, about a five-fold improvement over six years, or an annual improvement rate of 32 percent. In the four years between fiscal 2007 and 2011, an improvement of 2.6 times, or an annual improvement rate of 27 percent, is expected.

In considering the rate of performance improvement, the processing performance of a CPU is commonly held to the famous Moore's Law, whereby performance is reckoned to double every 18 months, that is, to increase at an annual rate of 58 percent. However, if the rate at which CPU performance increases exceeds that at which a server's energy-saving performance improves, increased performance will lead to an overall increase in energy consumption. However, even based on current results, it seems that we can expect an annual improvement in energy efficiency of at least 30 percent. In this case, the ITEE value could quadruple in five years.

The Top Runner standards also point to improvements in the energy efficiency of storage. In the six years from fiscal 2001 to 2007, there was a seven-fold improvement in the energy efficiency of storage devices, which is equivalent to an annual improvement rate of 38 percent, with projected improvement between fiscal 2007 and 2011 being 4.2 times, or 43 percent annually. Unfortunately, we cannot track the improvement in the energy efficiency of network equipment because no Top Runner standards are available for such equipment. However, as far as we see the improvements achieved for servers and storage to date, the ITEE value for all IT equipment including servers, storage and network equipment could be increased by a factor of four if all IT equipment is replaced with the latest equipment over the next five years.

2 Possibilities of improving the ITEU sub metric

The ITEU sub-metric measures the degree of the energy-saving performance of IT equipment that is in use. Although this depends on the type of equipment, it is generally believed that servers can be said to be operating at a high utilization rate if they are running at least 60 percent of the time. Among data center operators, there seems to be a rule of thumb whereby servers run at around 30 percent of the rated power. Interviews with several data center operators reveal that the current ITEU value is around 30 to 50 percent. Upon looking more closely at this difference, we found that it could be attributed to the factors of data center usage and the degree of integration.

The usage factor involves the difference between general corporate data centers and those that provide Internet services. In a general corporate data center, while servers provide online processing for end-users during the day, they are sitting idle or not utilized at night. This causes the utilization rate to fluctuate and the average utilization rate to fall. Using those servers to perform overnight batch processing is one way of improving the average utilization rate, but it is usually not enough to raise the levels sufficiently.

On the other hand, data centers that provide Internet services provide them around the clock, and therefore maintain high utilization rates. In this case, however, depending on the type of application software that is running, the utilization rate may vary depending on the time of day or day of the week. To help counter this fluctuation, rather than using individual small- or medium-sized servers for each application, applications are instead being integrated into large-scale servers so as to even out the utilization rate. Virtualization technology is used here. There have been several reports that the utilization rate has been improved by more than 10 percentage points by virtually integrating ten or so to even hundreds of servers with differing operational characteristics into a few large-scale servers.

Accordingly, even in those data centers where the ITEU currently stands at around 30 percent, it is thought that this could increase to around 50 percent, an improvement of 1.7 times.

3 Possibilities of improving the PUE sub metric

The PUE sub-metric indicates the energy efficiency of any non-IT equipment in a data center building such as air conditioning and power distribution units. Any improvement in the PUE value requires a reduction in the power used for cooling and power infrastructures. There have been reports of data centers that are located in cold climates where the air-conditioning equipment does not use electrical power to cool but instead uses colder outdoor air throughout the year to increase its energy efficiency, which could reduce the PUE value to 1.2 or less. In Japan, this approach can be applied in three or four months during the winter, but unfortunately not throughout the year.

Currently, those data centers in Japan that apply the best practices have a PUE of between 1.4 and 1.5, and this can be set as a realistic target for improvement. In the majority of existing data centers, the PUE value is on the order of 2.0. If the value could be reduced to around 1.4, the energy efficiency could be improved by a factor of 1.4.

4 Possibilities of improving the GEC sub metric

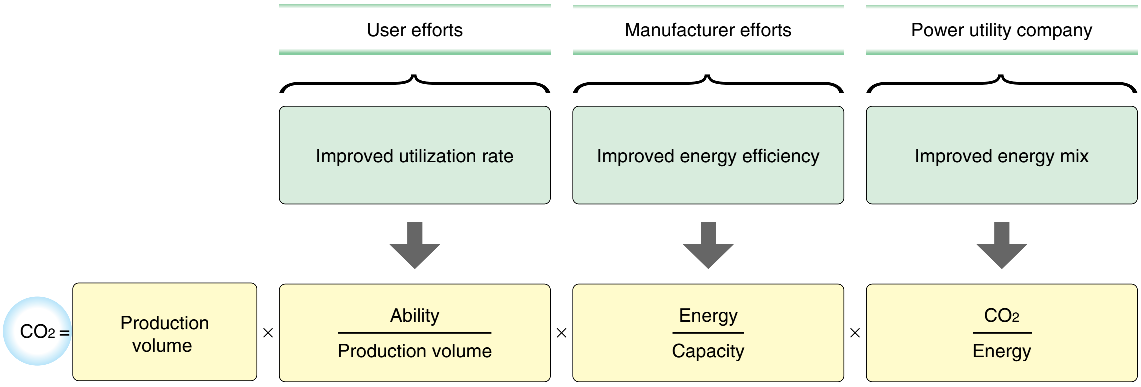
As for the use of green energy in Japan, only a limited number of data centers have currently introduced solar power. These data centers use solar power primarily for lighting within the center, which constitutes no more than a few percent of overall power consumption. In Japan, because it would be extremely difficult for a data center to obtain the vast land area necessary to set up huge solar arrays, the use of renewable energy by data centers is thought to be no more than 10 percent. If GEC could be increased from 0 percent to 10 percent, there would be a 1.1-fold improvement in energy efficiency.

5 Possibilities of improving the DPPE metric

If we substitute the potential improvements in each of the four sub-metrics constituting the DPPE metric into Formula (5) in Figure 9, we could obtain an overall potential improvement in energy efficiency for a leading-edge data center that achieves all targets.

As mentioned above, if we can improve the ITEE value by a factor of 4, the ITEU by 1.7, the PUE by 1.4 and the GEC by 1.1, we would be able to attain about a ten-fold improvement in energy efficiency through the efforts made over about five years. Of course, this

Figure 10. Reducing CO_2 emissions by the efforts of all concerned parties



assumes that we attain the maximum improvement for each of the four indicators, which would be difficult for every data center to attain. Nevertheless, by planning and applying optimum improvements after taking into account historical trends data in environment and usage of the each data center, an improvement approaching such a ten-fold increase should be possible.

VII CO_2 Reduction Synergies through Cooperation among All Concerned Parties

If data center users, IT equipment manufacturers, building facility manufacturers and power suppliers can each fulfill their part in reducing energy consumption and carbon emissions, a significant overall effect could be expected. Through the synergistic efforts of all concerned parties, a substantial reduction could be attained that would not be possible by any single party.

As shown in Figure 10, the relationship between production volume as a result of any energy use activities, without being limited to data centers, and the amount of CO_2 emission can be considered by multiplying the efficiency of each of the users, manufacturers and power suppliers. If power utility companies reduce CO_2 emissions per unit of energy generated, manufacturers increase the production capacity per unit of energy input, and users make the best use of those products, it would be possible to maximize overall production, while at the same time keeping CO_2 emissions to a minimum.

For example, if users increase their operation efficiency by 30 percent, manufacturers improve their energy-saving performance by 30 percent, and power utility companies increase the ratio of low-carbon power by 30 percent, we could achieve a CO_2 reduction of $0.7 \times 0.7 \times 0.7 = 0.34$, or about 66 percent, with the overall low-carbon ratio being threefold. If this were to be possible, even if there were a three-fold global increase in demand for production, global CO_2 emissions would remain flat.

Of course, each of these parties will not attain its 30 percent improvement at the same pace. Instead, improvements would be dependent on the circumstances of each party and progress in technology. If any attainments could be skillfully combined to give an average improvement of 30 percent, an overall reduction of 66 percent could be attained. Author feels that, the route that Japan will take towards reducing energy consumption substantially relies on this comprehensive strength generated by such combined efforts. Because this concept is shared among all concerned parties, how best to allocate the results of energy-saving efforts among industries is under study.

With respect to the energy-saving effects of a product during its life cycle such as energy-saving air conditioners and LED (light-emitting diode) light bulbs, the Green IT Promotion Council has been studying a rule of allocating the results according to the contributions made by users, retailers, assembly manufacturers, material manufacturers and other concerned parties. Underlying such moves of considering the allocation rule is the recognition among all parties that energy conservation can only be achieved through the cumulative efforts of all parties in the value chain ranging from material manufacturers to users.

As such, Japan's strength in environmental measures lies in combined efforts aiming at achieving substantial improvements among all parties that are involved in the life cycle of a product, with each party playing its role in contributing to the creation of a low-carbon society.

Japan's approach primarily aims to clarify the reduction target of each party involved in the commercial and transportation sectors where efforts to reduce CO_2 emissions have lagged behind other sectors and to generate the substantial effects achieved by multiplying the reduction amount of each party. In addition to data centers, which are a typical example in the commercial sector, we also look at an example in the transportation sector where CO_2 reduction is also a major challenge.

While Japan is attempting to reduce the CO_2 emissions of the transport sector, efforts are being made to improve fuel economy not only by automakers, but also by many other parties involved. These include drivers, fleet operators, automobile manufacturers, parts and components manufacturers and materials manufacturers. On the part of drivers, energy-conscious driving (eco-driving) is being promoted, while fleet operators are considering the use of optimized routes and timetables. Automobile manufacturers are developing hybrid and electric cars, and parts, components and materials manufacturers are designing and developing new materials to produce lighter and more energy-saving products. Through the combination of these efforts to reduce energy use in the processes ranging from the design and manufacture of vehicles through to their use, the transportation sector is aiming to achieve major reductions in CO_2 emissions.

As such, in Japan, moves to promote carbon reduction are not limited to any single industry, with the goal of generating significant effects through the combined efforts of users, manufacturers and energy suppliers. As shown in Figure 10, any increase or decrease in CO_2 emissions is determined by the following multiplication: production volume × efficiency at time of use × inherent energy efficiency of equipment × carbon dependence of energy. As we move towards 2050 to achieve the goal of halving global CO_2 emissions, even if global production volume were to double, the halving of emissions could be attained provided that the product of the above-mentioned three types of efficiency becomes one-fourth. If the efforts were left up to a single party, it would be very difficult to achieve a four-fold increase in the rate of low carbon emissions. Through role sharing, however, by aiming for a 30-percent increase in terms of user efficiency, a 30-percent improvement in equipment efficiency and a 30-percent increase in the ratio of low-carbon energy, significant achievements could be possible. By spreading these ideas globally, Japan would be able to become a world leader in the promotion of low-carbon lifestyles.

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Takao SHIINO is an NRI counselor and the chairman of the Environment Department of the Japan Information Technology Services Industry Association (JISA). His specialties include management strategy and IT strategy.

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Nomura Research Institute, Ltd.
E-mail: nri-papers@nri.co.jp
FAX: +81-3-6660-8370