

DPPE: Holistic Framework for Data Center Energy

Efficiency

- KPIs for Infrastructure, IT Equipment,
Operation (and Renewable Energy) -

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Japan National Body
/Green IT Promotion Council

1. Introduction

While Information and Communication Technologies (ICT) contribute greatly to improvement of energy efficiency, energy consumption by ICT themselves has been increasing. In particular, datacenters integrating large number of servers consume enormous energy and their consumption level is elevating year by year. Therefore, urgent action should be taken to control the CO2 emission indirectly introduced by the increasing usage of Electricity by datacenters. This could be achieved by enhancing the energy usage efficiency.

To enhance efficiency of datacenters, it is essential to evaluate it in a quantitative manner as a first step. Currently, "Power Usage Effectiveness" (PUE) is a widely acknowledged metric to evaluate energy efficiency of a datacenter. However, PUE is a metric to measure the energy efficiency of the datacenter facility. For improvement of the energy efficiency of a datacenter, it is necessary to improve both efficiency of the facility side and the efficiency of IT equipment.

To address this issue, "Green IT Promotion Council" (GIPC) has promoted the development of "Datacenter Performance per Energy" (DPPE), a set of novel metrics that describe the entire energy efficiency of a datacenter (as KPIs) and a Holistic Framework for evaluation of the datacenter efficiency by using these metrics. DPPE integrates an index to express efficiency of IT equipment in addition to PUE, an index to express energy efficiency of the facility. Besides, DPPE includes a metric evaluating the usage of Green Energies such as Photovoltaic power generation and Wind power generation. Datacenter operators and datacenter users could evaluate the efficiency of their entire datacenter (both Facility and IT equipment) objectively. This enables datacenter owners/operators to approach the initiative on continuous basis by visualizing the process of improving the facility and equipment as well as the efforts to rationalize their operations.

GIPC is currently promoting the realization of a set of metrics and the Holistic Framework in harmonization with both Japan domestic and International groups concerned including The Green Grid – TGG (USA)¹. Two objectives as below are established as GIPC's goals in the realization:

(1) Establishment of "Effective metrics"

An effective metric available for evaluation of the datacenter efficiency should be established.

(2) Proposal of a widely usable measurement method

A widely usable measurement method based on the facts of datacenters should be presented. To achieve these goals, GIPC has tried to establish a method to measure the energy efficiency by inclusive of existing systems as much as applicable and usable.

¹ "Harmonizing Global Metrics for Data Center Energy Efficiency 2011-02-28"
(http://www.greenit-pc.jp/topics/release/pdf/dppe_j_20110228.pdf)

Having above-mentioned situation as a background, GIPC is contributing this document to fulfill the following objectives²:

- Indicates basic definition of a set of metrics of DPPE and the Holistic Framework. Explains how these metrics are linked with the improvement of energy efficiency of datacenters (explained in Chapter 2)
- The Demonstration of the experimental data gathering project conducted between the years 2010 to 2011 with GIPC metrics developed for the energy efficiency has yielded the current status of the Japan domestic datacenters. Furthermore, it has indicated how to understand the energy characteristics of datacenters and promote the energy saving approaches by the use of Holistic Framework (explained in Chapter 3)

The specific details of the measurement method of each metric in datacenters are described in “DPPE Measurement Guideline³” and this document will only outline the characteristic and points of each measurement method which will be explained in Chapter 2.

² Definition of the metrics in this context is based on the proposal as of July 2012. The definitions and measurement guidelines may be susceptible to changes depending on the future discussion and developments.

³ “DPPE Measurement Guideline” Green IT Promotion Council (2011). See this Guideline for further details of the DPPE measurement method.

2. Basic definition of a series of metrics for energy efficiency and Holistic Framework

2.1 Concept of energy efficiency improvement in a datacenter

According to the report published by the U.S. Environmental Protection Agency – EPA in 2007⁴, energy consumption of datacenters in the United States has more than doubled from 28.2 billion kWh/year in 2000 to 61.4 billion kWh/year in 2006. To be more specific, the energy consumption attributed to the facility side, such as air conditioning and power distribution (datacenter infrastructure) and the energy consumption attributed to IT equipment such as servers / storages / network equipments and etc. occupy about a half of the total energy consumption of the datacenter respectively, and both of these parts are ever increasing (Fig. 2-1). This result shows that it is essential to approach the improvement of energy efficiency from both aspects of datacenter facilities and IT equipment.

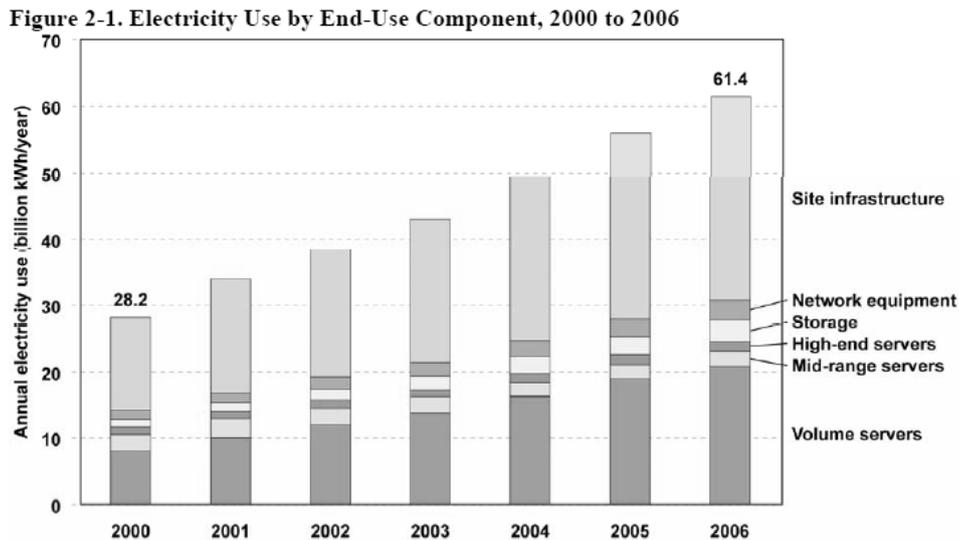


Fig. 2-1: Annual power consumption in US datacenters

The structure of energy consumption in a datacenter is shown in Fig. 2-2, from the procurement of energies to the energy consumption by IT equipment. First of all, energies for datacenters are procured as a commercially available power, Energy supplied from off-site sources and also Energy supplied from on-site sources. Then, the procured energies are consumed by the datacenter facilities (infrastructure) such as air conditioners, power distribution and lighting to provide a datacenter environment. Finally, energies were consumed by IT equipment.

Approaches to improve the datacenter energy efficiency could be implemented in each of these parts. At first, with the part of the energy procurement, quality of the energies

⁴ "Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431" (US Environmental Protection Agency (EPA), 2007)

to be procured can be improved by introduction of Green energies. (yield the reduction of CO2 emission). Secondary, with a part of facility (infrastructure), efficiency can be improved by introduction of highly efficient equipment and improvements on operations. Furthermore, the IT equipment category could be divided into Hardware / Software and Operation parts. Efficiency of the IT side could be improved by introduction of highly efficient IT equipment, and improvements of IT equipment Operations will complement both.

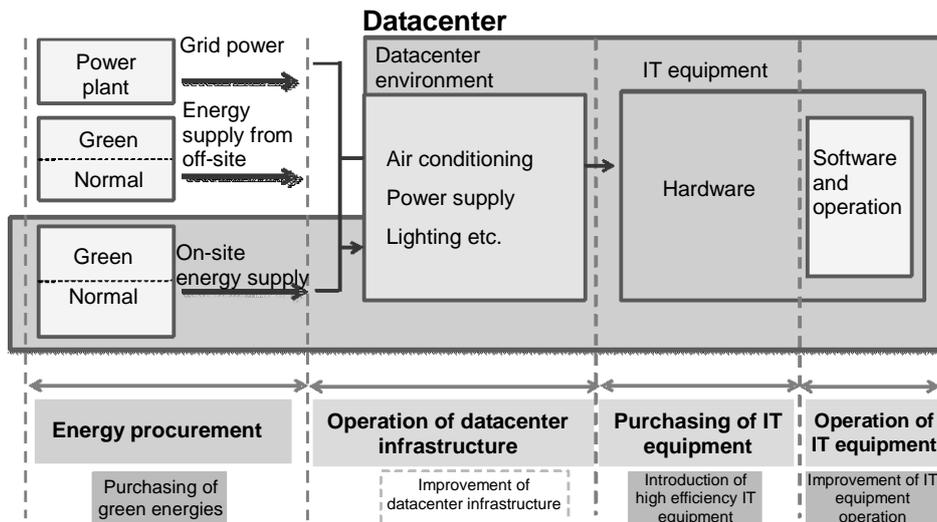


Fig. 2-2: Datacenter energy flow

By observing the division of energy flow of the entire datacenter, it is possible to examine the area needed to improve for the efficiency possibility of the datacenter without overseeing any specific components. Fig. 2-3 indicates an example for the process of promoting datacenter efficiency improvement performed by “Chief Information Officer” (CIO). Each part in Fig. 2-2 corresponds to the each operating unit (division) of any given datacenter. In accordance of each line of the operating unit, (1) CIO could establish an efficiency improvement goal for the entire datacenter first. Then, (2) the CIO could assign each operating unit with an action plan as their goal to be achieved. (3) Each operating unit (division), to which the goal is assigned, could promote their plans to achieve the goal in a manner most suitable to their responsibilities. Thus, by establishing linkages between the each individual goal of operating units of the entire datacenter could yield the total improvement of energy efficiency as a whole.

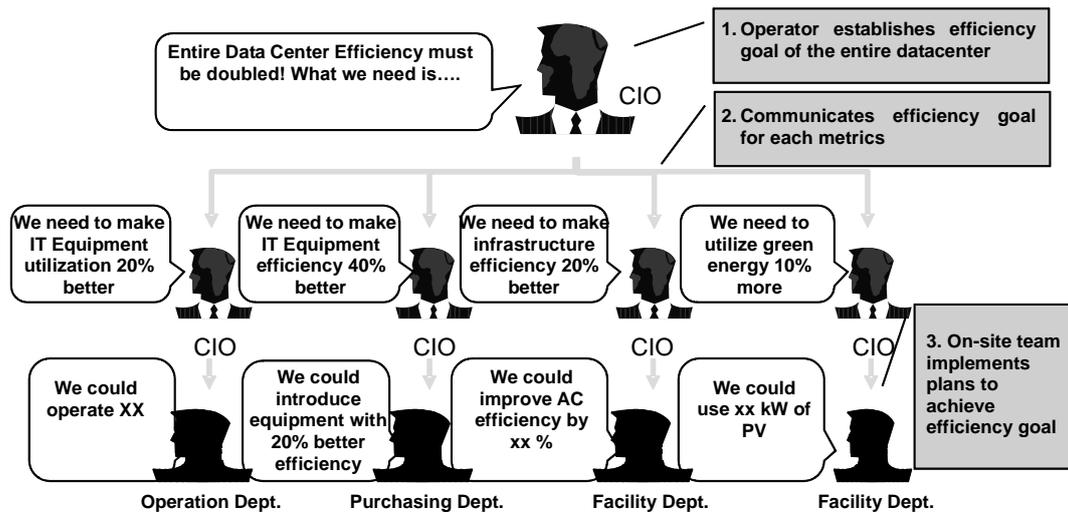


Fig. 2-3: Allocation of responsibility for each operating unit to improve energy efficiency of the entire datacenter as a whole.

2.2 Metrics for Energy Efficiency of Datacenter Infrastructure, IT Equipment and Operation

Datacenter energy efficiency could be defined as a production per consumed energy. Giving consideration to the energy procurement, Green energies could be deducted from the total energy consumption. Taking these factors into an account, energy efficiency = (data center production) / (non-green energy consumption).

As indicated in Chapter 2.1, improvement can be promoted efficiently by allocating the energy efficiency of the entire datacenter to each part. In order to approach the measurement task, the DPPE metrics were developed. DPPE has 4 specific metrics to be used to evaluate efficiency of each part (Table 2-1). By categorizing each of the energy efficiency, which is linked with the activities to improve the energy efficiency such as selection of the IT equipment and facility improvements in each part of the datacenter is shown in Fig. 2-2 and Fig. 2-3.

Table 2-1: A set of metrics composing the energy efficiency of a datacenter (DPPE)

Sub-metrics description	Equation	Corresponding action
ITEU (IT Equipment Utilization)	= Total energy consumption of IT equipment (actual) / Total rated energy consumption of IT equipment (rated)	Efficient operation of IT equipment: Approaches to improve utilization ratio through consolidation and virtualization and by reducing the number of equipment in operation.
ITEE (IT Equipment Energy Efficiency)	= Total rated capacity of IT equipment (rated) / Total rated power of IT equipment (rated)	Approaches to introduce IT equipment with higher energy saving performance.
PUE (Power Usage Effectiveness)	= Total energy consumption of datacenter (actual) / Total energy consumption of IT equipment (actual)	Approaches to reduce energy consumption caused by facilities such as efficiency improvement for air conditioning system and power transformer system as well as the programs to use natural environment effectively
GEC (Green Energy Coefficient)	= Energy level generated by green energies (natural energies such as photovoltaic power / wind power) (actual) / Total energy consumption of datacenter (actual)	Approaches to install and use equipment to generate green energies such as photovoltaic power, wind power and hydraulic power etc.

These four specific metrics (ITEU, ITEE, PUE, GEC) reflect the four types of independent approaches of energy savings. These were designed that any given one type of energy saving approach should not affect other metrics. In accordance, each of these elements could be used as a stand-alone metric also.

In this context, ITEU is the metric used for the efficient operation of datacenter IT equipment. In a datacenter where no IT equipment is operating, ITEU value is “0”. On the other hand, in a datacenter where IT equipment are all fully in operation (100% utilized), ITEU value is “1”.

ITEE is the metric to express the relationship between potential capacities of IT equipment in a datacenter and the energy consumption. ITEE is an average efficiency of all IT equipment installed in a datacenter. This value becomes larger when IT equipment with improved energy saving (efficient) is introduced (installed/replaced with).

PUE is the metric to express Datacenter’s facility energy efficiency. With increases in energy consumptions in a datacenter facility, the PUE value becomes smaller and will approach closer to “1”.

GEC is the metric for the amount of the usage of Green energy. It will become larger when Green energy usage increases, such as introduction of Photovoltaic and Wind based power and etc. (i.e. energies which would not generate CO2 in production).

These four metrics (where only with PUE, an inverse is used) were defined in the way that the energy efficiency should improve when each metrics’ value would become larger. By the usage of these four types of sub-metrics, it is possible to identify the efforts to improve the energy efficiency of the entire datacenter (Fig. 2-4). The four sub-metrics correspond to the energy saving approaches of each line units (division) indicated in Fig. 2-3.

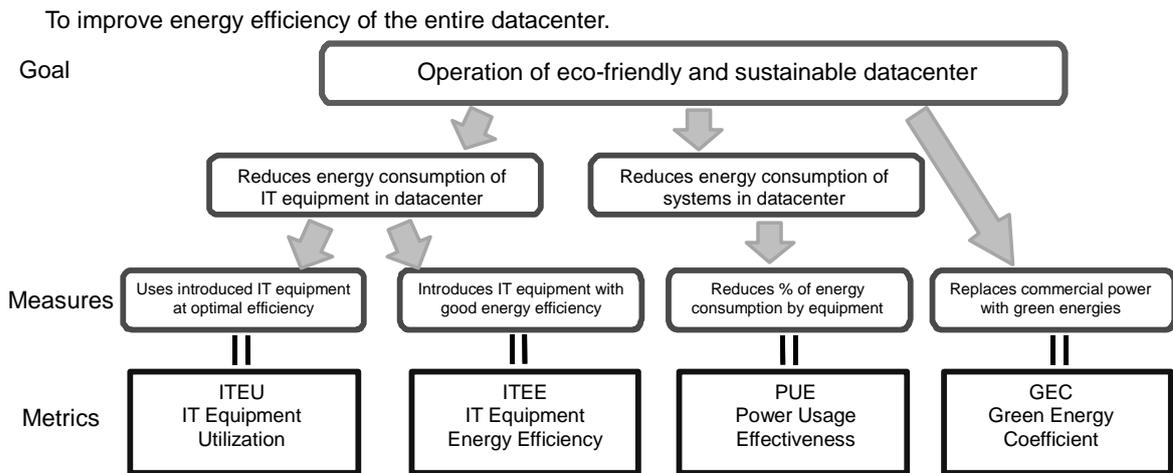


Fig. 2-4: Breakdown of overall datacenter energy efficiency: DPPE

2.3 Outline of IT Equipment Utilization (ITEU)

2.3.1 Definition of the metric

ITEU is a metric to indicate how efficient IT equipment is used in the performance. This metric contributes to the enhancement of IT equipment utilization ratio and specific only to the server, reduction of server idling power usage. It indicates the level of energy saving achieved by virtualization technology and operational aspects of engineering that enable efficient use of potential capacity of IT equipment.

Because ITEU is the metric to indicate utilization ratio of the IT equipment, it is desirable to obtain the ratio of actual performance (such as server utilization ratio) versus the rated performance for each IT equipment type such as server, storage, network and other equipment and to calculate the average. However, it is practically difficult to measure the utilization ratio of all types of IT equipment in many datacenters at present time. Therefore, “the ratio of the total measured power level versus the total rated power level of IT equipment” is used as a substitute for this metric’s concept. This method is used, because the measured power level is considered to approach the rated power level with the increase of equipment utilization ratio.

$$\text{ITEU} = \text{Total energy consumption of IT equipment (actual) [kWh]} / \text{Total rated energy consumption of IT equipment (rated) [kWh]}$$

The calculation scope for ITEU includes all the IT equipment including server, storage, network and other IT equipment. All the IT equipment that are redundant in normal operation status shall be included in calculating the ITEU. On the other hand, stand-by state equipments in the power shutdown status shall be excluded from the calculation because no power consumption occurring. The measurement period and measurement points of the measured power level shall be based on the published measurement method of “PUE measurement guideline”.

ITEU is the weighted average of the power utilization ratio where the rated power of individual IT equipment is regarded as weight:

$$\text{ITEU} = 1 / (\text{total rated energy consumption}) \\ \times (\sum (\text{rated energy consumption of individual equipment}) \times (\text{energy consumption of individual equipment}) / (\text{rated energy consumption of individual equipment}))$$

Therefore, IT equipment with larger rated power will have bigger effect to the entire ITEU number.

2.3.2 ITEU calculation example

If measured power consumption level of an IT equipment is 396,000 kWh during the measurement period (30 days), and the total rated power level is 1,500 kW × 24 hours × 30 days=1,080,000 kWh:

$$\text{ITEU} = 396,000[\text{kWh}] / 1,080,000[\text{kWh}] = 0.367 = 36.7 [\%]$$

2.4 Outline of IT Equipment Energy Efficiency (ITEE)

2.4.1 Definition of the metric

ITEE is defined as total rated capacity of IT equipment divided by total rated power of IT equipment (rated work units). Promotion of the energy saving is targeted by encouraged to introduce an equipment with higher processing capacity per unit of power consumed.

$$\text{ITEE} = \text{Total rated capacity of IT equipment [Work]} / \text{Total rated power of IT equipment [W]}$$
However,

$$\text{Total rated capacity of IT equipment [Work]} = \alpha \times \Sigma (\text{Server capacity [GTOPS]}) + \beta \times \Sigma (\text{Storage capacity [Gbyte]}) + \gamma \times \Sigma (\text{Network capacity [Gbps]})$$

In ITEE calculation, all of IT equipment composing a datacenter are classified into 3 categories (i.e. server equipment, storage equipment and network equipment) for simplification. The equipment impossible to classify into any of these categories are excluded from the scope of the total rated capacity calculation.

Because ITEE is a rated work rate, a simple calculation method is adopted for the rated performance and the rated power, where IT equipment specification values for energy saving performance cited (published) in catalogues are used. However, catalogue values may not be used for some cases due to some cases such as “old equipment purchased before the mandatory description of energy saving performance” or “out of the scope of mandatory description” and etc. Therefore, with regards to the total rated power and the total rated capacity, the total value obtainable of the IT equipment shall be used for both of these metrics calculations.

With regard to the server capacity, storage capacity and network capacity, two types of approaches have been discussed. The first approach is based on the adoption of the energy consumption efficiency cited in the Energy Saving Act, as it has been considered as the easiest value to use in the Japan domestic arena. The second approach emphasizes the convenience in the global arena based on the globally common elements. Specific definition of each approach is described in Section 2.4.2 and Section 2.4.3.

α , β and γ are the coefficients to integrate the capacity of server, storage and network equipment. α is defined as an inverse of the energy consumption efficiency of the standard server as of 2005. Respectively, β and γ are the inverses of the energy consumption efficiencies of the standard storage and network equipment as of 2005. Therefore, “Total rated capacity of IT equipment” is the weighted average of the capacity, where the inverse of energy consumption efficiency for the standard server, storage and network equipments as of 2005 is regarded as “weight”. If ITEE is calculated only for server equipments, storage equipments or network equipments, the ITEE constitutes the ratio versus “processing capacity per unit energy” (total rated capacity / total rated power) of the standard server, storage or network equipment as of 2005. Common value for α , β and γ shall be used even if the datacenter in scope or period of calculation is different.

In the same way as with ITEU and ITEE are defined as the weighted average of the efficiency of IT equipment, where the rated power of the IT equipment serves as weight. Therefore, the contribution to the ITEE value is larger if the IT equipment has a higher rated power.

$$\begin{aligned}
ITEE &= \alpha \times \Sigma (\text{Server capacity}) + \dots / \text{Total rated energy of IT equipment} \\
&= \Sigma (\text{Rated energy} \times \alpha \times \text{Server capacity} / \text{Rated energy}) + \dots / \Sigma (\text{Rated energy}) \\
&= \Sigma (\text{Rated energy} \times \text{Normalized energy efficiency}) / \Sigma (\text{rated energy})
\end{aligned}$$

Based on the definition, the ITEE value of the datacenter that has average equipment as of 2005 is set as “1”.

Furthermore, the product of the ITEE, which is the rated work unit, and the ITEU, which is the actual utilization ratio, could be considered with an approximation of the energy efficiency proxy of the IT equipment at a datacenter in operation.

2.4.2 Definition of capacity (Japan domestic application)

At present, there is no internationally unified method to compare capacity or energy consumption efficiency of IT equipment (server, storage and network equipment) which are essential to calculate the total rated capacity of the IT equipment. Because description of the value of energy consumption efficiency is mandatory in Japan domestic catalogues based on the Energy Saving Act, this value is used as a server performance in ITEE calculation, when application is limited to the Japan domestic market (Table 2-2).

Table 2-2: Equipment capacity used in the Energy Saving Act

	Capacity	Remarks
Server	Composite theoretical performance	-
Storage	Memory capacity	-
Network equipment	Transmission capacity (Throughput)	Currently in review

W/MTOPS was used as the unit of the energy consumption efficiency of servers in 2007 Version of the Energy Saving Act, while revision was made to use W/GTOPS from 2010 Version. Therefore, a conversion using the following equation is necessary when using the values for the energy consumption efficiency appeared in 2007 Version.

$$\begin{aligned}
&\text{Value equivalent to the energy consumption efficiency [W/GTOPS] in 2010 Version} \\
&= \text{Energy consumption efficiency [W/MTOPS] in 2007 Version} \times 1,000
\end{aligned}$$

[Calculation of Coefficients α , β and γ]

Coefficients α , β and γ can be obtained in the following method:

Based on the research result of the Green IT Promotion Council⁵, typical capacity and power consumption of server, storage and network equipments as of 2005 are determined as indicated in Table 2-3.

⁵ FY2009 Report by Research Analysis Committee, Green IT Promotion Council (<http://www.greenit-pc.jp/activity/reporting/110628/index.html>)

Table 2-3: Typical equipment as of 2005

	Capacity (a)	Power consumption (b)	Processing capacity per unit energy (a / b)
Server	36 GTOPS/unit	278 W/unit	0.129 GTOPS/W
Storage	300 Gbyte/unit	28 W/unit	10.7 Gbyte/W
Network equipment	4.2 Gbps/port	30 W/port	0.14 Gbps/W

Values as below are obtained based on the definition that Coefficients α , β and γ are the inverses of “processing capacity per unit energy” of the standard equipment:

Server equipment coefficient $\alpha = 1/0.129 = 7.72$ [W/GTOPS]
 Storage equipment coefficient $\beta = 1/10.7 = 0.0933$ [W/Gbyte]
 Network equipment coefficient $\gamma = 1/0.14 = 7.14$ [W/Gbps]

2.4.3 Definition of capacity (Global application)

While the energy consumption efficiency is used as IT equipment capacity due to its wide penetration in the Japan domestic IT Industry, it is necessary to use more globally established metrics for IT equipment capacity calculation when calculating ITEE for Global audience. At present, it is considered advantageous to use following metrics as the metrics to satisfy the above-mentioned requirement:

Server capacity = Adjusted Peak Performance (APP)
 Storage capacity = Capacity of Storage
 Network equipment = Transmission speed of network equipment

In the same way as with the Coefficients α , β and γ in Japanese Version, these values are obtained from estimated data of the typical equipment as of 2005 shown in Table 2-4.

Table 2-4: Typical equipment as of 2005

	Capacity (a)	Power consumption (b)	Processing capacity per unit energy (a / b)
Server	1.8×10^{-3} WT/ unit	278 W/unit	6.5×10^{-5} [WT/W]
Storage	300 Gbyte/unit	28 W/unit	10.7 [Gbyte/W]
Network equipment	4.2 Gbps/port	30 W/port	0.14 [Gbps/W]

Values listed below are obtained based on the definition that Coefficients α , β and γ are the inverses of “processing capacity per unit energy” of the standard equipment:

Server equipment coefficient $\alpha = 1.54 \times 10^5$ [W/WT]
 Storage equipment coefficient $\beta = 0.0933$ [W/Gbyte]
 Network equipment coefficient $\gamma = 7.14$ [W/Gbps]

While “APP” is the most promising metric for the capacity in the global version currently, it might be used also as a server performance, if use of the U.S. EPA’s Energy

Star 2.0 is more prevalent in the future.

2.4.4 ITEE calculation example

The following paragraph describes the calculation example of ITEE based on the Japan domestic version indicated in Section 2.4.2.

Because this is not a capacity in itself, but energy consumption efficiency is stated in a catalogs based on the Energy Saving Act, it is necessary to determine the capacity of the server and the storage by using the rated power and the energy consumption efficiency.

Server: 420 [unit], Max. Power consumption 209 [W], Energy consumption efficiency 0.0016 [d Segment] $209 [W] / 0.0016 [W/MTOPS] \times 1000 = 131 [GTOPS] /unit$

Storage: 42 [unit], Max. power consumption 4620 [W], Energy consumption efficiency 0.025 [AAA] $4,620 [W] / 0.025 [W/Gbyte] = 184,800 [Gbyte] /unit$

With regards to the capacity of the network equipment, the definition is currently under review in the light of the Energy Saving Act. In accordance, capacity of the network equipment is calculated based on the available transmission speed per port (NB: it is not a communication line speed).

Network: 84[unit], Max. power consumption 145[W], Max. Transmission speed 1 [Gbps], number of port per 1unit 24
(Among these, setting of 10/100 [Mbps] is possible for all ports. Further, setting of 1 [Gbps] is possible for 14 ports among them.)
 $10 \times 0.1 [Gbps] + 14 \times 1 [Gbps] = 15 [Gbps] /unit$

ITEE can be calculated by multiplying the above-mentioned IT equipment capacity by each unit number.

$$\begin{aligned} \text{ITEE} &= (7.72 [W/GTOPS] \times 130 [GTOPS] \times 420 [unit] \\ &\quad + 0.00933 [W/Gbyte] \times 184,800 [Gbyte] \times 42 [unit] \\ &\quad + 7.14 [W/Gbps] \times 15 [Gbps] \times 84 [unit]) \\ &\quad / (209 [W] \times 420 [unit] + 4,620 [W] \times 42 [unit] + 145 [w] \times 84 [unit]) \\ &= 3.98 \end{aligned}$$

2.5 Outline of Power Usage Effectiveness (PUE)

2.5.1 Definition of the metric

“PUE” is the metric to measure the power efficiency of the datacenter which was at first proposed by The Green Grid (TGG), in 2007. It allowed an easy measurement of the energy efficiency of the datacenter.

In this context, the definition of PUE is based on the TGG’s White paper and the agreement at the International Conference in February 2011 (Global Harmonization of Datacenter Energy Efficiency Metrics)⁶. Additionally, the details of the measurement were determined by the Japan Data Center Council (JDCC) as a standard.

PUE is obtained by dividing the total energy consumption of a datacenter (entire energy consumption of the datacenter as a whole facility) by energy consumption of the entire IT equipment (Fig. 2-5). It is a metric to indicate/gauge how many time of energy in a ratio at a datacenter (entire datacenter as a whole facility) in energy consumption for its operation when compared to the energy consumed by the entire IT equipment.

$$\text{PUE} = \frac{\text{Total energy consumption of datacenter [kWh]}}{\text{Total energy consumption of IT equipment [kWh]}}$$

Smaller PUE value represents better energy efficiency. This value must be higher than “1.0”. A datacenter has better energy efficiency when PUE approaches “1.0”.

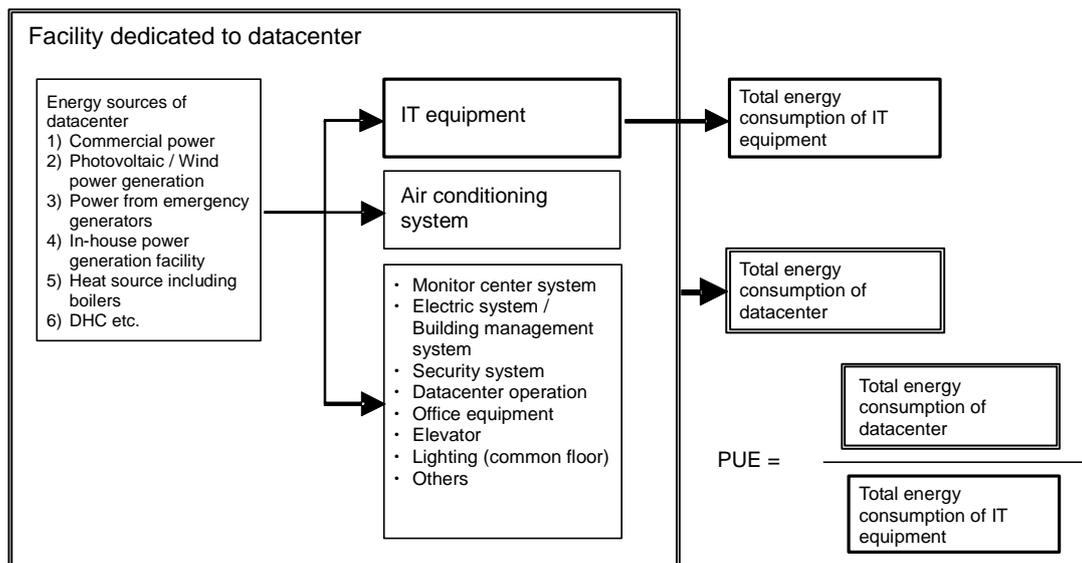


Fig. 2-5: PUE concept for dedicated type datacenter

⁶ “Harmonizing Global Metrics for Data Center Energy Efficiency 2011-02-28” (http://www.greenit-pc.jp/topics/release/pdf/dppe_j_20110228.pdf)

2.5.2 Type of datacenter energy source and measurement points of total energy consumptions

The total energy consumption of an entire datacenter facility includes all the energy consumption with the use of air conditioning, lighting and other infrastructures besides the energy consumption by IT equipment.

The total energy consumption of the entire datacenter facility is measured at the interface between the entire datacenter facility and the external area (Utility handoff). The measurement shall include all the energy sources (commercial power, fuel oil, gas and etc.) (Fig. 2-6). The Energy in the scope of measurement shall be measured as Source Energy Level (to be described later in detail: Initial energy level that generates energy: petrol level, gas level etc.) and all energies are summed up and converted into the electrical power equivalent (kWh).

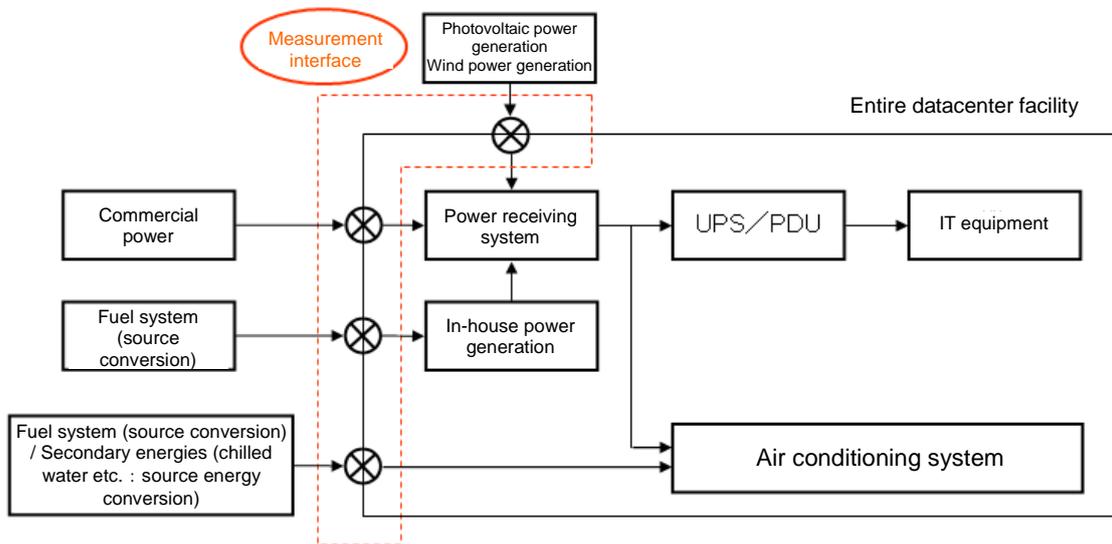


Fig. 2-6: Interface between entire datacenter facility and external area: Utility handoff

The main energy sources to be used by the datacenter currently include; (1) power supplied by the electric utility, (2) photovoltaic power and wind power generations, (3) power from emergency generators and (4) power from in-house generator facility such would include “co-generation”. Besides electric power, a datacenter may use non-electric energies for thermal source of air conditioning such as (5) boilers using gas and heavy oil for fuels as well as heat supply from in-house co-generation facility, and (6) heat supply from District Heating & Cooling (DHC) service (Fig. 2-7).

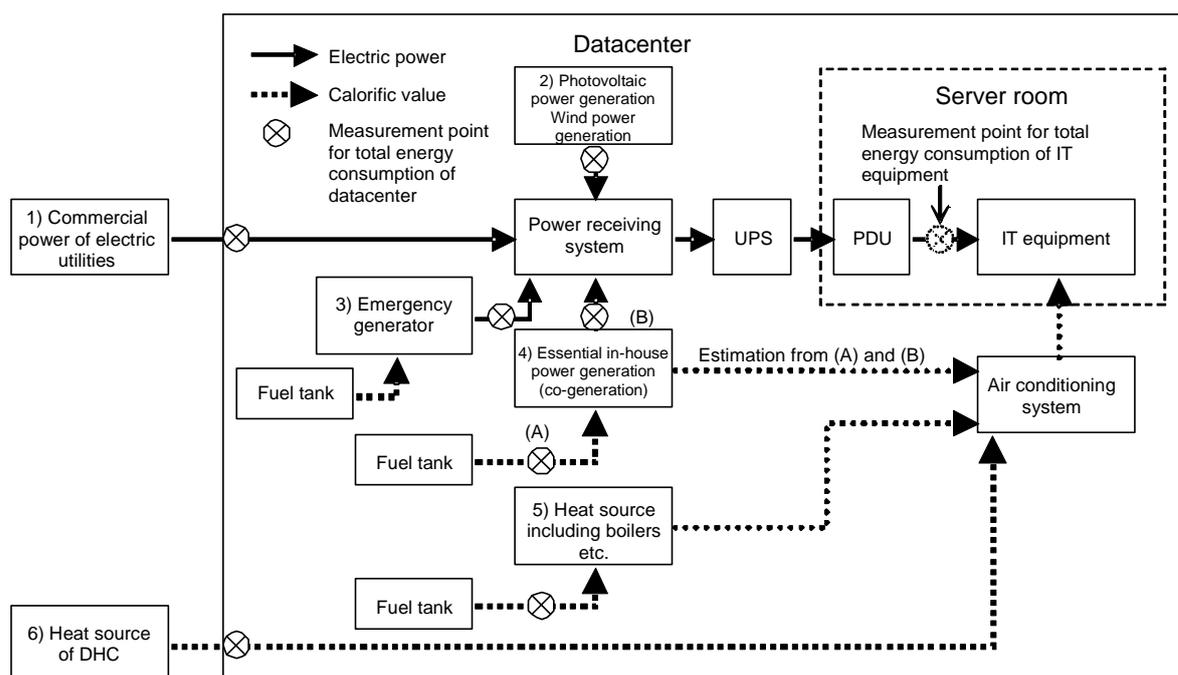


Fig. 2-7: Type of datacenter energy sources

The summed total of all of these energies are needed for the PUE calculation. Because it is necessary to sum up the electric energy and other types of energies upon unifying their units, [kWh] is used as the basic unit for all energies. As indicated in Chapter 3, PUE will show monthly fluctuation depending on the seasons. Therefore, it is recommended to use annual average in its reporting. When reporting PUE values measured in different time period of the year, clear indication of the measurement period (month/season) is recommended.

When converting the energy from non-electric energy sources into [kWh], the calorific value based on energy type converted into kWh cited in “The Ordinance for Enforcement of the Energy Saving Act” is used.

The measurement points for the total energy consumption of datacenter shall be the power level at the specific power feed input point of the datacenter (i.e. inlets of power receiving unit, outlets of photovoltaic and wind power generation units, and outlets of emergency generators and essential site power generation [co-generation] units) respectively. The loss associated with power generation and power transmission shall be excluded from the calculation.

Energies from non-electric energies such as those from boilers shall be calculated from their fuel consumption and etc.

In Section 2.5.3, a method of the PUE calculation in the presence of a heterogeneous energy sources is explained. In Sections 2.5.4 - 2.5.5, outline for the PUE measurement points are explained.

2.5.3 Types of energies in the scope of consumption and the concept of energy totaling

The types of energies in the scope of consumption include all types of energies

including electric power, fuels (heavy fuel oil, gas etc.) and secondary energies (chilled water for DHC service and etc.). Particularly, attention should be given to the fact that heavy fuel oil and gas and etc. are used for the cooling equipment or power generation unit.

Concept of source energy level

The basic concept is that all types of energies should be converted into electric power level before summing/totaling.

Considering as the energy level for creating 1 kWh commercial power (a), an energy of approximately three times (source conversion coefficient δ) is needed ($\delta \times a$), when giving a consideration to the power generation efficiency at the power plant and the power transmission loss from the power plant to the datacenter. This energy level of approximation of three times is called "source energy level." Contrary to the fact, the energy level (a) [kWh] that does not consider these losses is called "site energy level."

An agreement was achieved in the International Conference in February 2011 that the basic approach is to use this source energy level for evaluating the energy level of a datacenter.

Meanwhile, with regards to the fuel energies, the energy consumed in the datacenter is regarded as the source energy level. The amount of heavy fuel oil and etc. converted into electric power level (b) [kWh] is used.

With regards to the secondary energy (c) such as the chilled water for DHC service, the amount of energy needed to make the chilled water (source conversion coefficient ϵ) is used upon conversion into "electric power level ($\epsilon \times c$)" [kWh].

Totaling method based on the source energy level

Based on the above-mentioned concept, the summing/totaling of the source energies could be expressed with the following calculation equation:

$$\text{Total source energy} = \delta \times (a) + (b) + \epsilon \times (c)$$

However, if this equation is used for summing/totaling, a significantly high PUE may occur for datacenters where majority of the energy is supplied from Commercial electric power. Because portion of the energy attributed by the use of the commercial power is expressed with the value three times higher than other energies, the apparent electric power level in these facilities could become three times higher than other facilities, resulting in higher PUE value. This is compared with the conventional PUE announced by TGG.

In accordance, to consolidate the scale with conventional PUE value, the entire level has been normalized by using the value of the conventional commercial electric power (power meter value), so that the entire level should be equivalent to the site energy level.

$$\text{DC total energy consumption} = (a) + (1/\delta) \times (b) + (\epsilon/\delta) \times (c)$$

Following values are used globally for source energy conversion coefficients:

- *Source energy conversion coefficient for commercial electric power: $\Rightarrow 1.0$
- * Source energy conversion coefficient for fuels: $1/\delta \Rightarrow 0.35$
- * Source energy conversion coefficient for secondary energies: $\epsilon/\delta \Rightarrow 0.40$

Table 2-5: Source energy conversion coefficient for each energy

Energy type	Source energy conversion coefficients
Commercial electric power	1.0
Gas (natural gas, city gas etc.)	0.35
Heavy / Light fuel oil etc.	0.35
Other fuels	0.35
Chilled water etc. (DHC)	0.40

In accordance with the consideration of the source conversion coefficient in the total energy consumption level, an average source energy conversion coefficient of electric power consumed in the datacenter is given a consideration with regards to the energy consumption of IT equipment.

Total energy consumption of IT equipment
= Site energy of IT equipment x Average source energy conversion coefficients
for DC power,

where

Average source energy conversion coefficients for DC power
= (Source energy used for procurement / generation of total electric power
consumed in the DC) / (Site energy of total electric power consumed in the DC).

Based on above, following equation is obtained:

$$\text{PUE} = \text{DC total energy consumption} / \text{Total energy consumption of IT equipment}^7$$

2.5.4 Measurement points for the total energy consumption of IT equipment

The point for measuring energy consumption of IT equipment (electric power level) should be the output of the PDU (power distribution unit). If the measurement is conducted at the UPS output, the power loss between the UPS and IT equipment should be considered. (Fig. 2-8). If there are multiple “Down Transformer” between IT equipment and the measurement points, the loss associated with the Down Transformer and cablings and etc. should be given a consideration. If the measurement of the PDU output is infeasible, the measurement results collected in the substitute measurement points shown in the following figure should be used. These results are converted into the values equivalent to the PDU output measurement based on the method specified in the guideline.

⁷ Harmonizing Global Metrics for Data Center Energy Efficiency 2011-02-28” Some examples of PUE calculation is shown in (http://www.greenit-pc.jp/topics/release/pdf/dppe_j_20110228.pdf).

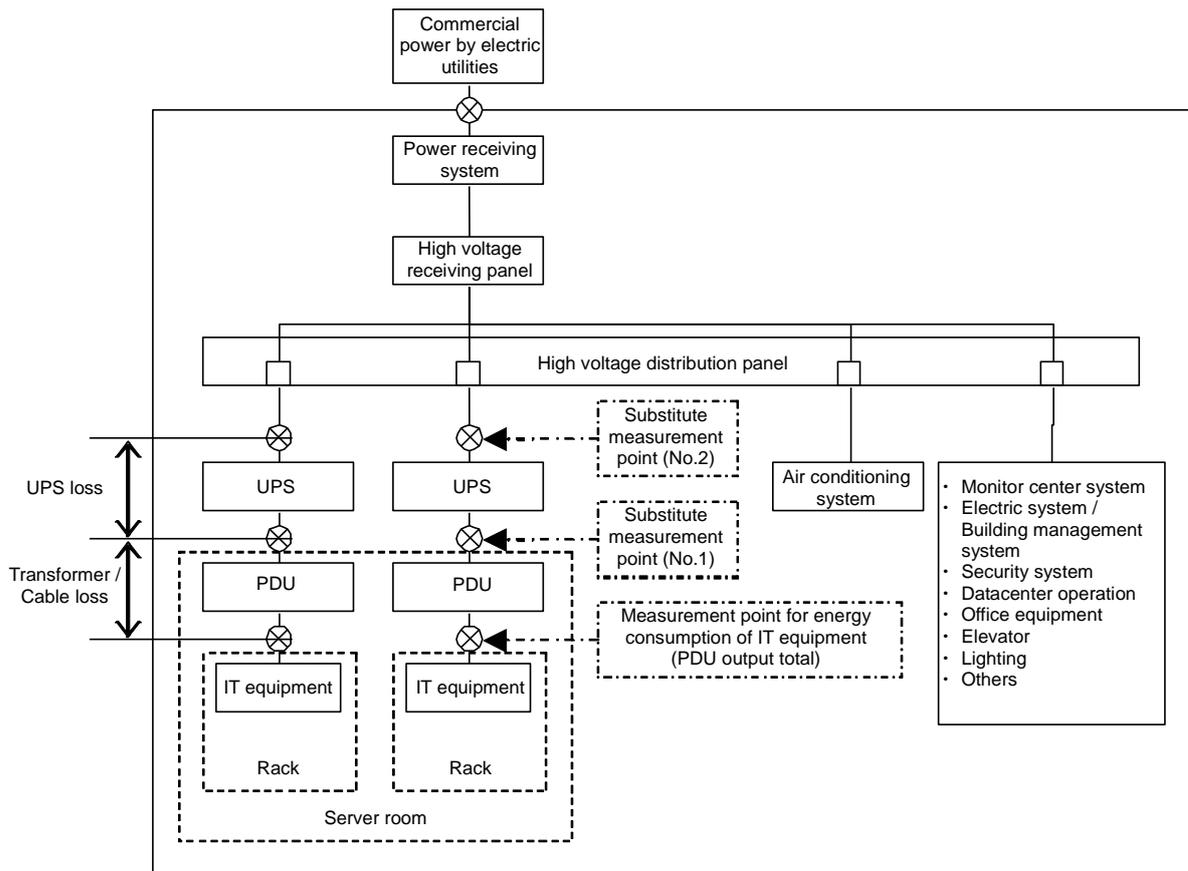


Fig. 2-8: Measurement points of IT equipment

***Measurement of power factor**

The actual total power consumption (kW) of IT equipment is calculated by - Voltage (V) × Current (A) × Power factor (%), which is different from kVA = Voltage (V) × Current (A). Therefore, in calculating the PUE, it is recommended to give consideration to the power factor.

If the total energy consumption of IT equipment (power level [kVAh]) is obtained without giving any consideration to the power factor, the value of the total energy consumption of IT equipment becomes larger than the actual level. This may lead to significantly more advantageous data for the PUE calculation.

Therefore, when measuring the total energy consumption of IT equipment (power level [kVAh]), measurement should be conducted by giving a consideration to the power factor instead of just calculating the value by the use of - Current [A] × Voltage [V] equation.

While power factor depends on the system configuration of the IT equipment downstream of the PDU, it is known from the actual sample data obtained that the chronological fluctuation maybe small. Therefore, it is acceptable to obtain the total energy consumption of IT equipment by multiplying the power level measured continuously in current / voltage. An average value of the power factor measured by using portable terminals and etc. on temporal basis in the past could be utilized. If the power factor is unknown or impossible to measure, then the “95%” may be used as a recommended

substitution value.

Table 2-6: Example of the power factors determined on actual data samplings

Ave	Var	Max	Min
95.8%	46.6%	100%	64%

2.5.5 How to obtain the datacenter total energy consumption for a non-Standalone type datacenter

Many datacenters are accommodated in a combined mixed building facility, where both the datacenter function (floor) and non-datacenter function (floor) such as general office irrelevant to the datacenter would co-exist within one site. When calculating the PUE in such, only the total energy consumption used for the datacenter function should be extracted from the total energy consumption of the entire building (which includes the energy consumption associated with non-datacenter function).

For the mixed facility non-Standalone type datacenters, the usage function of the building floor could be divided into three types (datacenter function, non-datacenter function and common function.) In this context, the common function refers to the equipment / floor in the building which is commonly used to manage, maintain and operate both datacenter and non-datacenter functions. To be specific, following equipment are included; (1) Management system and security system for the entire building. (2) Air conditioning, Elevators and Lightings of the common floors. Besides these, Hall area, Corridors, Bathrooms and shared use Meeting rooms in the building would be included into this category.

The total energy consumption used by the datacenter function could be defined as the sum of the energy spent for the datacenter function and an adjusted part of the energy used by the common function. With regards to the energy spent for the common function, an appropriate ratio should be determined between the part of the consumption by the datacenter function and the part of the consumption by the non-datacenter function (general office and etc.). With all these, only the part of consumption for the datacenter function should be added to the already measured energy consumption for the dedicated datacenter function.

To be more specific, the calculation is carried out in the following process;

First, the energy consumption for the datacenter function and the energy consumption for the non-datacenter function are deducted from the energy consumption of the entire building. And then the energy consumption for the common section is calculated. The energy consumption for the common section is divided into the energy consumption associated with Air conditioning and the energy consumption associated with the other consumption sources (Fig. 2-9). The energy consumption associated with Air conditioning in the common function area is sub-divided into the ratio between the power levels for the IT equipment + related systems in the datacenter section and the power level of the non-datacenter function (i.e. OA power for office section and etc.). Additionally, the energy consumption other than those from Air conditioning such as the consumption associated with Lighting and Elevators and etc. are divided into both for datacenter function and non-datacenter function parts (office part and etc. - excluding the area for shared use, such

as Hall area, Corridors, Bathrooms and Meeting rooms) based on the area of percentage.

For the simplification purpose, it is acceptable to include all of the energies spent for the common function into the energy consumption of the datacenter function in calculation. In this case, however, the PUE could worse than the actual usage situation.

Furthermore, if the PUE is calculated solely for the purpose of the volunteered approach for datacenter improvements, an approach to emphasize ease of measurement may be acceptable by neglecting the energy consumption in the common area regardless of the above-stated methodology⁸. However, it should be noted that the PUE value differences from those considering the impact of calculating common area could be obtained in this case.

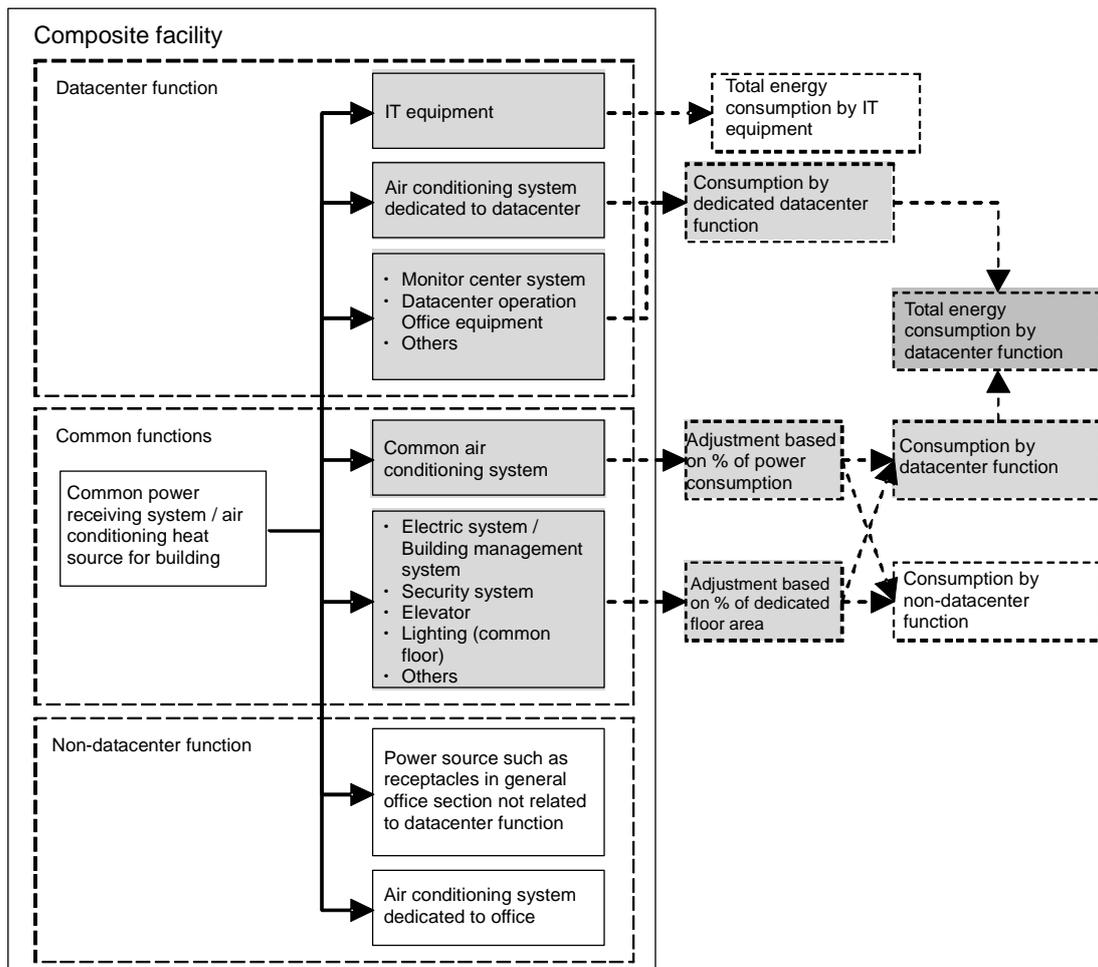


Fig. 2-9: Schematic image of a combined mixed-use type datacenter (non-Standalone), and how to determine the total energy consumption

⁸ "Harmonizing Global Metrics for Data Center Energy Efficiency 2011-02-28" (http://www.greenit-pc.jp/topics/release/pdf/dppe_j_20110228.pdf)

2.5.6 PUE calculation example

It is assumed that the datacenter receives commercial power of 350,000 [kWh], power supply of 40,000 [kWh] from the photovoltaic power generation and consumes 20.3[kl] (kilolitre) boiler fuel (A heavy fuel oil) for Air conditioning. The power consumption by IT equipment is assumed as 30,000 [kWh] (However, all boilers are used to generate chilled water).

In this case.

$$\begin{aligned} \text{PUE} &= (350,000[\text{kWh}] + 40,000[\text{kWh}] + 20.3[\text{kl}] \times 10,861[\text{kWh/kl}]) / 30,000[\text{kWh}] \\ &= 2.03 \end{aligned}$$

(Average source energy conversion coefficients for IT power = 1.0.)

2.6 Outline of GEC (Green Energy Coefficient)

2.6.1 Definition of the metric

GEC is the value obtained by dividing the Green energy, or Renewable energy, (Photovoltaic power, Wind power, and etc.) used in a datacenter within the total energy consumed by the datacenter.

$$\text{GEC} = \frac{\text{Green energy [kWh] used in DC site}}{\text{Total energy consumption of datacenter [kWh]}}$$

The Green energies in this context refer to the energies generated from Natural energies such as Photovoltaic power and Wind power. Among these, the scope of the GEC includes the part of Green energies (electric power and etc.) legally entitled to the datacenter. Namely, following rules were applied:

- The precise definition (scope) of Green energies should be the scope adopted by Tradable Renewable Energy Certificates and etc. of each country.
- If Tradable Renewable Energy Certificates are purchased, the purchased amount is also included in the Green energies.
- The energies generated on the datacenter site whose title is not sold to external parties as Tradable Renewable Energy Certificates are also regarded as Green energies. Application of the Tradable Renewable Energy Certificates system is not always necessary, as long as the energy is generated and consumed within the Datacenter boundary/site. The measurement points for on-site power generation of Photovoltaic power and Wind power and etc. are indicated in Fig. 2-10.

To maintain consistency with the total energy consumption, [kWh] is used for the energy basic unit.

The energies using the exhaust heat from any system used for other purposes (e.g. boilers for product manufacturing and etc.) are not included in the Green energies, even if they are generated on site, because these are regarded as equivalent to the thermal source for boilers or DHC service and etc.

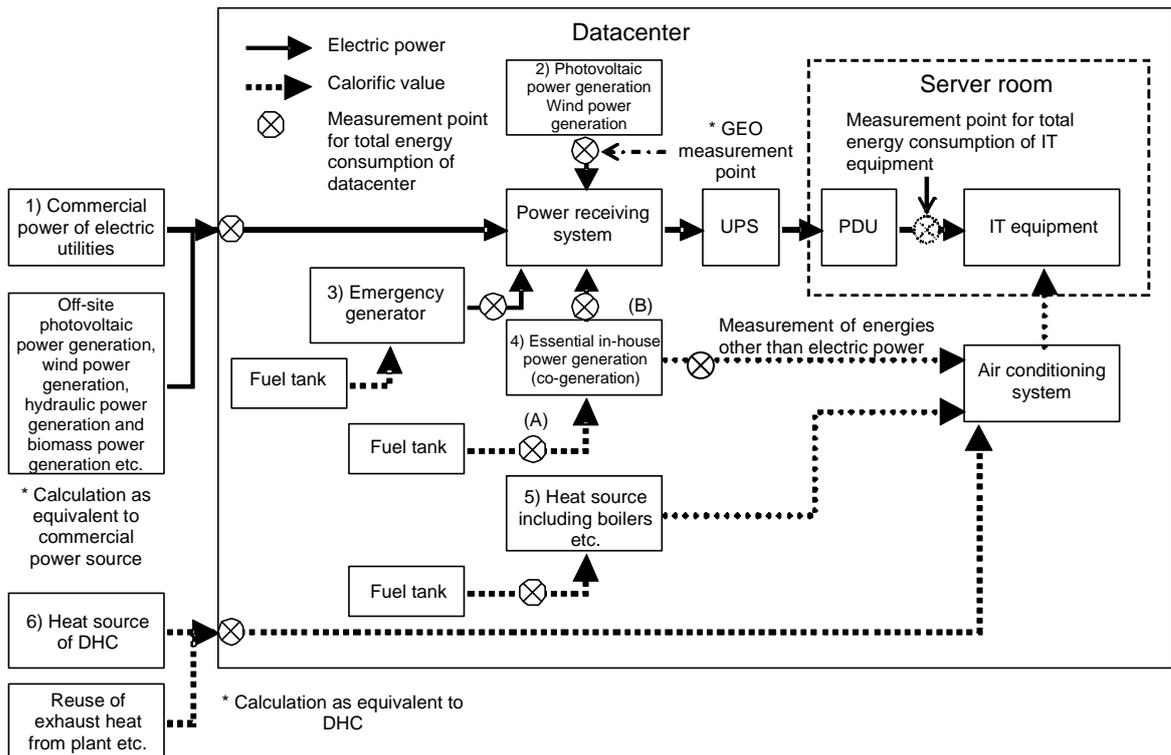


Fig. 2-10: GEC measurement points and handling of the use of Green electric power / exhaust heat

2.6.2 GEC calculation example

It is assumed that the datacenter receives commercial power of 350,000 [kWh], power supply of 40,000 [kWh] from Photovoltaic power generation and consumes 20.0[kl] (kilolitre) boiler fuel (A heavy fuel oil) for air conditioning.

$$\begin{aligned} \text{GEC} &= 40,000[\text{kWh}] / (350,000[\text{kWh}] + 40,000[\text{kWh}] + 20.3[\text{kl}] \times 10,861[\text{kWh/kl}]) \\ &= 6.6 [\%] \end{aligned}$$

2.7 Rationality of selecting Four metrics

In Chapter 2.2, four types of metrics (ITEU, ITEE, PUE and GEC) were introduced as metrics to compose DPPE, energy efficiency of the entire datacenter, by dividing energy consumption flow of the datacenter in a quantitative manner.

In a quantitative approach, the energy efficiency of the entire datacenter could be expressed as below:

$$\begin{aligned}
 &\text{Energy efficiency} \\
 &= (\text{Data center production}) / (\text{Non-green energy consumption}) \\
 &= (\text{Data center production}) / (\text{Energy consumption of IT equipment}) \\
 &\times (\text{Energy consumption of IT equipment}) / (\text{Energy consumption of datacenter}) \\
 &\times (\text{Energy consumption of datacenter}) / (\text{Non-green energy consumption}) \\
 &= (\text{IT productivity}) \times (\text{Facility efficiency}) \times (\text{Deduction of green energies}),
 \end{aligned}$$

where

IT productivity: $\text{Production (Information processing by IT equipment)} / \text{Energy consumption of IT equipment}$

Facility efficiency: $\text{Energy consumption of IT equipment} / \text{DC energy consumption} (=1/\text{PUE})$

Deduction of green energies: $\text{DC energy consumption} / \text{non-green energy consumption} (=1 / (1-\text{GEC}))$

Further, if equations indicated below are valid in approximate manner:

$$\begin{aligned}
 &\text{IT productivity} = (\text{Average utilization ratio of IT equipment}) \\
 &\times (\text{IT equipment rated capacity}) / (\text{IT equipment rated energy consumption}) \\
 &\text{Average utilization ratio of IT equipment} = (\text{Actual consumption energy of IT equipment}) / \\
 &(\text{IT equipment rated energy consumption}),
 \end{aligned}$$

It constitutes the following relationships:

$$\begin{aligned}
 &\text{Energy efficiency} \\
 &= (\text{Actual consumption energy of IT equipment}) / (\text{IT equipment rated energy consumption}) \\
 &\times (\text{IT equipment rated capacity}) / (\text{IT equipment rated energy consumption}) \\
 &\times (\text{Energy consumption of IT equipment}) / (\text{Energy consumption of datacenter}) \\
 &\times (\text{Energy consumption of datacenter}) / (\text{Non-green energy consumption}) \\
 &= \text{ITEU} \times \text{ITEE} \times (1/\text{PUE}) \times (1 / (1 - \text{GEC}))
 \end{aligned}$$

ITEU×ITEE was evaluated in the actual datacenter system as a part of experiment for IT productivity proxy evaluation carried out by The Green Grid. As a result, it was demonstrated that ITEU×ITEE was useful as a proxy of IT productivity and proved its simplicity in measurement. Particularly, the ease of measurement is considered to be a significant feature of the ITEU×ITEE, as emphasis is placed on the feasibility of actual measurement in any datacenter.

These results showed that the energy efficiency of the entire datacenter could be evaluated by using these four metrics “ITEU”, “ITEE”, “PUE” and “GEC”. In an application of these metrics, metrics are separated and differentiated from each other in each term of multiplications. There is no mutual influence to each other (mutually independent).

In accordance, these four metrics “ITEU”, “ITEE”, “PUE” and “GEC” are proved to be a

combination which could evaluate the energy efficiency of the entire datacenter without any redundant measurement efforts.

Based on the above, the GIPC proposes to construct a comprehensive evaluation system/ comprehensive evaluation metrics by the use of these specific metrics comprised of "ITEU", "ITEE", "PUE" and "GEC". This comprehensive evaluation system is called "Datacenter Performance per Energy" - (DPPE) which was created by the GIPC.

2.8 Comprehensive energy efficiency evaluation using Four metrics - Holistic Framework -

As one of the approaches to evaluate the energy efficiency of the datacenter using metrics, a method to indicate four metrics on a spider web chart is proposed. This method allows understanding of the status of energy saving activities in a datacenter for each selected target and its approach. The comprehensive understanding of multiple aspects of the energy efficiency by this approach is defined here as “Holistic Framework.”

As the combination of the four metrics is designed to allow evaluation of energy efficiency of an entire datacenter, each metric could be allocated to each axis of the spider web chart. The each characteristic indicated by each of the four metrics are shown as below:

- IT equipment operation efficiency
- IT equipment hardware efficiency
- Infrastructure efficiency
- Utilization level of green power

Fig. 2-11 indicates an example of the spider web chart.

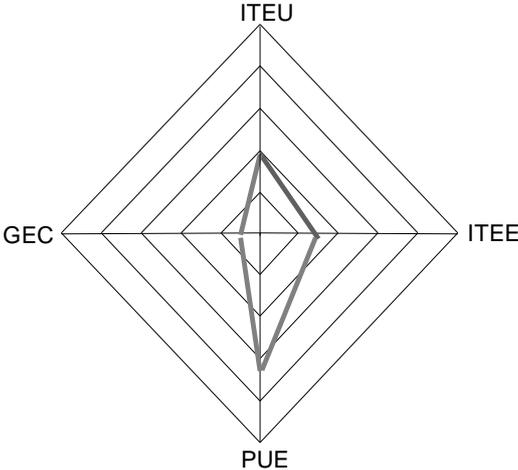


Fig. 2-11: Spider web chart of the Holistic Framework

In the spider web chart in Fig. 2-11, selected axes values for an individual datacenter could be compared with those numbers of average datacenters. In this way, datacenter operators could understand the characteristics of each datacenter, and focus on their efforts with the largest aspect for the improvement. For an example, if the hardware efficiency of the IT equipment is significantly lower than that of the average datacenter, then a renewal of the IT equipment could be a promising option for the improvement of the energy efficiency. Following these options could be considered as countermeasures for the efficiency improvement;

- Improvement of the IT equipment operation
- Use of the highly efficient IT equipment
- Improvement of the infrastructure efficiency (Air conditioning, Power supply and etc.)
- Introduction of Renewable energies

3. Introduction of the actual experimental DPPE measurement projects - (Japan domestic and International collaboration)

With the purpose to verify the usability and the correctness of the energy saving metrics for datacenters, and to understand the current status of energy consumption in datacenters, an experimental project for energy efficiency measurements in datacenters were performed under the cooperation of 15 Japanese datacenter operators and 2 overseas datacenter operators (in Singapore and Vietnam). The experimental measurement period was from August 2011 to January in 2012 (6 months) for domestic operators and a short duration in September 2011 for 2 overseas operators.

The outline and the outcome of the experimental measurement project are summarized in the following sections.

3.1 Implementation outline of the measurement project

With the participation of 20 datacenters owned or operated by 15 Japanese datacenter operators, measurements were carried out during 6 months from August 2011 to January 2012. Data collected (i.e. Data Center and Equipment power consumption and etc.), which were necessary to determine the four metrics “PUE”, “GEC”, “ITEU” and “ITEE”. These measurements were implemented in compliance with the “DPPE Measurement Guideline” created in previous year by the GIPC work group. Prior to the experiment, the instruction and explanation meetings were held for the participating datacenter operators.

The Implementation Overview of the measurement project is shown in Table 3-1. The type of feasible data measured were different depending on the datacenter and not all could measure the data on monthly basis due to some operational restrictions. The sample number of data collected from datacenters were different depending on the metrics or time period (month).

Table 3-1: Outline of the measurement project outcome

- Number of participant operators: 15 Japan domestic and 2 overseas operators
- Number of participant datacenters: 20 Japan domestic and 2 overseas datacenters
- Measurement period: August 2011 - January 2012
- Outline of participant datacenters
 - Number of datacenters in each regional area:
 - <Japan>Hokkaido / Tohoku / Hokuriku (3), Kanto (15),
Tokai / Chubu / Kinki (0), Chugoku / Shikoku / Kyushu / Okinawa (2),
 - <Overseas> (2) Singapore and Vietnam
 - Datacenter establishment year range: 1985 - 2010
 - Total floor area: Approx. 800 - 145,000 m²
 - Floor area for server rooms: Approx. 10 - 16,500 m²

○Number of data collected (based on each month) between 2011-2012

	August	September	October	November	December	January
PUE	19	19 (2)	18	18	17	16
GEC	19	19 (2)	18	19	18	16
ITEU	16	16 (2)	15	16	15	16
ITEE	11	11 (2)	10	11	11	11

The numbers in parentheses are those from overseas datacenters

3.2 Experimental Measurement results

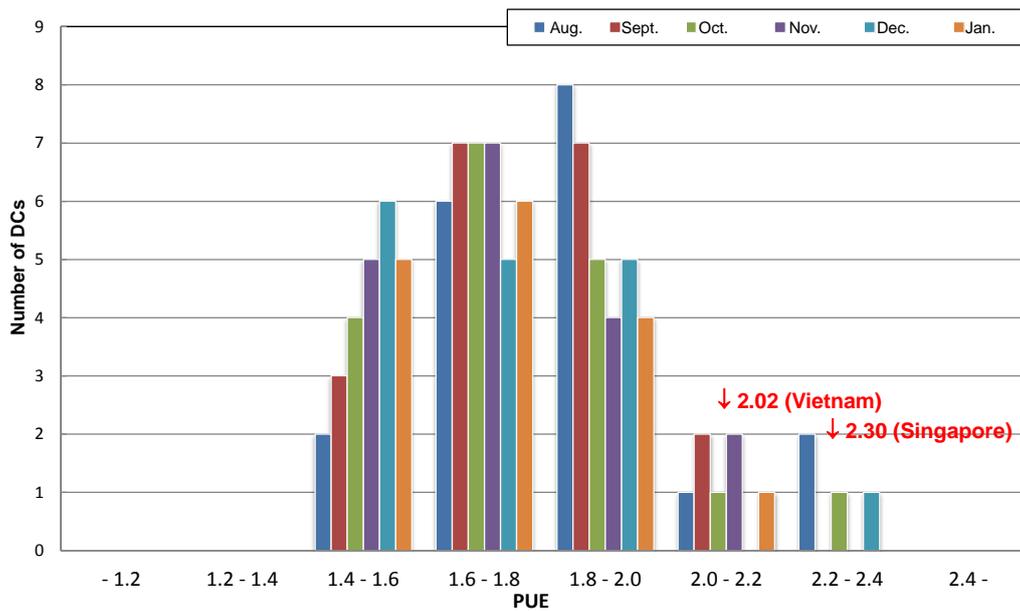
3.2.1 PUE

Actual PUE in this project measured on monthly basis during the period between August 2011 and January 2012 was; 1.70 - 1.85 on average (Fig. 3-1).

The maximum value in this period was; 2.34 and the minimum value was; 1.41.

These measurements were considered to be appropriately conducted.

The overseas measurement results for PUE were; 2.30 for Singapore and 2.02 in Vietnam.



	August (n=19)	September (n=19)	October (n=18)	November (n=18)	December (n=17)	January (n=16)
Average	1.85	1.79	1.75	1.71	1.70	1.70
Minimum	1.43	1.41	1.45	1.44	1.42	1.42
Maximum	2.34	2.15	2.28	2.09	2.26	2.05

Fig. 3-1: PUE monthly distribution

Fluctuation of the average PUE based on each month revealed that the PUE in August tends to be the highest due to its Hot Seasonal Climate with a high average temperature. Similarities were seen in the results from previous year. The PUE tends to show lower value after September as the hot season ended (Fig. 3-2).

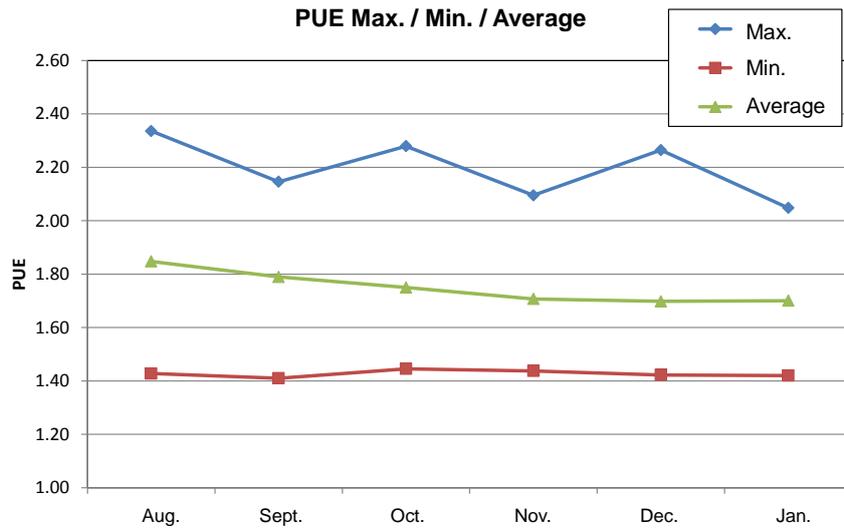


Fig. 3-2: PUE monthly average / Max. / Min. values

With regards to the relationship between datacenter age (number of years since built) and the PUE, the PUE of the datacenters built within the last five years indicated relatively lower PUE numbers. The PUE tends to become higher with older datacenters with their age. However, the PUE of the datacenters built more than 20 years ago indicated lower PUEs. This result was attributed by the fact much older datacenters did replacement their older air conditioning system to newer ones. This result demonstrates the improved energy efficiency through the countermeasure (Fig. 3-3).

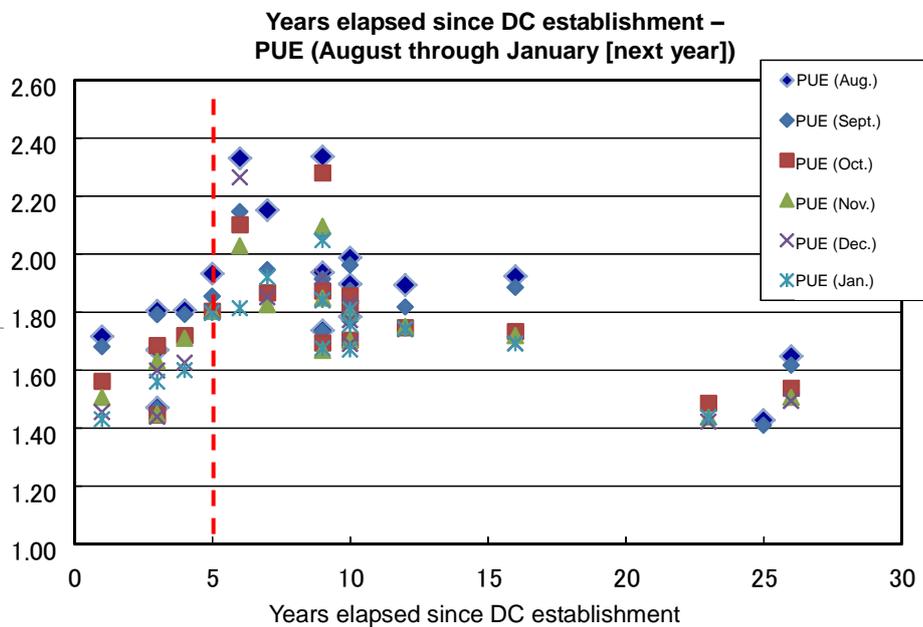


Fig. 3-3: Datacenter age and PUE

Furthermore, the relationship of the PUE and “Total floor size of the building” vs. “server room floor size” was analyzed. The datacenters with higher PUE tend to have relatively smaller floor size. The result indicated that datacenters with larger than some certain floor size could achieve better energy efficiency (Fig. 3-4).

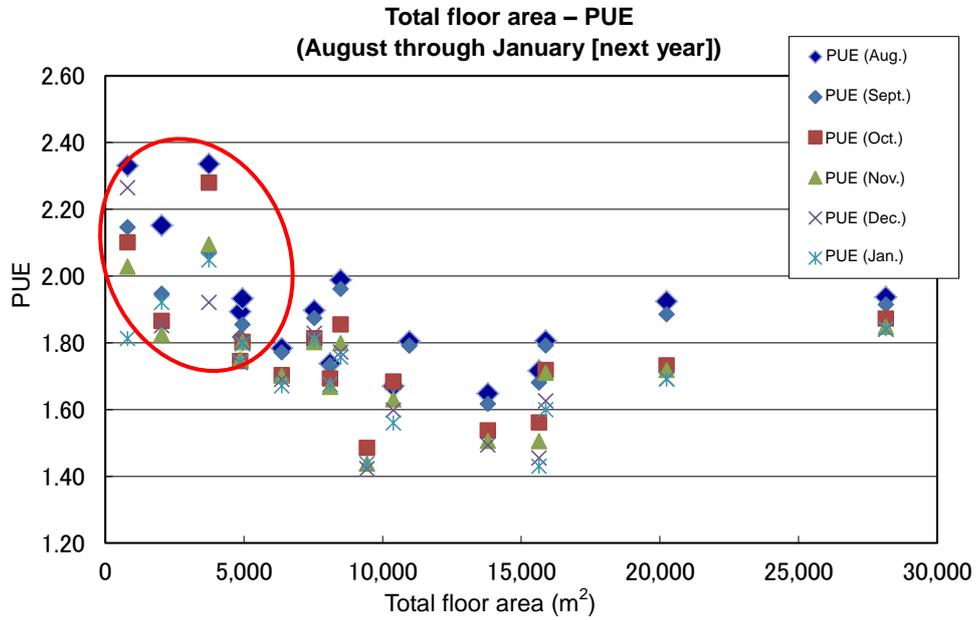


Fig. 3-4: Total floor size of datacenter building and the PUE

o Comparison with the results from previous year's measurement.

The PUE measurement results were compared with the PUE data collected in 3 months in the previous year (pre trial data collection). The comparison result demonstrated that, in general, the PUE distribution observed in 2011 tends to show lower value than 2010 (Table 3-2, Fig. 3-5).

Table 3-2: Comparison of average / Min. / Max. PUE between years

		2010	2011
Average	August	1.93	1.84
	September	1.84	1.78
	October	1.82	1.75
Minimum	August	1.22	1.43
	September	1.18	1.41
	October	1.76	1.45
Maximum	August	2.69	2.34
	September	2.22	2.15
	October	1.97	2.28

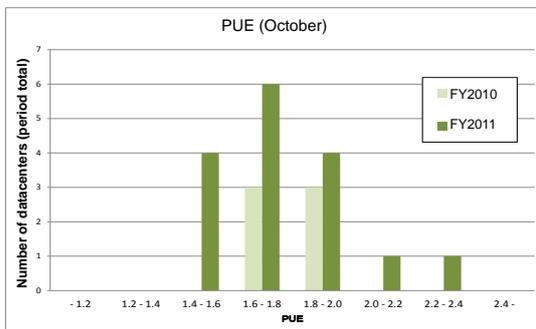
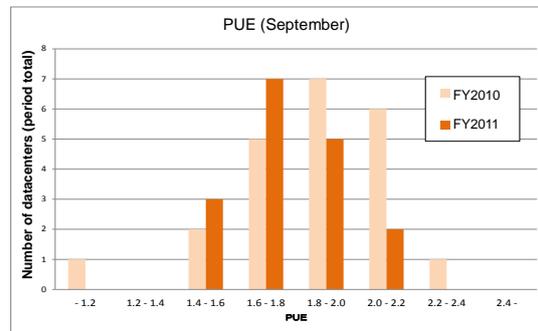
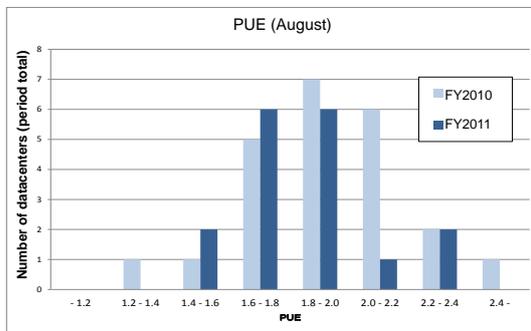


Fig. 3-5: Two years comparison of the PUE

To verify these trends, comparative analysis of the temperature and the PUE between two years of measurements were conducted with those datacenters with available data. (Table 3-3 shows the temperature and the PUE.)

Table 3-3: Two years comparison of the PUE based on datacenters
(the numbers in parentheses in lower line indicate an average temperature of the same month)

Datacenter Description		August	September	October	November	December	January	Average
Datacenter A (Outsourcing etc.)	2011	1.81 (27.1)	1.79 (24.9)	1.72 (19.2)	1.71 (14.8)	1.63 (7.5)	1.60 (4.8)	1.71
	2010	1.93 (28.6)	1.89 (24.7)	1.81 (18.6)	1.73 (13.4)	1.70 (9.9)	1.64 (5.3)	1.78
Datacenter B (Dedicated DC)	2011	1.78 (27.5)	1.77 (25.1)	1.70 (19.5)	1.70 (14.9)	1.69 (7.5)	1.67 (4.8)	1.72
	2010	1.89 (29.6)	1.84 (25.1)	1.77 (18.9)	1.69 (13.5)	1.76 (9.9)	1.77 (5.1)	1.79
Datacenter C (Outsourcing etc.)	2011	1.94 (27.1)	1.91 (24.9)	1.87 (19.2)	1.85 (14.8)	1.84 (7.5)	1.84 (4.8)	1.88
	2010	2.06 (28.6)	2.01 (24.7)	1.97 (18.6)	1.90 (13.4)	1.89 (9.9)	1.88 (5.3)	1.95
Datacenter D (Sler)	2011	2.15 (26.7)	1.95 (23.0)	1.87 (15.4)	1.83* (10.9)	1.85* (3.2)	-	1.99
	2010	1.97 (26.2)	2.00 (28.8)	1.82 (16.7)	-	-	-	1.93

Note: *This value is excluded from calculated average because the data for FY2010 is not available.

These data were plotted on the X-Y axis representing the temperature and the PUE, and linear approximations for each distribution were conducted. As the result, gradient of the approximation line in year 2011 is smaller than that of the 2010. It is indicating that the elevation of the PUE accompanying the temperature elevation is smaller in 2011 (Fig. 3-6). This result suggests that sophistication of energy management has progressed, which may be the result of attributable influences of Japanese nationwide power saving campaign of the year 2011.

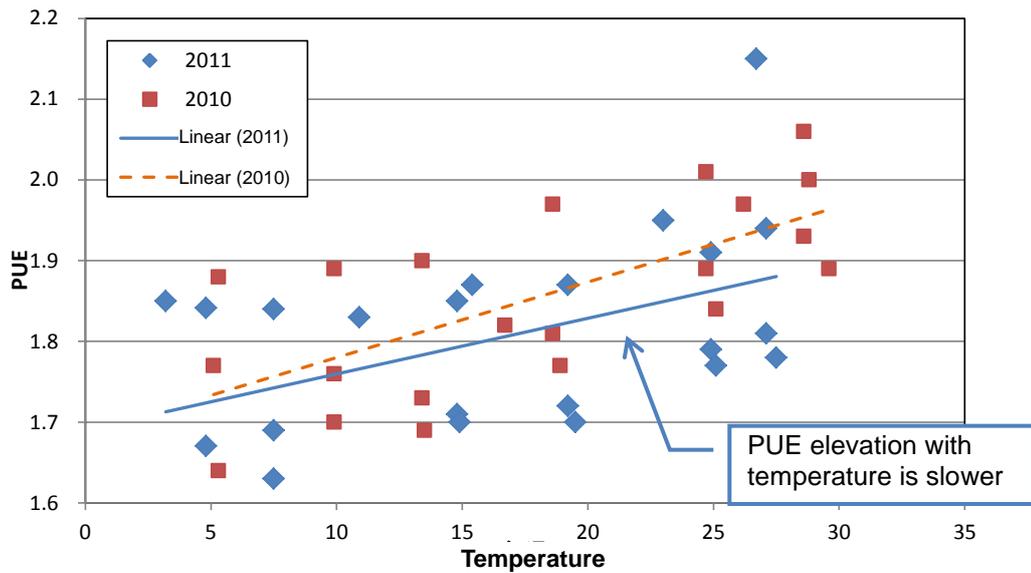


Fig. 3-6: Two years comparison of the PUE

3.2.2 GEC

The GEC indicates the percentage of Renewable (Green) energies which were generated and consumed within the datacenter site compared with the total energy consumed by the datacenter.

With in the current measurements, 4 out of 5 datacenters generate power by Photovoltaic system. The type of Natural energy, monthly total energy consumptions and monthly GECs in each datacenter are shown in Table 3-4.

Table 3-4: Datacenters with GEC results

	Datacenter A	Datacenter B	Datacenter C	Datacenter D	Datacenter E
Purpose / Application of building	Dedicated to datacenter				
Type of natural energies	Photovoltaic	Photovoltaic	Photovoltaic	(Unknown)	Photovoltaic
GEC (Average)	0.00336	0.000131	0.002057	0.003047	0.001937

(note: Green power generation method of 1 datacenter is not specified.)

In these datacenters, the GEC values are extremely small compared with the total energy consumed. Even with the Datacenter “A” with the highest GEC reported, the GEC remains very low at approx. 0.34% of the total energy consumption. These results indicate that the role of Green energies utilized in current datacenters is still insignificant.

3.2.3 ITEE

The ITEE indicates the percentage of total rated capacity of the IT system compared with the total rated power of the IT system. Higher processing capacity per unit of a power could result in higher ITEE number. The estimated ITEE range was approximately 1.0 to 4.42.

In this project, datacenters could measured ITEE were 11 in Japan and 2 in overseas locations. In Table 3-5, the ITEE results from January 2012 are shown. ITEE value will not change unless the replacement of IT equipment will occur.

The measurement result indicated very scattered values between 0.16 and 3.95. In 3 datacenters, ITEEs were lower than 1.0. As for the reference, the project calculated the ITEE for each datacenter based on the real IT equipment configuration (Server, Storage and Network). It is considered that the ITEE based on the IT equipment configuration could indicate the strength and weakness of each configuration at each datacenter.

Table 3-5: ITEEs based on IT system configuration

System Type	ITEE (January)	ITEE (Reference)			Year of DC Establishment*
		Server	Storage	Network	
Brokerage System 1	1.53	1.24	2.17	1.55	2005 -
Brokerage System 2 (Enterprise)	0.74	0.63	1.99	1.21	2005 -
Brokerage Trading System	2.17	1.38	4.90	2.00	2005 -
Banking System	2.27	2.15	6.09	0.41	2005 -
ASP System	1.42	1.64	3.01	0.10	2000 -
Cloud Service	2.61	3.77	4.02	1.60	Unknown
IDC Integrated Housing Service	1.18	2.29	-	0.35	2000 -
Order Entry System	1.41	1.44	1.39	0.95	1980 -
Hosting Service	3.95	3.93	4.09	3.65	2005 -
Unknown	0.16	0.00	-	1.28	2005 -
Unknown	0.55	0.01	3.46	4.74	1990 -
Average	1.64	1.68	3.46	1.62	
Singapore (September)	1.64				
Vietnam (September)	1.16				

(*1) coefficient x total rated capacity (Server/Storage/Network) ÷ total rated power (Server/Storage/Network)

(*2) Estimation based on PUE profile

3.2.4 ITEU

The ITEU indicates the percentage of total energy consumption of an IT system versus the total rated power of the IT system (work unit). The estimated ITEUs were approximately 0.2 to 0.8.

In this project, datacenters could measure ITEUs were 16 in Japan and 2 in overseas. The ITEUs during the period between July 2010 and January 2011 were 0.41 - 0.48. The maximum was at 0.58 and the minimum was at 0.26. All these numbers are within the estimated range for the ITEU.

The ITEU is an index to show the level of equipment usage in a datacenter. While there were slight differences in these results among datacenters, no significant variations were observed with most of datacenters with the comparison based on measured months (Table 3-6).

Table 3-6: ITEU / month based on the IT system type

System Type	Average	Year of DC Establishment *
Brokerage System 1	0.50	2005 -
Brokerage System 2 (Enterprise)	0.47	2005 -
Brokerage Trading System	0.41	2005 -
Banking System	0.51	2005 -
ASP System	0.48	2000 -
Cloud Service	0.42	Unknown
IDC Integrated Housing Service	0.37	2000 -
Order Entry System	0.31	1980 -
IT outsourcing business system 1	0.46	2010 -
IT outsourcing business system 2	0.44	2000 -
Housing	0.38	2000 -
Hosting Service	0.43	2005 -
ITEU measurement experiment 1	0.41	1995 -
ITEU measurement experiment 2	0.47	2005 -
Unknown1	0.46	2005 -
Unknown2	0.60	1990 -
Average	0.44	
Singapore	0.74	
Vietnam	0.25	

* Estimation based on the PUE profile

The System type and average ITEU and other data for each datacenter were summarized in the Table 3-9. However, it is not appropriate to consider these ITEU values as the actual utilization ratio, because the rated power levels for IT equipment such as servers are designed to have larger margin than actual maximum value. Judging from the measurement results to date, it is safe to consider that the average ITEU is approximately 0.45 and the benchmark for the high utilization ratio ITEU is approximately 0.6.

2 overseas results are presented as reference only data, because their measurement conditions were different from Japanese datacenter environment.

3.3 Examples of “Holistic Framework” Expression

In Section 3.2, the results were presented with focusing on the distribution of individual (sub) metrics. In this section, the description of the method will be shown to understand the characteristics of Energy efficiency in each datacenters based on the actual examples by the simultaneous presentation of four metrics with the use of a Holistic Framework.

- (1) This Example of a datacenter where improvement of efficiency is possible by the IT hardware renewal

Fig. 3-7 indicates four metrics of a datacenter using a spider web chart. Thick solid line indicates the data for this datacenter and the dotted line indicates the average result from the experimental measurement project.

While this datacenter is indicating the ITEU and PUE numbers higher than the average, its ITEE is lower than the average. This result indicate that a possibility of an example of High efficiency Operation. However, its IT equipment are somewhat older. Thus, accordingly, replacement of the IT equipment is considered to be a promising approach to improve the efficiency of this datacenter.

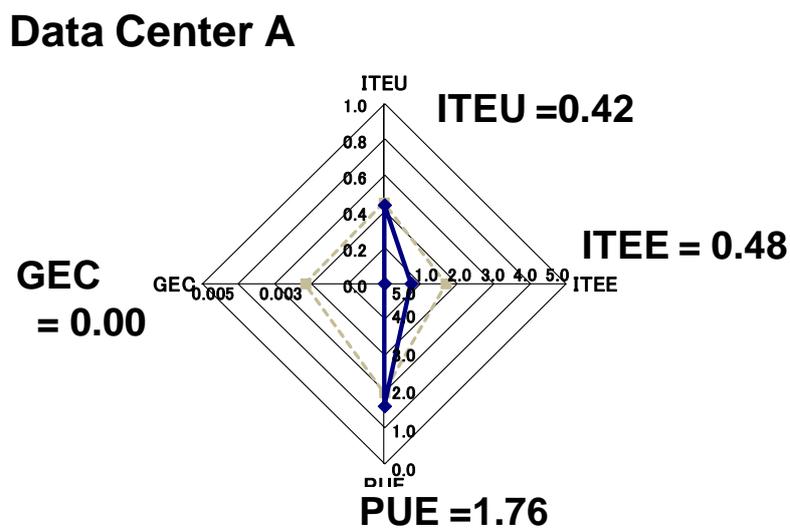


Fig. 3-7: Spider web chart of Holistic Framework of Datacenter A

(2) This Example of datacenter where improvement of operation efficiency is possible in the future

The Datacenter B in Fig. 3-8 indicates lower ITEU while its ITEE and PUE are better than the average compared with the above example of Datacenter A. Because ITEU is closely related to the application used at each datacenter, it is rather difficult to make immediate judgment. However, the data may suggest a possibility of the IT equipment of this brand-new datacenter is designed to have larger capacity margins. If this is the case, the ITEU value will become higher with increases in equipment utilization ratio at this datacenter.

Data Center B

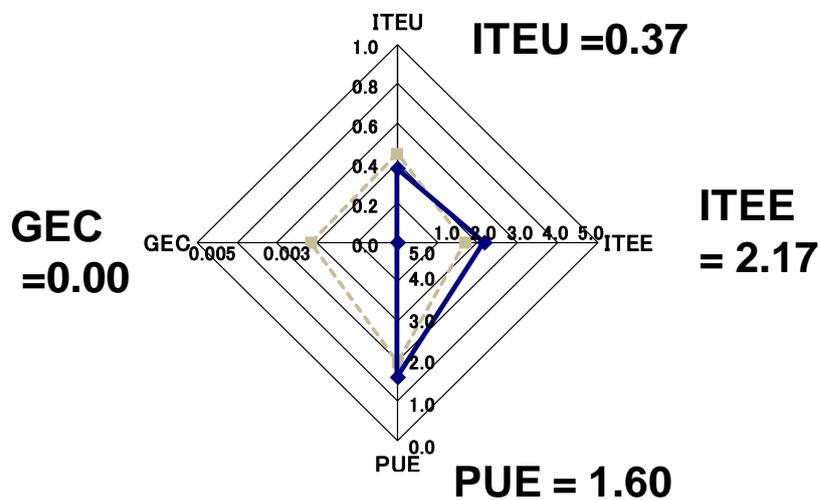


Fig. 3-8: Spider web chart of Holistic Framework for Datacenter B

(3) The Datacenter with improved efficiency in terms of both hardware and operation

Furthermore, Fig. 3-9 indicates an example of a datacenter, where all of the ITEU, ITEE and PUE numbers are favorable values. This datacenter already demonstrates a good efficiency in terms of hardware and operation of IT equipment and its Datacenter infrastructures. The only point requiring any further improvement is the introduction of Green energies. Because this Datacenter has not yet introduced a Green energy, further improvement of the efficiency may be achieved by the Green energies.

Data Center C

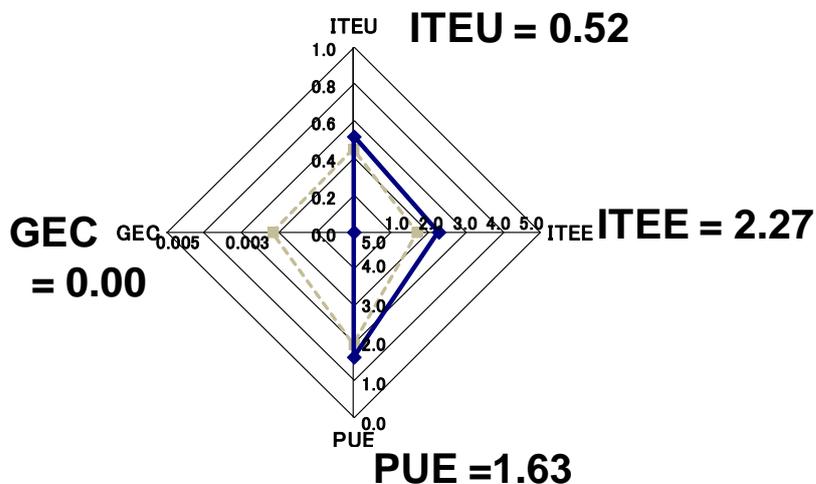


Fig. 3-9: Spider web chart of Holistic Framework for Datacenter C

(4) Chronological comparison of the energy efficiency

At last, Fig. 3-10 indicates an example of datacenter aging related changes in 2 years period. Comparing the data between 2010 and 2011, improvements of the ITEU and PUE are observed, while there is no significant change in ITEE. This result indicates that a further improvement of efficiency is could be performed in terms of the facility and IT equipment, while keeping the level of hardware efficiency for IT equipment could be maintained.

In this case, the use of the Holistic Framework will allow the Datacenter owner/operator to track the outcome of all efforts for improving the datacenter efficiency.

**Data Center D
- Comparison between FY2011 and FY2010 -**

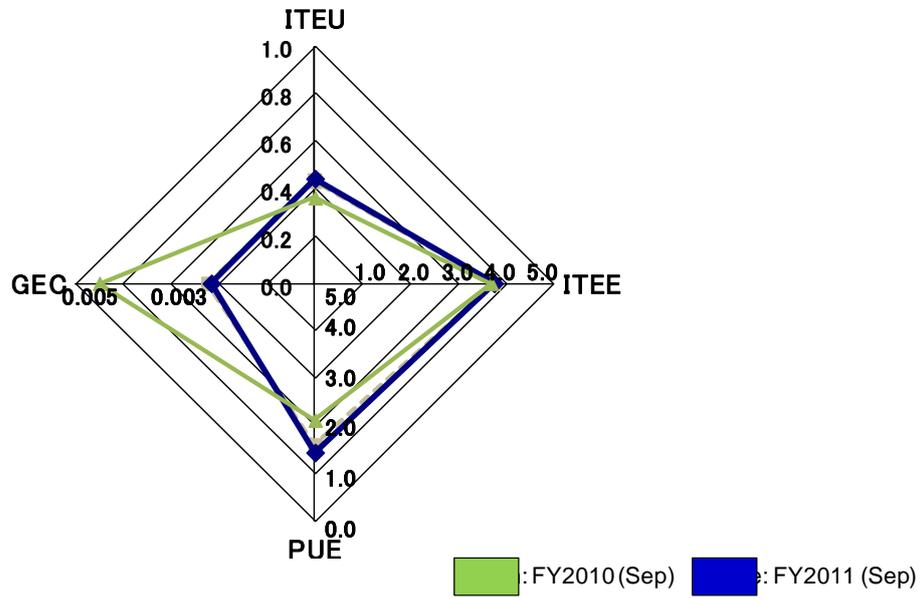


Fig. 3-10: Periodic Spider web chart of Holistic Framework for Datacenter D

4. Summary

To address the recent increase of Energy consumption in datacenters, the GIPC has promoted the development of metrics to evaluate the energy efficiency and the evaluation framework for the entire datacenter, which is called “DPPE”. In this development, the GIPC tried to establish the metrics which could evaluate not only the datacenter infrastructures, but also to improve the IT efficiency and introduction of the Green energy source.

By sub categorizing the efficiency target of the entire datacenter into four metrics to compose the energy efficiency, it was possible to determine the efficiency in each categories and developed effective measures to improve the Energy efficiency.

Furthermore, while promoting the development of these metrics, the GIPC investigated the usages of these metrics by implementing the Energy efficiency experimental measurements at more than 20 datacenters in Japan and overseas locations.

This research revealed the current status of the Japanese domestic datacenters. Also, by the use of the Holistic Framework with Four metrics, characteristics of the energy efficiency in each datacenter were determined. In addition, the GIPC demonstrated that the analysis could guide each datacenter for which specifics to focus for the effort of efficiency improvement. The GIPC consider that the improvement of Energy efficiency for entire datacenter is feasible, and without any limitation of the scope to infrastructures by the usage of this framework. The GIPC is planning to promote this approach for further improvement of the metrics as the future work.

Acknowledgement

The GIPC would like to express the deep appreciation for the parties involved in the International Global Harmonization activities including; The Green Grid, U.S. EPA, U.S. DOE, EU and EC - EU Code of Conduct, and BCS - British Computer Society for their elaborate advice in developing the metrics for the datacenter energy efficiency and, particularly, in reviewing the actual utilization in a global scale.

With regards to the sophistication of the PUE measurement guideline, the GIPC are very thankful to the great contribution of the JDCC – Japan Data Center Council. For the measurement project in 2010 and 2011, more than 20 datacenter operators participated in the project. The GIPC appreciate their cooperation.

For the activities of metrics development, Global Harmonization and International Standardization in general, enormous supports were extended by Information and Communication Electric Division Team of Commercial and Information Policy Bureau, Japanese Ministry of Economy Trade and Industry - METI.

And at last, all of these supports were essential to the accomplishment of this project.