



## **Concept of New Metrics for Data Center Energy Efficiency**

Introduction of Datacenter Performance per Energy  
[ DPPE ]

Green IT Promotion Council, Japan

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## Abstract

Power Usage Effectiveness (PUE) is being widely recognized as a measure of indicating data center energy efficiency. However, to improve the energy efficiency of data centers, it is necessary to implement energy saving for both facilities and IT equipment in data centers, and therefore the PUE metric to prompt the improvement of facility power efficiency alone is not sufficient. As such, the Green IT Promotion Council (GIPC) is studying Datacenter Performance Per Energy (DPPE) as a new metric indicating the energy efficiency of data centers as a whole. At present, we are promoting the establishment of DPPE to measure data center energy efficiency and make it an effective metric for evaluation while working in concert with domestic and foreign related organizations such as The Green Grid in the U.S.

Basically, we are designing DPPE as a metric for indicating data center productivity per unit energy. That is, this design began with  $DPPE = (\text{production of data center}) / (\text{energy})$ . When defining DPPE, it is necessary to determine the method of defining productivity, the range of energy, and other considerations. We believe that these should be linked to the effect of energy-saving measures taken by data centers. Therefore, we focused on four kinds of data center energy-saving measures to define sub-metrics.

| Name of sub-metric                   | Formula   | Corresponding action measure           |
|--------------------------------------|---|--|
| ITEU<br>(IT Equipment Utilization)   | IT equipment usage in data center   | Effective operation of IT equipment    |
| ITEE(IT Equipment Energy Efficiency) | Total rated capacity of IT equipment / total rated energy consumption of IT equipment | Installation of efficient IT equipment |
| PUE<br>(Power Usage Effectiveness )  | Total energy consumption of data center / total energy consumption of IT equipment    | Energy saving of facilities            |
| GEC<br>(Green Energy Coefficient)    | Green (natural energy) energy / total energy consumption of data center               | Use of Green Energy                    |

DPPE is then expressed as the function of these four sub-metrics as shown below.

$$DPPE = f(ITEU, ITEE, PUE, GEC)$$

If these defined sub-metrics are applied, DPPE is represented as indicated below.

$$DPPE = ITEU \times ITEE \times 1/PUE \times 1/(1-GEC)$$

The concept is shown below.

$$\begin{aligned} DPPE &= (\text{IT equipment usage} \times \text{total capacity of IT equipment}) / \\ &\quad (\text{DC total energy consumption} - \text{Green Energy}) \\ &= (\text{Actual usage of IT equipment}) / (\text{grid energy usage}) \end{aligned}$$

# 1 Company Awareness of Data Center Energy Efficiency Metrics

We believe it is important for data center energy efficiency metrics to be formulated to maximize the energy improvement activities of data centers. We first conducted interviews and surveys of data center companies in Japan and collected information on their present energy efficiency improvement activities and their opinions on energy efficiency metrics. The conditions required for energy efficiency metrics, which were obtained as this result, are classified and summarized in the stages of the definition, measurement, and usage/declaration of metrics (Table 1). The present situation of Japanese data centers, which was obtained through the questionnaire, is shown in the Appendix.

**Table 1: Conditions required for data center energy efficiency metrics**

| Stage                 | # | Business Requests   |
|-----------------------|---|---|
| Definition            | 1 | Clarification of the definition of data center performance / energy <ul style="list-style-type: none"> <li>Clarifying the method of defining IT equipment productivity</li> </ul>   |
|                       | 2 | Usage of a number of metrics linked to energy-saving activities and the scope of data center management <ul style="list-style-type: none"> <li>The scope of data center management varies according to the type of service.</li> <li>The solution provided for energy efficiency improvement varies according to company activities.</li> </ul> |
| Measurement           | 3 | Clarification of measurement regulations <ul style="list-style-type: none"> <li>Streamlining of regulations on measurement methods</li> <li>Streamlining of regulations on estimation methods in cases where measurement is difficult</li> <li>Clarification of measurement conditions such as service level</li> </ul>                         |
|                       | 4 | Reduction of measurement costs  |
| Usage/<br>declaration | 5 | Consideration of the data center diversity <ul style="list-style-type: none"> <li>Segmentation of data centers</li> </ul>   |
|                       | 6 | Elimination of declaration bottlenecks <ul style="list-style-type: none"> <li>Security considerations</li> </ul>  |
|                       | 7 | Motivation for both businesses and tenants (users) <ul style="list-style-type: none"> <li>Provision of numerical information</li> <li>Evaluation of and cooperative efforts for energy efficiency improvement activities</li> </ul>   |

## 1.1 Details Regarding Data Center Business Requests Discovered through Interviews and Surveys

### 1.1.1 Clarification of the definition of data center performance / power

In defining energy metrics, some respondents wanted the definitions to be easy to understand. They can appeal to their management and users for such metrics if the definitions are easy to

understand, thereby broadening the usage range and influence of these metrics. Therefore, we believe that it is necessary to create metrics that can be understood as easily as possible.

[Sample interview responses]

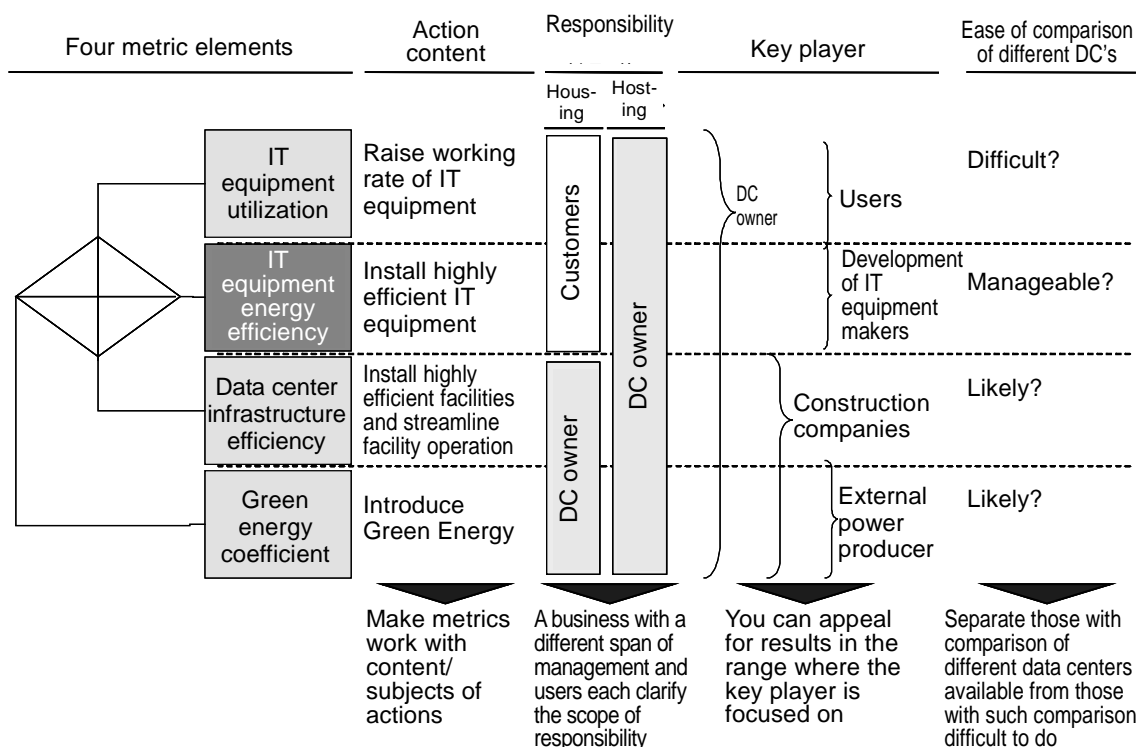
- “Metrics should be simple and easy to understand for anyone instead of complex terms found using mathematical formulas. I think special equipment should not be a necessary condition for measurement in order to make such metrics pervasive.”

### 1.1.2 Use of a number of metrics linked to energy-saving actions and the scope of data center management

The scope of data center management varies according to the type of service such as one's possessions and housing/hosting service. For this reason, data center owners do not manage all equipment but the matters subject to energy-saving actions are limited depending on the type of service.

We received one comment stating that it is desirable to classify energy-saving actions at data centers and break down energy metrics according to such classifications so that data center owners and users will each clarify the scope of responsibility for actions subject to management and promote energy-saving actions.

To concretely summarize the interviews, the energy efficiency improvement activities of a data center may be roughly classified into four different types (Fig. 1), each of which has a different administrator and solution provider and dividing metrics leads to the clarification of the scope of responsibility.



**Fig. 1: Associated concept: four actions at a data center and metrics**

[Sample interview responses]

For a data center service provider, the management scope varies depending on the type of service. Knowable figures and possible actions also vary.

- “If you lease a floor, you can deal with the floor but you cannot work on the racks. In leasing racks, you can handle the racks but are unaware of anything beyond them.”

Conversely, when viewed from the tenant side, the range controllable by the company will be limited.

- “It is difficult to motivate the owner and so there are not many options for energy-saving actions possible for the company.” (Resale business)

### 1.1.3 Clarification of measurement regulations

With a wide variety of equipment to be housed, data centers need to determine guidelines for a range of electric power measurement and methods thereof. At present, the details of such guidelines are under review. Some data center owners said that they cannot easily make measurements without knowing the measuring methods and other owners hesitate to declare numerical values because they can arbitrarily change the measuring methods and consequently think such figures are less reliable.

#### 1.1.4 Reduction of measurement costs

The results of the questionnaire showed that measurement cost and lack of know-how are the current issues facing the measurement of data center energy metrics. Before building a new data center, energy efficiency measurement can be reviewed from the beginning and necessary measuring equipment can be set up. On the other hand, there were many comments saying that there would particularly be considerable cost-related difficulty in adding such measuring equipment at old data centers.

To avoid such situations, there were also suggestions stating that regulations for estimating methods should be defined in the proper way for numerical values not directly measurable at old centers.

#### 1.1.5 Consideration of the data center diversity

There are many types of data centers where energy efficiency also greatly varies. For example, a data center placing importance on reliability doubles up on all equipment and, consequently, the energy consumption of the data center is naturally worse than that of a data center that places no importance on redundancy when they provide the same service.

Additionally, a data center in the form of sales is built with a larger floor area in consideration of future expansion and, consequently, the rate of operation is low when services starts, thereby decreasing energy efficiency.

There were many comments pointing out that much of this data center diversity occurs irrespective of efforts made to save energy and therefore energy efficiency should be evaluated by considering these factors as well.

As we further proceeded with interviews to determine what points should be considered, we received comments saying the three points of type of service (including scale), reliability, and site location should be reviewed for classification. If these points differ, energy efficiency will vary greatly and it is difficult for the data center to control these differences. Consequently, we received comments saying that such points should be considered when evaluating the value of data center energy efficiency metrics.

| Axis of type    | Reason for different energy efficiency   | Reason for a failure to change different energy efficiency   |
|-----------------|--|--|
| Type of service | <ul style="list-style-type: none"> <li>- The manageable range of a business varies according to one's possession, housing or hosting.</li> <li>- The required number of staff, versatility of equipment, and time and effort for management vary according to the type of service.</li> </ul>      | <ul style="list-style-type: none"> <li>- The area to be managed by customers (IT equipment, etc.) cannot be controlled.</li> <li>- There is a difference in time and effort for management between a data center providing a single service and a data center operating a variety of systems.</li> </ul>   |
| Reliability     | <ul style="list-style-type: none"> <li>- Consumption energy significantly changes according to the securement of equipment redundancy for assuring reliability.</li> <li>- Electric power system, communication system, system, etc. for backup</li> </ul>   | <ul style="list-style-type: none"> <li>- The securement of equipment redundancy is required to secure redundancy.</li> <li>- However, the required level varies according to how good the infrastructure is?</li> </ul>  |
| Site location   | <ul style="list-style-type: none"> <li>- The load of air conditioning significantly changes according to ambient conditions such as weather.</li> <li>- Data centers in urban areas</li> <li>- Data centers in a country with a warm climate and those in a country with a cool climate</li> </ul> | <ul style="list-style-type: none"> <li>- Site locations are limited depending on customer needs.</li> <li>- Data centers to which customers can rush in case of emergency, etc.</li> <li>- Site locations are limited to secure staff depending on the service level.</li> <li>- A case where shipment work requiring manpower is provided as a service, etc.</li> </ul> |

**Fig. 2: Examples of type axes for data centers**

[Sample interview responses]

Compatibility with various data centers is required to diffuse metrics.

- “We can’t release numerical values in a stage where they are not fully understood as metrics.”
- “Reliability and security are oriented in opposition to ecology. Therefore, if we emphasize them, the energy utilization efficiency will naturally become worse. Going forward, we need to have a way of working together with ecology while assuring reliability and security. For example, we can implement reliability with 1 + 0.7 pieces of equipment instead of doubling up to assure reliability.”

#### 1.1.6 Elimination of declaration bottlenecks

Two items serve as bottlenecks in declaring metric values: security and disjuncture of management scope.

First, data centers are characterized by high confidentiality to prevent its information from being disclosed, as their facilities exist to store user data. Consequently, comments were made saying that it is necessary to review methods for declaring energy efficiency metric values by adopting methods such as a scale of one to five.

Both data center owners and tenants said that disclosing information and assisting one another are not sufficient. For data centers for external housing, for example, the owner cannot control the energy efficiency of IT equipment brought in by users and therefore, the owner cannot work on energy saving in terms of this point. Additionally, if the IT equipment has low energy efficiency,

the air-conditioning system will have a heavy load due to high levels of waste heat, thus affecting the energy consumption of the data center facility section. On the other hand, tenants also said that owners do not disclose sufficient information, so the actions which tenants can undertake to improve energy efficiency are limited.

#### 1.1.7 Motivation for both businesses and users to improve energy efficiency

According to the results of the questionnaire, it became clear that data center businesses in Japan are very conscious of improving energy efficiency. However, there were comments saying that their expectation and motivation for comparable effects are not sufficient when actually working out the investments required to improve energy efficiency.

Data center owner pointed out that one of the causes is that users are not motivated to improve energy efficiency. In terms of user concerns in selecting data centers, high energy efficiency follows behind reliability, security, and cost. Comments were also made saying that it will be difficult to promote energy saving activities in a situation where owners are responsible for greenhouse gas emissions and users using highly energy efficient data centers will not be evaluated properly.

[Sample interview responses]

User spheres of responsibility should be clarified and user efforts to improve efficiency should be appreciated.

- “In the current situation, this action will only be used as a reason for price reduction negotiations. Therefore we cannot announce PUE (directly connected to cost).”
- “The systems we are renting outside the company should also be subject to evaluation within the user spheres of responsibility. Efficiency should be better if we use data centers with consolidated systems. Users using highly-efficient systems must be appreciated.”

Environmental load reduction of society as a whole using data centers should be taken into consideration.

- “We want to see evaluation indicators which can reflect the “Green by IT” effects in any way when IT equipment at user sites is moved to data centers.”
- “The data center business provides central facilities which customers essentially operate in their places of business. Therefore, we do not want the concept of CO2 reduction limited to data center businesses (cap-and-trade, etc.). We want you to review systems and mechanisms while recognizing that we can contribute to CO2 reduction more than customers operating machines can. Expand investment assistance to contribute to the environment. (Expand fields, amount of money)”
- “Information is not limited by location, and as such it may go anywhere if irrational

regulations are imposed. For example, data centers may move overseas and instead reduce the efficiency of society as a whole.”

#### Necessity of balancing regulations and promoting competition

- “We think servicers, who want to avoid declaration of PUE because of increasing pressure to cut prices, may be dumped into the trash. If this situation is excessively protected by issuing regulations limiting the location of data centers handling personal information in Japan, we feel there is a risk of Japanese data centers losing international competitiveness”

## 2 Reviewing New Metrics

The Green IT Promotion Council (GIPC) has been reviewing its original data center energy efficiency since 2008. In developing metrics, the approach we took emphasized the following:

- Calculate or measure energy efficiency easily,
- Able to compare different data centers, and
- Track energy saving efforts continuously.

The contents of the metrics under review are introduced below.

### 2.1 Data Center Model

Fig. 3 shows the data center model in the scope of this review.

Various organizations and groups have modeled data centers all over the world. Their model may be part of equipment in a data center, a facility only or even larger area. The model, which we assumed for this review, focuses on a controllable area from a data center development and operation point of view.

The inside of the data center is divided into IT equipment such as servers, facility equipment such as air-conditioning/power-supply systems, and operation for each type. Electricity is required to input data into the data center and obtain output. Electricity is sorted out into grid power and Green Power generated in the data center. Output is also accompanied by waste heat. Since the natural environment (for example, a site location in a cold area) and recycling of waste heat are large factors for input, waste heat is also incorporated into this model this.

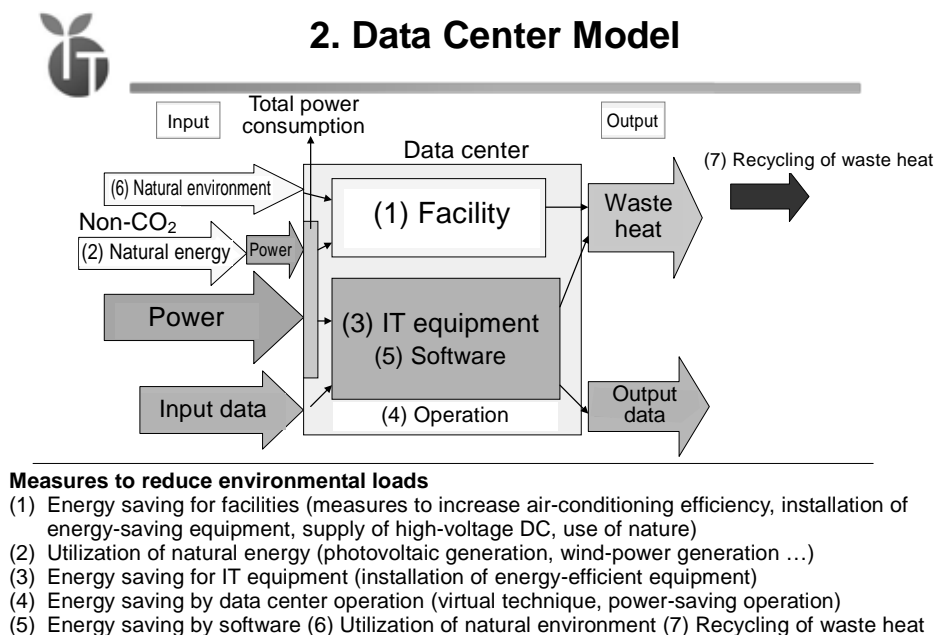


Fig. 3: Data center model

## 2.2 Actions Taken for to Improve Energy Efficiency at Data Centers

Actions to be taken to improve energy efficiency at data centers may be classified into the following four items:

1. Energy saving by efficient IT equipment operation  
To try to reduce physical equipment and increase the work rate by consolidation, virtualization, etc.
2. Energy saving by installing efficient IT equipment  
To try to install IT equipment with even higher energy-saving performance  
In Japan, a standard for energy-efficient IT equipment has been established according to the Japanese Energy Conservation Law.
3. Energy saving for facilities  
To try to reduce energy consumption for facilities by more efficient use of air-conditioning equipment, more efficient use of energy conversion equipment, and use of devices that utilize the natural environment
4. Use of renewable energy  
To try to use Green Energy generated by data center efforts, such as photovoltaic power generation, wind power generation, and hydroelectric generation

In terms of Datacenter Performance Per Energy, we believe it is necessary to formulate the respective metrics and an overall metric according to the four actions described above.

At present, The Green Grid has also proposed Power Usage Effectiveness (PUE), which is a recognized metric for facilities. The recognition and visualization of PUE are accelerating energy saving for facilities. However, PUE is a specialized metric for facility efficiency at data centers and is not satisfactory for representing the overall efforts for energy saving made by data centers.

The Green Grid has proposed Data Center Energy Productivity (DCeP) as a metric for the next stage but comparing numbers from different data centers is difficult to do at present. Many Japanese data centers are leased for external housing so that the measurement of the work rate (number of tasks completed per unit time) is also difficult to do.

## 2.3 Configuration of Metrics

The metrics covered by this review are based on the previously mentioned four actions for energy saving. The metrics (IT Equipment Utilization (ITEU), IT Equipment Energy Efficiency (ITEE), Power Usage Effectiveness (PUE), Green Energy Coefficient (GEC)) corresponding to the respective energy-saving measures will be created or adopted and, at the same time, Data Center Performance Per Energy (DPPE), which integrates the four, will be defined (Fig. 4). The four metrics (ITEU, ITEE, PUE, GEC) reflect four kinds of independent energy-saving efforts and are

so designed to prevent one kind of energy-saving effort from affecting other metrics. For this reason, each element may be used independently as a metric. DPPE incorporates four metrics and is expressed as a function.

Datacenter Performance Per Energy (DPPE) is expressed by the function of the following four energy saving metrics. These metrics can also be used independently.

$$\begin{array}{c}
 \text{Datacenter} \\
 \text{Performance} \\
 \text{Per Energy}
 \end{array}
 = F \left( \begin{array}{cccc}
 1 & 2 & 3 & 4 \\
 \text{IT} & \text{IT} & \text{Power} & \text{Green} \\
 \text{Equipment} & \text{Equipment} & \text{Usage} & \text{Energy} \\
 \text{Utilization} & \text{Energy} & \text{Effectiveness} & \text{Coefficient} \\
 & \text{Efficiency} & & 
 \end{array} \right)$$

= DPPE (Datacenter Performance Per Energy)

**Fig. 4: Configuration of Datacenter Performance Per Energy**

Here, IT Equipment Utilization (ITEU) is a metric for energy saving according to the efficient operation of data centers. ITEU is 0% at data centers which are not used at all and ITEU may be defined close to the target value at data centers performing the most efficient operation. IT Equipment Energy Efficiency (ITEE) is a metric which represents the relationship between the potential capacity and power consumption of the IT equipment of a data center. The more efficient the IT equipment installed, the larger the value becomes. Power Usage Effectiveness (PUE) is a metric indicating power saving for facilities. The more facility power is reduced the smaller the value becomes. Finally, for Green Energy Coefficient (GEC), the value becomes larger if the production of non-CO2 energy is increased in the company, which is represented by photovoltaic power generation as other such types of power generation. These four metrics will be defined so that as they (the reciprocal number for PUE) increase Data Center Performance per Energy (DPPE) increases as well.

## 2.4 Definitions of Individual Metrics

The results of reviewing the definitions of each individual metric are summarized below.

### 2.4.1 ITEU

First, IT Equipment Utilization (ITEU) represents the degree of energy saving by virtual techniques and operational techniques using the potential IT equipment capacity without waste. Reduction of equipment to be installed is promoted by using the number of devices to meet the required IT capacity without waste.

ITEU is essentially the average utilization factor of all IT equipment included in a data center. However, the adoption of a method using the ratio of total measured power to total rated power of IT equipment is under review by examining the ease of measurement in a concrete calculation (Fig. 5).

$$\text{ITEU} = \frac{\text{Total measured power of IT equipment}}{\text{Total rated power of IT equipment}}$$

**Fig. 5: Definitional identity of ITEU**

#### 2.4.2 ITEE

IT Equipment Energy Efficiency (ITEE) is defined as the value obtained by dividing the total capacity of IT equipment by the total rated power of the said IT equipment. This metric aims to promote energy saving by encouraging the installation of equipment with high processing capacity per unit electric power. The concept is similar to DCeP of The Green Grid. However, it is considered difficult to make actual measurements because a single data center contains a mix of various kinds of equipment and services. Therefore, consideration will be given to the method of simply calculating it using the spec values of the data sheet. For this reason, ITEE will be the weighted average efficiency of the energy saving performance in the catalogs of IT equipment in a data center.

- IT equipment that configures a data center is defined as consisting of the following three types: server, storage, and NW equipment.

$$\text{ITEE} = \frac{\text{Total server capacity} + \text{total storage capacity} + \text{total NW equipment capacity}}{\text{Rated power of IT equipment}}$$

**Fig. 6: Definitional identity of ITEE**

Here, “total capacity of IT equipment” is defined as the total of all the capacities of the server, storage, and NW equipment (Fig. 6). As the purposes of the three kinds of equipment differ from one another, it is very difficult to add the respective capacities, and we are presently reviewing two calculation method proposals at present.

The first proposal is a concept using energy consumption efficiency. Energy consumption

efficiency is adopted in the Top Runner System and the Japanese Energy Conservation Law. In Japan, the power per unit capacity of each device is always written in the data sheet. For NW equipment, it is necessary to wait for future description and therefore the throughput of the equipment has been tentatively adopted. The second is a proposal using benchmarks. To calculate the total capacity of IT equipment by either method, it is necessary to convert the spec value of each device to its capacity. We are currently reviewing the calculation method.

### 2.4.3 PUE

Next, Power Usage Effectiveness (PUE) is the metric proposed by The Green Grid (Fig. 7). However, since many feel that standardization and guidelines for measurement are necessary, we are now preparing consistent measurement guidelines through collaboration with The Green Grid.

$$\text{Power Usage Effectiveness} = \frac{\text{DC total power consumption}}{\text{Power consumption of IT equipment}} = \text{PUE}$$

**Fig. 7: Definitional identity of PUE**

### 2.4.4 GEC

Finally, the Green Energy Coefficient (GEC) is a value obtained by dividing Green Energy produced and used in a data center by total power consumption (Fig. 8). Introduced to promote the use of Green Energy, from a power consumption reduction point of view it is positioned differently than the other three metrics defined above.

$$\text{GEC} = \frac{\text{Green Energy}}{\text{DC total power consumption}}$$

**Fig. 8: Definitional identity of GEC**

### 2.4.5 DPPE

Considering the definitions of the above four metrics, Data Center Performance Per Energy (DPPE) may be expressed by the product of the respective metrics (Fig. 9). However, when actually numerically rating this metric, we believe that it is necessary to correct the relationship between the fluctuation band of each metric and the ease of energy saving effort according to the

data.

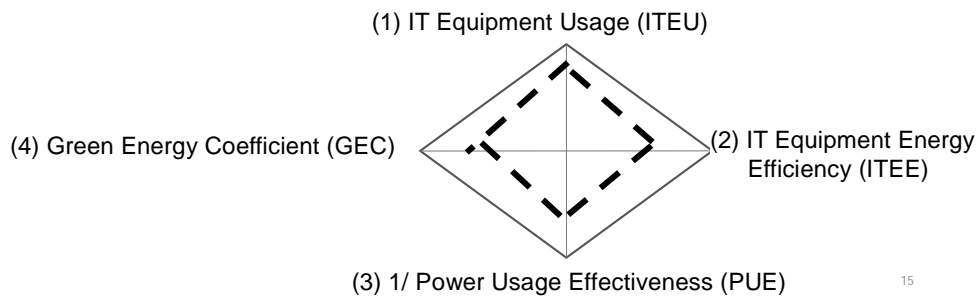
$$DPPE = ITEU \times ITEE \times \frac{1}{PUE} \times \frac{1}{1 - GEC}$$

**Fig. 9: Relationship between DPPE and each metric**

## 2.5 How to Use Metrics

Before using the defined metrics, it is necessary to review the following two points: how to use individual metrics and data center type classification.

First, for how to use metrics, it is possible to show the four individual metrics in parallel. DPPE is an integrated metric calculated from the four metrics and singly represents the entire efficiency. Visualizing DPPE by the cobweb chart as shown in Fig. 10 allows for understanding the level of each action for energy saving at a given data center.



**Fig. 10: Example of visualization of metrics by cobweb chart**

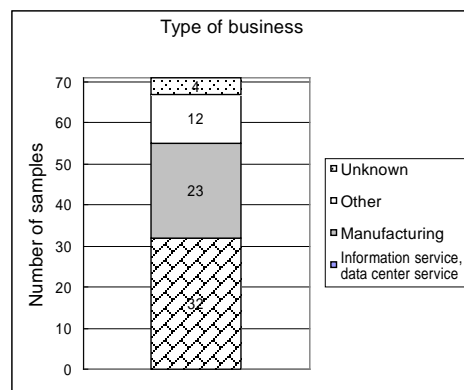
## Appendix – Present Situation of Data Centers in Japan

In February 2009, we conducted a questionnaire on the present situation of data centers in Japan and their actions to improve energy efficiency. The number of valid responses collected was 71. Here, we introduce the characteristics of data centers in Japan, which we learned about through the questionnaire. The questionnaire was conducted with the assistance of The Green Grid.

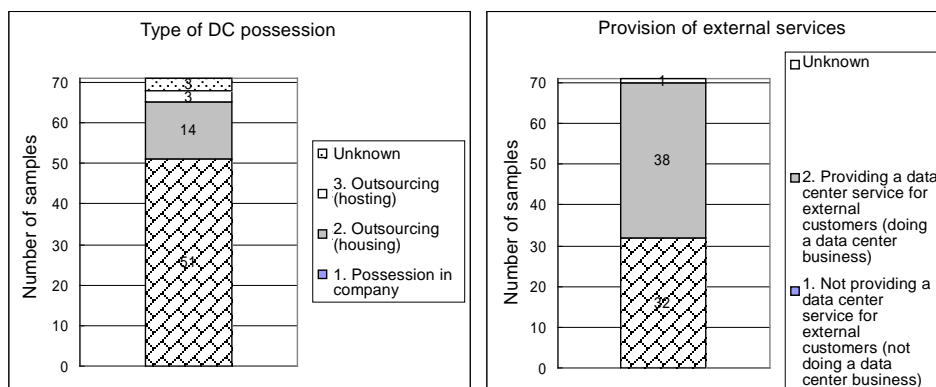
### A.1 Profile of data centers of companies responding to the questionnaire

Fig. 11 summarizes the types of business of the companies responding to this questionnaire. The responding companies consist of many information service firms and manufacturers and also include service businesses, public services, and financial companies. The majority of the respondents were those in charge of data center operation and management.

When we asked about the companies' most representative data centers in terms of data center possession types, many of the companies surveyed have their own in-house data centers for their information systems, followed by those in the form of housing (Fig. 12). The ratio of data centers for internal utilization and those providing external services was 1:1.



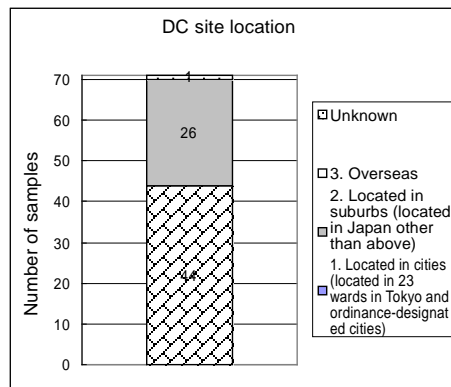
**Fig. 11: Types of business of responding companies**



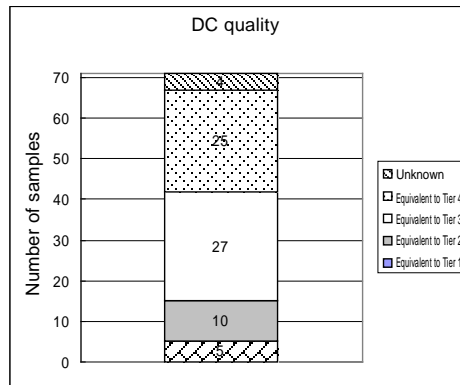
**Fig. 12: Possession of data center and type of service provision**

When we further asked about the site location of the data center, 41% of the data centers (57% overall) were located in cities, thus showing the characteristic that many Japanese data centers are located in cities (Fig. 13).

In terms of data center quality, there were many reliable data centers equivalent to Tier 3 and Tier 4 according to the standards<sup>1</sup> of the Uptime Institute.



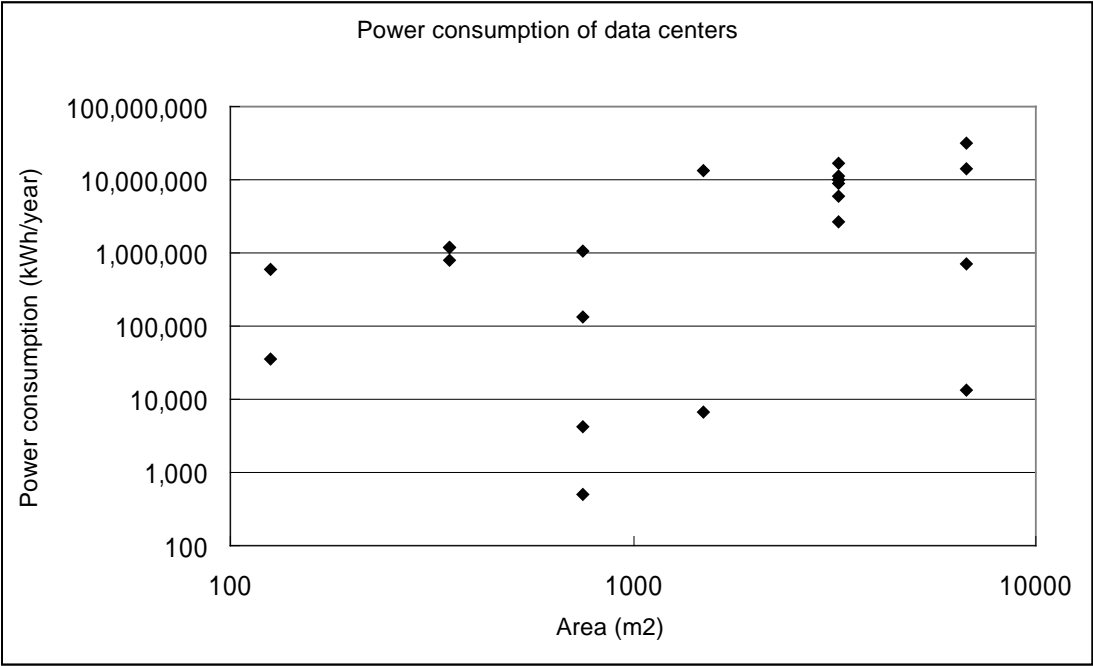
**Fig. 13: Site location of data centers**



**Fig. 14: Quality of data centers**

<sup>1</sup> Uptime Institute HP (<http://uptimeinstitute.org/content/view/22/56/>)

Furthermore, Fig. 15 shows data center power consumption by area. There are large variations in power consumption and even data centers that are similar in area show extraordinary differences in power consumption. When we also asked about the PUE value, the values ranged from 1.7 to 2.3, but there were few responses (5) and therefore, it is not known whether they represent an average.

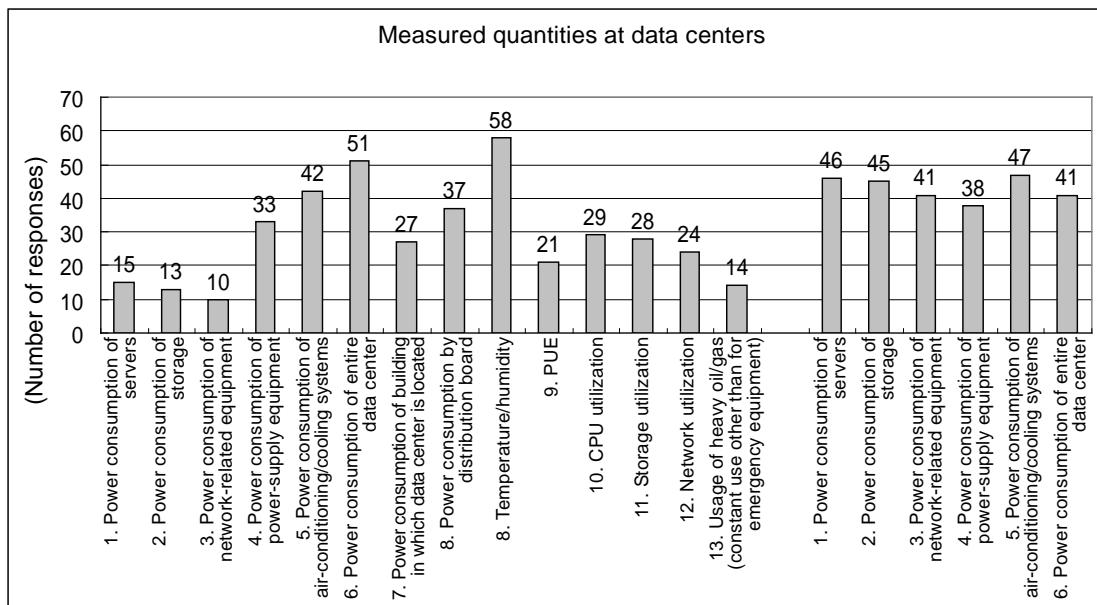


**Fig. 15: Data center power consumption by area**

## A.2 Actions for improving data center energy efficiency

Next, we asked about their current actions for improving data center energy efficiency.

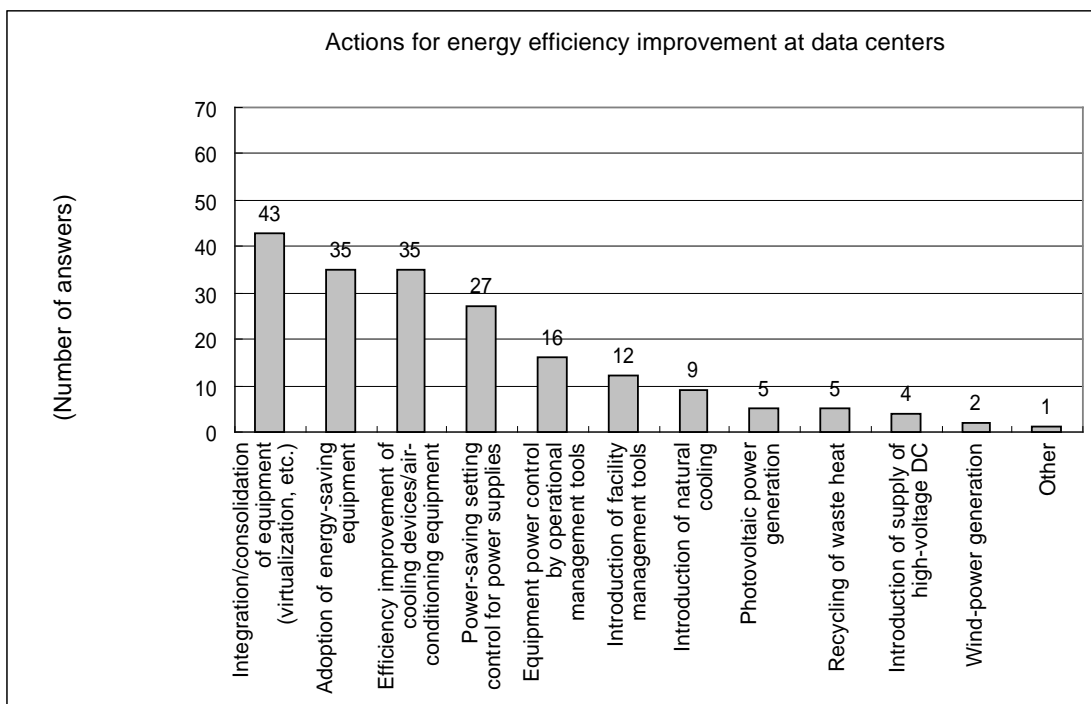
First, we asked about measurable amounts at data centers (Fig. 16). The amounts measured at many of the data centers represent power consumption of the entire data center and the power consumption of facilities as well as the temperature and humidity necessary for managing the data center. The rated values are more understood than the measured values with the same amounts, so the rated capacity and rated power consumption of IT equipment are understood. On the other hand, there are more data centers which do not measure power consumption by smaller power consumption measurement classifications such as by server and storage. Based on this, we presume that the measured values understood at present represent the power consumption of the entire data center or the power consumption of all IT equipment and the entire facility.



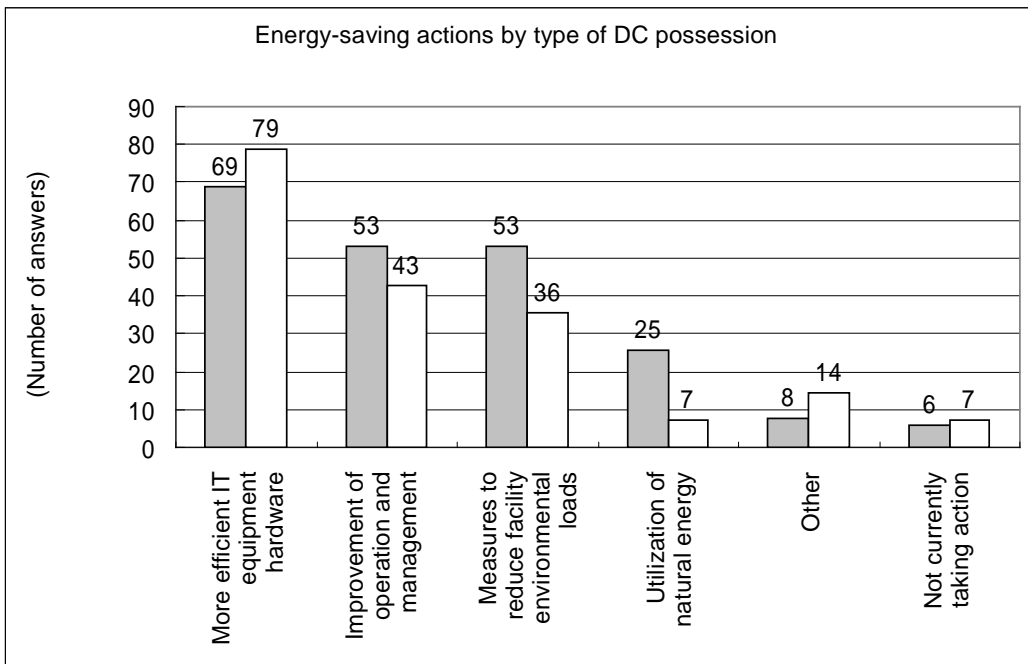
**Fig. 16: Measurable amounts at data centers**

Fig. 17 shows the working situation for energy efficiency improvement at data centers. The most taken action to improve energy efficiency was integration/consolidation of equipment (virtualization, etc.). There were the same number of answers for installation of highly-efficient IT equipment and highly-efficient facility equipment. It is clear that actions for energy efficiency improvement at data centers are not focused on only one of the actions listed below but wide-ranging efforts are being made.

When comparing energy-saving actions by possession or use of data centers, such as in-house or by housing, the rate of actions being taken, such as facility environmental load reduction and utilization of natural energy, of companies using data centers in the form of housing is lower than that of companies whose data centers are in-house. This is probably because the scope of management is limited to IT equipment and consequently, there are not many options for possible actions, thus indicating that energy saving actions which can be taken by businesses vary according to the type of service.



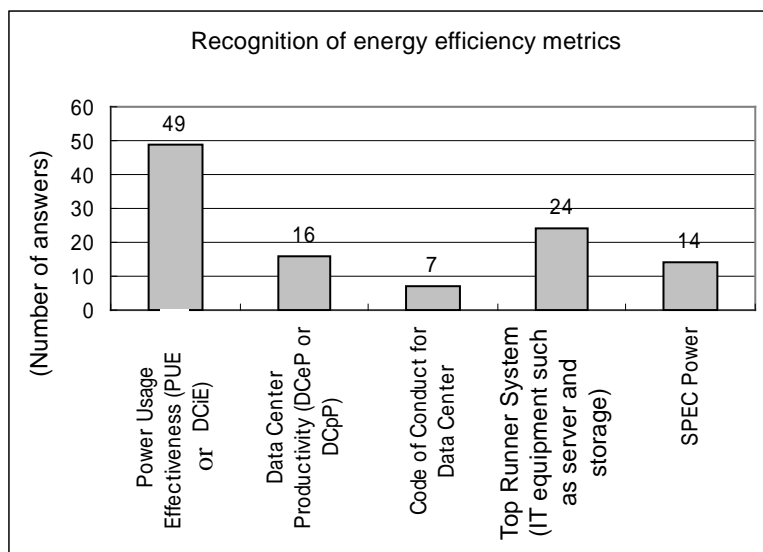
**Fig. 17: Actions for energy efficiency improvement at data centers**



**Fig. 18: Energy-saving actions by type of data center possession**  
**(Black: in-house data center, White: use of housing)**

### A.3 Existing energy efficiency metrics

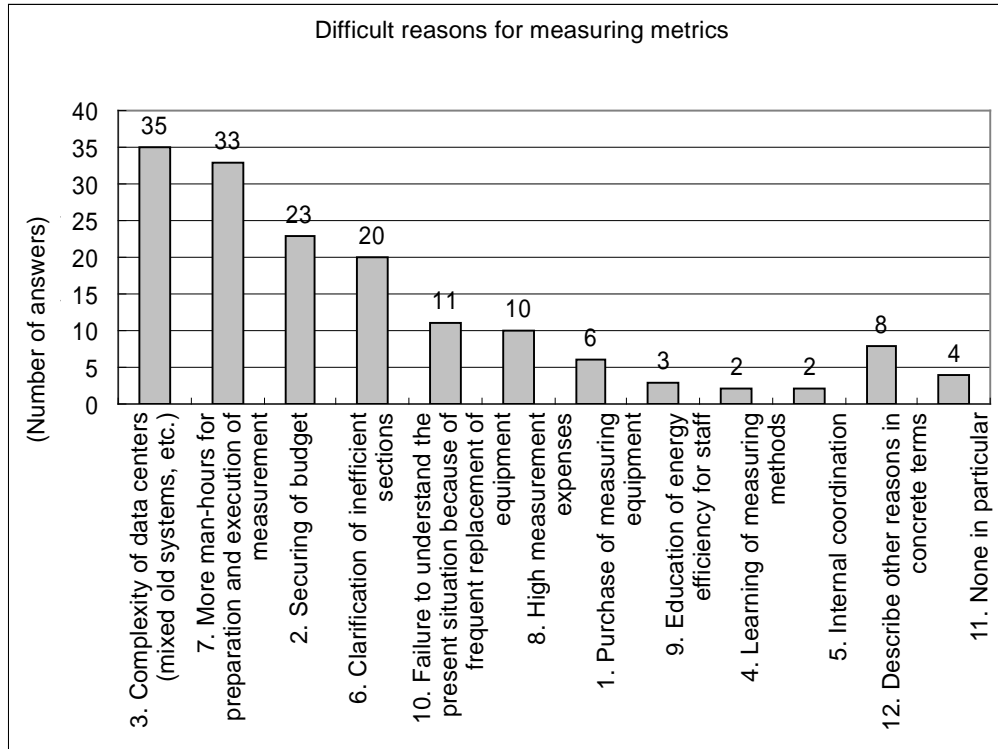
Next, we examined awareness of existing metrics. As a result, we found that at present the most recognized metric is PUE, proposed by The Green Grid, but awareness of the Top Runner Standard given in the Japanese Energy Conservation Law is also high in Japan (Fig. 19). Furthermore, the same tendency was also observed not only in awareness but also in utilization.



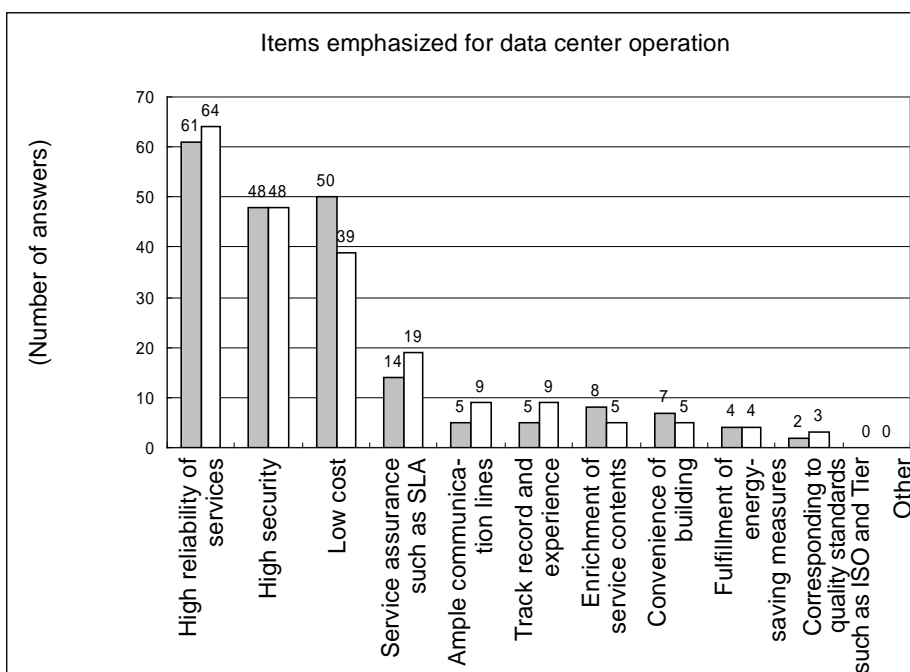
**Fig. 19: Recognition of existing metrics**

We further asked them about reasons for the difficulty of measuring existing metrics (Fig. 20). Hurdles given include the existence of old data centers, measurement cost, and more.

For the items emphasized in data center operation, security, reliability, and cost are given priority and energy-saving performance is ranked low (Fig. 21).



**Fig. 20: Difficult reasons for measuring metrics**



**Fig. 21: Items emphasized for data center operation**  
**(Black: Information system, White: Main system)**

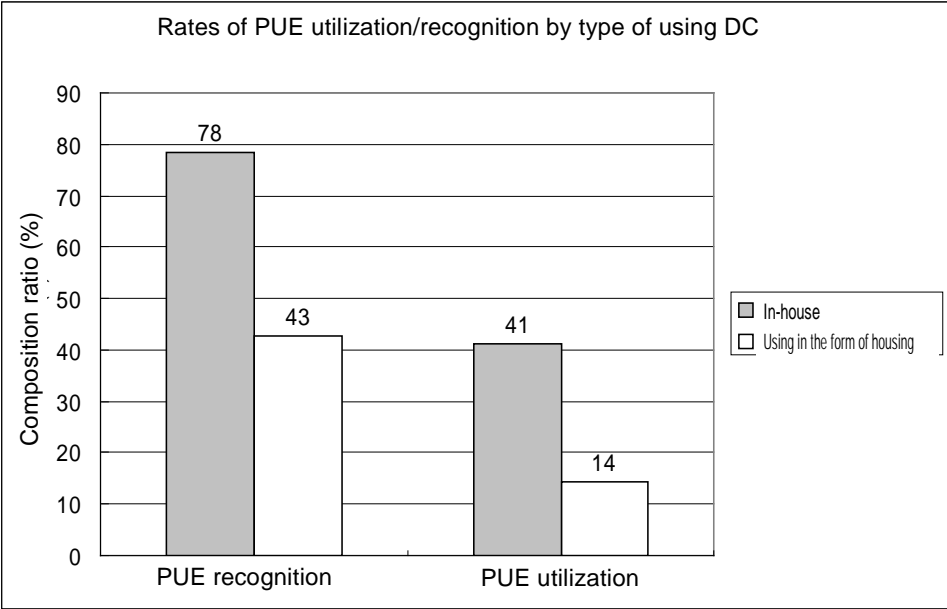
#### A.4 Characteristics by data center type

As shown in Fig. 19, PUE is the most recognized energy efficiency metric among companies using data centers. We examined the interest level by type for energy efficiency metrics by observing the PUE awareness and utilization by data center type.

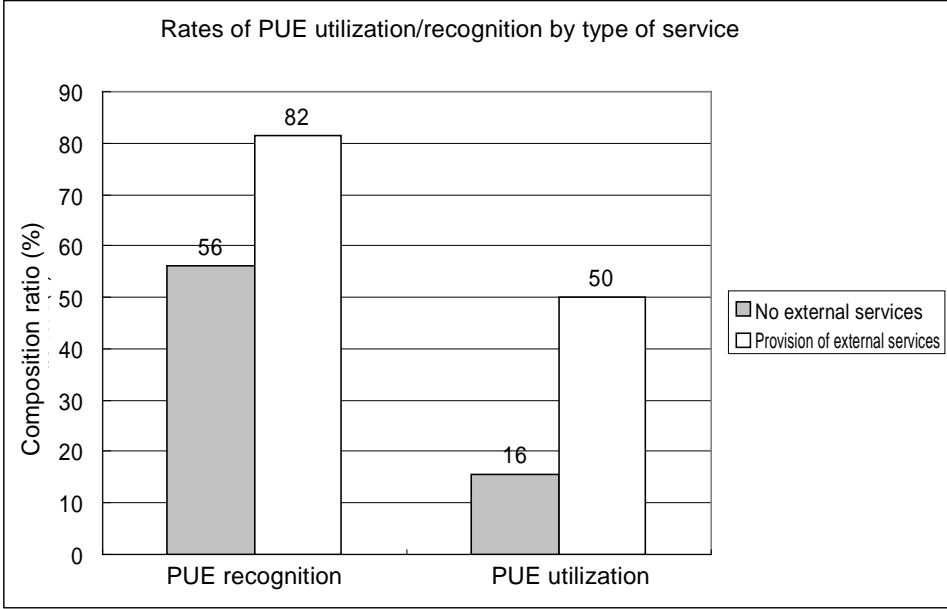
Fig. 22 and Fig. 23 show the rates of PUE awareness and utilization by type of data center and by provision/non-provision of external services, respectively. Fig. 22 examined the rates of PUE awareness and utilization by dividing the companies into those which possess in-house data centers and those which use external data centers in the form of housing. Fig. 23 examined the rates of PUE awareness and utilization by dividing the companies into those which provide external services and those which provide services for in-house use.

Fig. 22 shows that there is a big difference in the rates of PUE awareness and utilization between companies which possess in-house data centers and those which use external data centers in the form of housing. The rate of PUE awareness of the companies which possess in-house data centers is about 80% while that of the companies using data centers in the form of housing is about 40%, half of the former. PUE is a metric indicating the energy-saving efficiency of the facility section and therefore it is believed that the difference in recognition has been affected by the fact that this area cannot be directly controlled by companies using data centers in the form of housing.

Comparing the companies providing external services with those using in-house services (Fig. 23), PUE utilization and awareness of companies providing external services are higher than those of the companies only using in-house services.

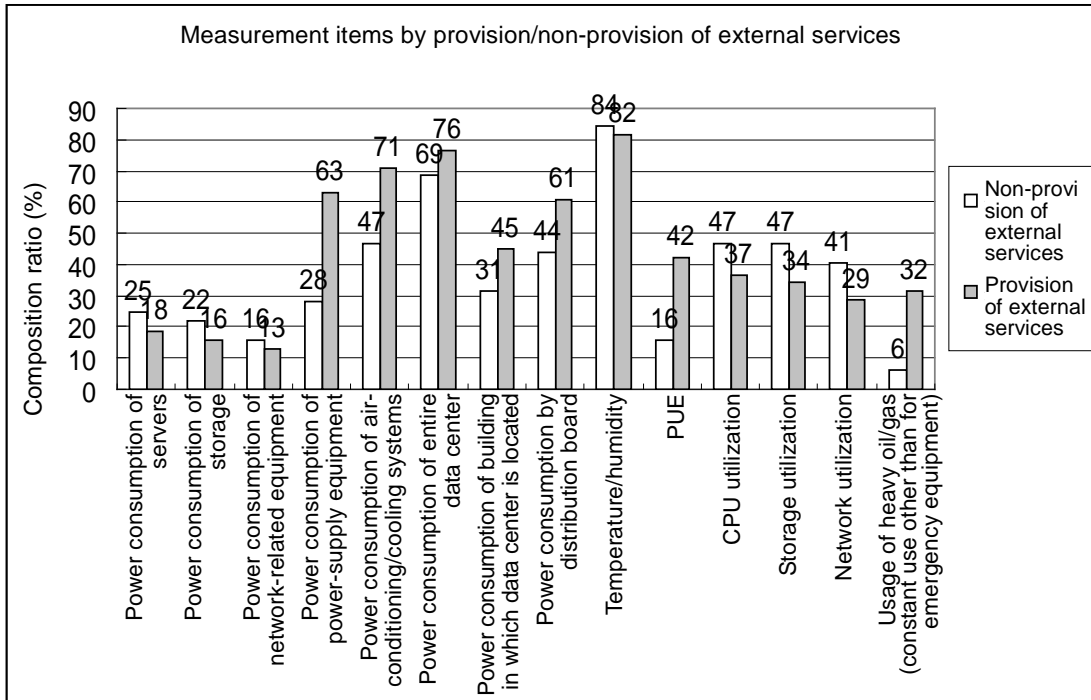


**Fig. 22: Rates of utilization/recognition by type of data center**



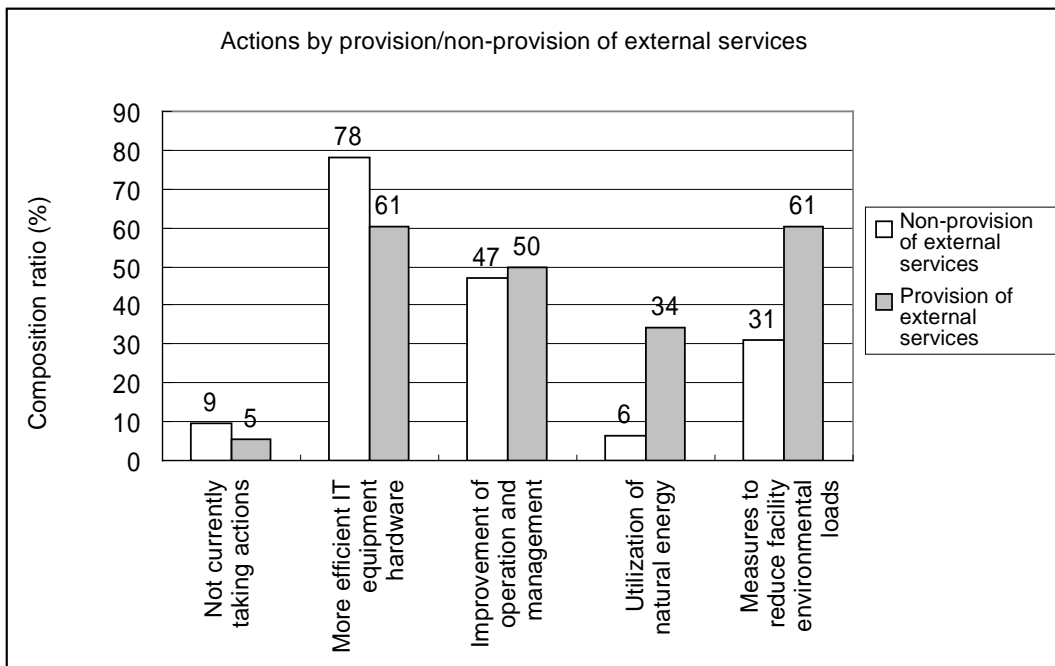
**Fig. 23: Rates of recognition/utilization of PUE by provision/non-provision of external services**

In observing the items measured by data centers by provision/non-provision of external services, there is a big difference in the measurement execution rate in measurement of power consumption of power-supply equipment and facility equipment between the above types (Fig. 24).



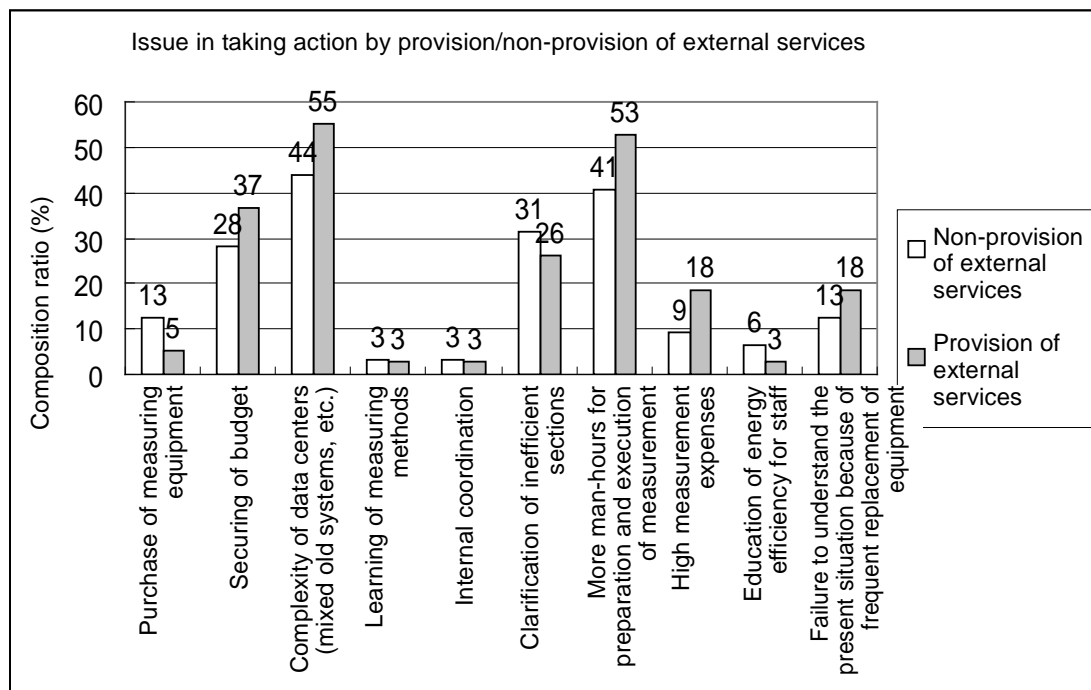
**Fig. 24: Measurement items by provision/non-provision of external services**

Further observing actions by segment, we found that the data centers providing external services have higher execution rates for utilization of natural energy and facility energy efficiency improvement (Fig. 25).



**Fig. 25: Status of energy-saving approaches by provision/non-provision of external services**

However, we found that there is not a big difference between the provision and non-provision of external services concerning points felt to be difficult in terms of taking action, and the same problems are regarded as difficult to solve in either case (Fig. 26).



**Fig. 26: Issues in taking energy-saving actions by provision/non-provision of external services**