Introduction of Datacenter Performance Per Energy (DPPE)

Takeshi Ueoro (NTT Data Corp.)

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1.Outline of DPPE

Introduction

It is necessary to create a usable and agreeable Metrics to express energy efficiency of the entire data center with both IT equipments and Data Center infrastructure.

TGG created “PUE” metric is widely used and accepted throughout the world.

However, there is an increasing need for a metric which could do more precise measurement of the entire data center.

“Power Usage Effectiveness” (PUE) was introduced by The Green Grid in 2007 .

PUE maybe understood as a metric which has a focus on the Data Center Infrastructure.

$$\text{PUE} = \frac{\text{Overall consumption by Data Center}}{\text{Consumption by IT equipments}}$$

Throughout the world, EPA Energy Star, EU Code of Conduct and such, the PUE is widely accepted as a current primary metric of the Data Center energy efficiency indicator.

Introduction

Category	Change in "PUE" number
Infrastructure (Power, A/C etc)	Improvement on Energy Consumption will change PUE
IT Equipment (Server, Storage, NW)	Effort of Energy Consumption will not appear on PUE – i.e. Highly Efficient IT Equipment will not necessary yield good PUE number.

As PUE is a metric focusing on a data center infrastructure, a new metric expressing energy efficiency of the entire data center is investigated by many organizations.

GIPC has therefore developed Datacenter Performance Per Energy (DPPE), and is actively promoting DPPE for its wide acceptance and the use worldwide.

DPPE(Datacenter Performance Per Energy)

Datacenter Performance Per Energy (DPPE) is a new metric for data center energy efficiency, which satisfies the following requirements:

(1) To calculate energy efficiency easily
(2) To compare different data centers (available for International comparison)
(3) To track energy saving efforts continuously
(4) Available for regulation

DPPE consists of the following four sub metrics.

		Sub metric 1		Sub metric 2		Sub metric 3		Sub metric 4	
Datacenter Performance Per Energy (DPPE)	= f(	Data Center Usage	,	IT Equipment Energy Efficiency	,	Facility Energy Efficiency	,	Green Energy Coefficient	)

Each sub metric can be used independently.

Note) DC : Data Center

DPPE & its 4 sub metrics

DPPE, a total productivity of Datacenter, can be calculated, when all four sub metrics are measured.

The concept of DPPE is based on the following formula:

$$\text{DPPE} = \frac{\text{DC Work}}{\text{DC energy} - \text{Green energy}}$$

$$= \frac{\text{IT equipment work rate} \times \text{IT equipment work Capacity}}{\text{DC energy} - \text{Green energy}}$$

$$= \text{IT equipment work rate} \times \frac{\text{IT equipment work capacity}}{\text{IT equipment energy}} \times \frac{\text{IT equipment energy}}{\text{DC energy}} \times \frac{\text{DC energy}}{\text{DC energy} - \text{Green energy}}$$

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

Note) DC : Data Center

DPPE and Sub-metrics

$$\text{DPPE} = \frac{\text{IT work measured}}{\text{DC grid electricity measured}}$$

$$= \underbrace{\frac{\text{IT work measured}}{\text{IT energy measured}}}_{\text{This term itself is difficult to measure.}} \times \underbrace{\frac{\text{IT energy measured}}{\text{DC energy measured}}}_{= 1 / \text{PUE}} \times \underbrace{\frac{\text{DC energy measured}}{\text{DC grid electricity measured}}}_{= 1 / (1 - \text{GEC})}$$

Thus, as a proxy, following term is adopted:

$$\underbrace{\text{IT usage rate}}_{\text{This term itself is difficult to measure.}} \times \underbrace{\frac{\text{IT work capacity}}{\text{IT energy max}}}_{= \text{ITEE}}$$

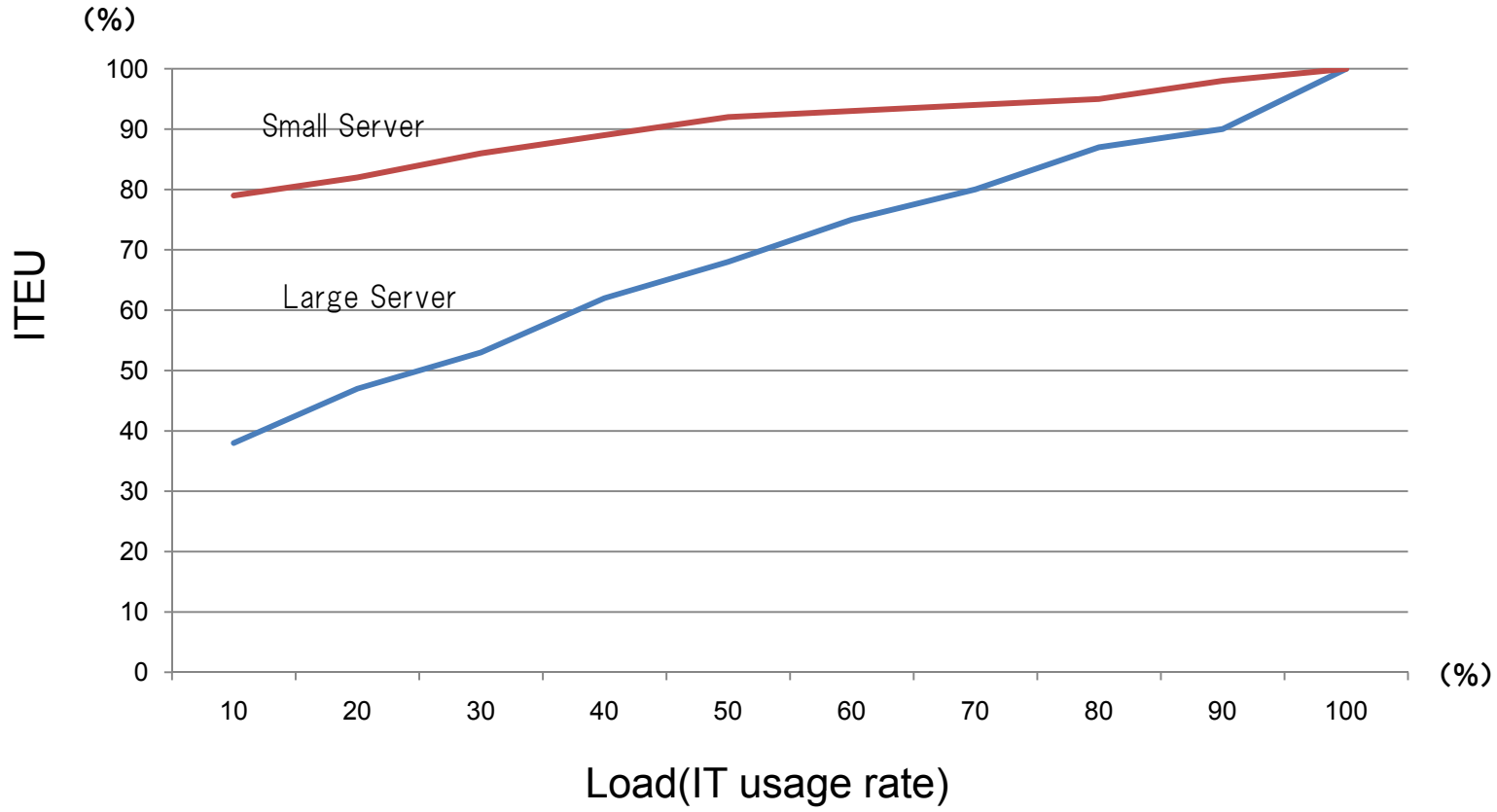
$$\underbrace{\frac{\text{IT energy measured}}{\text{IT energy max}}}_{= \text{ITEU}}$$

Proxies are used for variables which are hard to measure.

Proxies should be calculated from measurable data in data centers.

Relationship between load (IT usage rate) and ITEU

- Relationship between ITEU and IT usage rate is different for each equipment.
  When considered as a whole Datacenter, it is averaged.



Formula of DPPE and sub-metrics

Datacenter Performance Per Energy (DPPE) represents the energy productivity of a total datacenter

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

$$ITEU = \frac{\text{Total measured energy consumption by IT devices [kWh]}}{\text{Total rated energy consumption by IT devices [kWh]}}$$

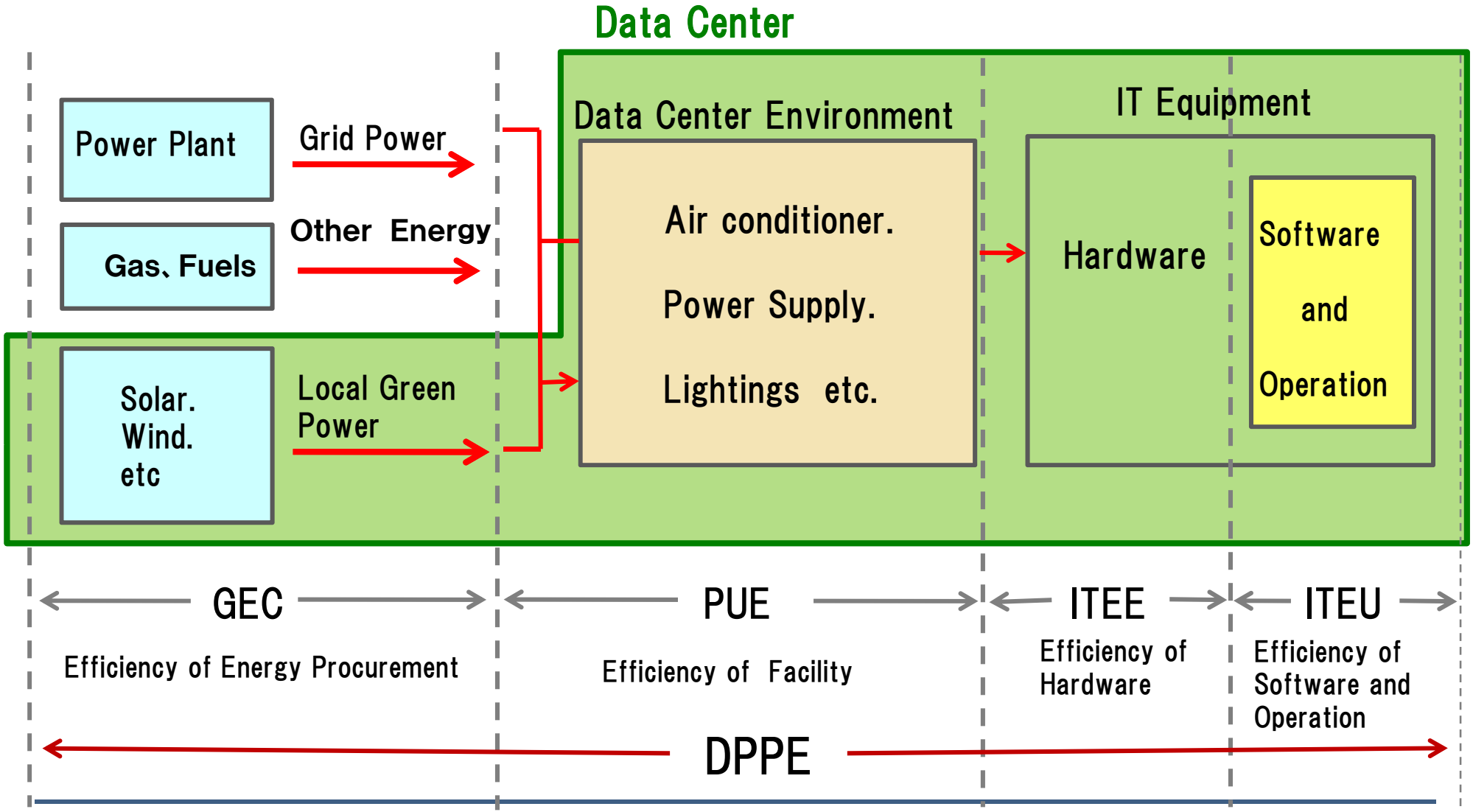
$$ITEE = \frac{\alpha \times \Sigma\text{Server Capacity} + \beta \times \Sigma\text{Storage Capacity} + \gamma \times \Sigma\text{Network Capability}}{\text{Total rated power of IT device [W]}}$$

$$PUE = \frac{\text{Entire Data Center Energy Consumption [kwh]}}{\text{Entire IT Equipments' Energy Consumption [kwh]}}$$

$$GEC = \frac{\text{Green Electricity (Energy) [kwh]}}{\text{Data Center Energy Consumption [kwh]}}$$

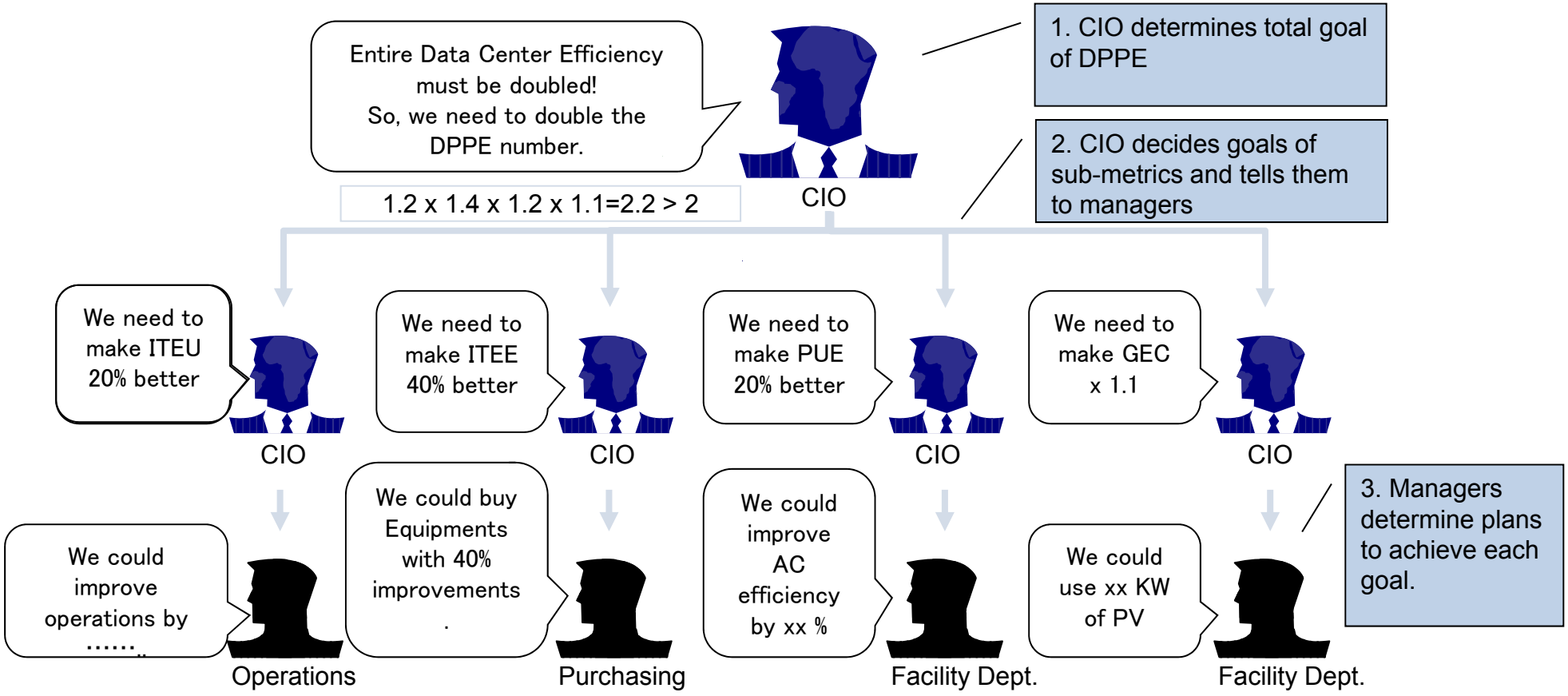
DPPE (Data Center Performance Per Energy)

Datacenter Energy Flow and Boundary of Metrics



Useful use of the DPPE explained

By the separate application of DPPE's 4 sub metrics for each line of responsibilities, the entire effort for the Energy Efficiency of the Data Center could be divided into 4 different responsibilities.



2. Trial Measurement of DPPE

2.1 Outline of the DPPE Measurement Project in Japan

After formulating the Measurement Guideline, the measurement project measured the DPPE (including PUE) of about 20 data centers in Japan.

Outline of the Project

Guideline Formulation

GIPC/JDCC formulate detailed measurement guidelines.

- Japan Data Center Council (JDCC) led examination of how to treat PUE in particular
- Clarify measurement points, measurement quantities, frequency, etc.
- DPPE, ITEU, ITEE, PUE, GEC

Measurement

DC operators are measuring DPPE/PUE.

Participants: 18 companies (21 DCs)

Interval: Monthly from July 2010

Scope:

- PUE, GEC: Total DC
- ITEU, ITEE: Portion of device racks

Sample Data

System No.		2
System application		Finance
PUE	July	1.91
	Aug.	1.93
GEC	July	0.00
	Aug.	0.00
ITEU	July	0.56
	Aug.	0.56
ITEE	July	2.14
	Aug.	2.14
DPPE	July	0.63
	Aug.	0.62

Definition of ITEU

- IT Equipment Utilization (ITEU)

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

- Measuring ITEU
  - Total energy consumption = Accumulated power consumption for 1 month
    - When accumulated power consumption cannot be measured, measure voltage, current and the (power factor's) instantaneous value once a month, calculate the power (voltage × current × power factor), and convert to 1 month's accumulated power consumption
  - Total rated energy consumption = Catalogue rated power × Measurement time (24 hours × Number of days measured)
    - The configuration of the IT equipment to be measured in the racks and the rated power consumption of each piece of equipment was researched using catalogues, etc. then converted to 1 month's total rated energy consumption
  - Include all IT equipment
  - The equipment configuration used in calculations is the configuration as of the end of each month.

Calculation Sheet of ITEU

The value of ITEU is calculated from the data inputted into the worksheet.

Data Input

Server	"Energy consumption efficiency" and "Energy consumption efficiency division name" are the values that were set by "Conservation of Energy Law", and published in														
No	Model Name	maximum spec electric power	unit	Energy consumption efficiency	unit	Energy consumption efficiency division name		Ability	Unit	unit数	Unit	Total of the maximum spec electric power	Unit	Total of Ability	Unit
1	JEITAxxxx	209	W	0.0016	MTOPS/W	A		131	GTOPS/unit	20	unit	4,180	W	2,613	GTOPS
2	JEITAxxxx	209	W	0.0016	MTOPS/W	B		131	GTOPS/unit	10	unit	2,090	W	1,306	GTOPS
3	JEITAxxxx	209	W	0.0016	MTOPS/W	C		131	GTOPS/unit	30	unit	6,270	W	3,919	GTOPS
4	JEITAxxxx	209	W	0.0016	MTOPS/W	A		131	GTOPS/unit	40	unit	8,360	W	5,225	GTOPS
5	JEITAxxxx	209	W	0.0016	MTOPS/W	B		131	GTOPS/unit	50	unit	10,450	W	6,531	GTOPS
6	JEITAxxxx	209	W	0.0016	MTOPS/W	C		131	GTOPS/unit	60	unit	12,540	W	7,838	GTOPS
7	JEITAxxxx	209	W	0.0016	MTOPS/W	A		131	GTOPS/unit	70	unit	14,630	W	9,144	GTOPS
8	JEITAxxxx	209	W	0.0016	MTOPS/W	B		131	GTOPS/unit	80	unit	16,720	W	10,450	GTOPS
9	JEITAxxxx	209	W	0.0016	MTOPS/W	C		131	GTOPS/unit	60	unit	12,540	W	7,838	GTOPS
						※1GTOPS=1000MTOPS			Total	420	unit	87,780	W	54,863	GTOPS

Results

ITEU of this system			
A	Total consumption energy of this system for period (The actual measurement value is filled in. Measure active power that considers "Power factor" about the electric power of the IT equipment.)	86,400	kWh
	"Power factor" of this system, when measuring it is filled in. When the recommended value of this guideline is used, 95% is filled in.	95	%
	The method of measuring "Power factor" is filled in (Real-time measurement value, Mean value measured in the past, and Guideline recommendation value.).	Guideline	Text
	"Continuous integration" measurement with integration wattmeter for one month, or "Moment once a month" Measurement (measurement once *24H * days for one month), or "integration on a day" Measurement (integration measurement 1 day * days for one month)	Continuous integration	Text
	Accuracy of measuring instrument (% error range to measurements)	5	%
B	The total maximum rated energy of this system=(Server maximum rated power + Storage maximum rated power + Network Equipment maximum rated power + Other equipment maximum rated power)*24hour*days	362,412	kWh
C	ITEU of this system = Total comsumption energy of this system / Total maximum rated energy of this syster	0.238	

Results of ITEU Measurement

The range of measured ITEU is 0.3 – 0.6

ID No. of DC		2	4	8	9	13
System application		Finance	Showroom, solutions evaluation/ testing	Cloud	Hosting	IDC integrated surveillance system
ITEU	July	0.56	0.31	0.36	0.30	0.35
	Aug	0.56	0.26	0.36	0.33	0.34

	July	Aug.
Average	0.38	0.37
Min.	0.30	0.26
Max.	0.56	0.56

Summary of PUE Measurement

GIPC and JDCC compiled detailed PUE measurement guidelines and took measurements in Japan.

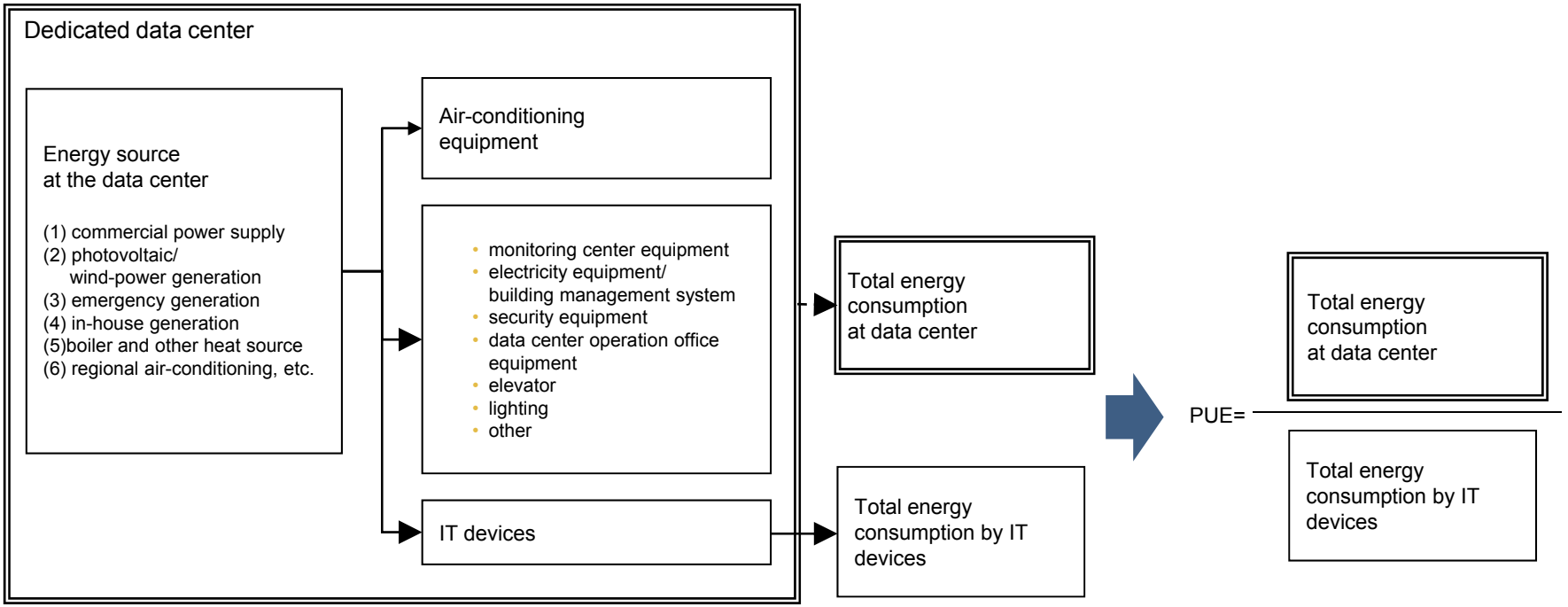
As the discussion over the definition of PUE is ongoing, these measurements were conducted by adding a definition of non-electric energy to the conventional PUE (site energy).

- Consider all the energy related to the data center
  - Use the unit of GJ to measure energy from both electricity and other sources (fuel, etc.).
  - 1 kWh ＝ 0.0036 GJ for electricity. Convert fuel using the conversion coefficients referred from Energy Conservation Law in Japan.
  - Measure electric energy (accumulated power) from grid power, solar power and emergency power generation. Measure fuel consumption and electricity generated from in-house power generation, boilers and district heating/cooling.
- Measure the energy consumption of IT equipment at PDU output.
  - Base measurements on PDU output.
  - When PDU measurement is not possible, alternative points such as UPS output / input are used. The PDU output equivalent is estimated by multiplying the loss conversion factor to the UPS output / input.
- When accumulated power (kWh) is not measurable, the effect of power factor be considered.
  - Measuring the power factor is required to accurately calculate the amount of energy consumption of IT equipment.
  - When the power factor cannot be measured, the past measurement value or the recommended value (95%) is used.

Details of PUE Definition in the Project

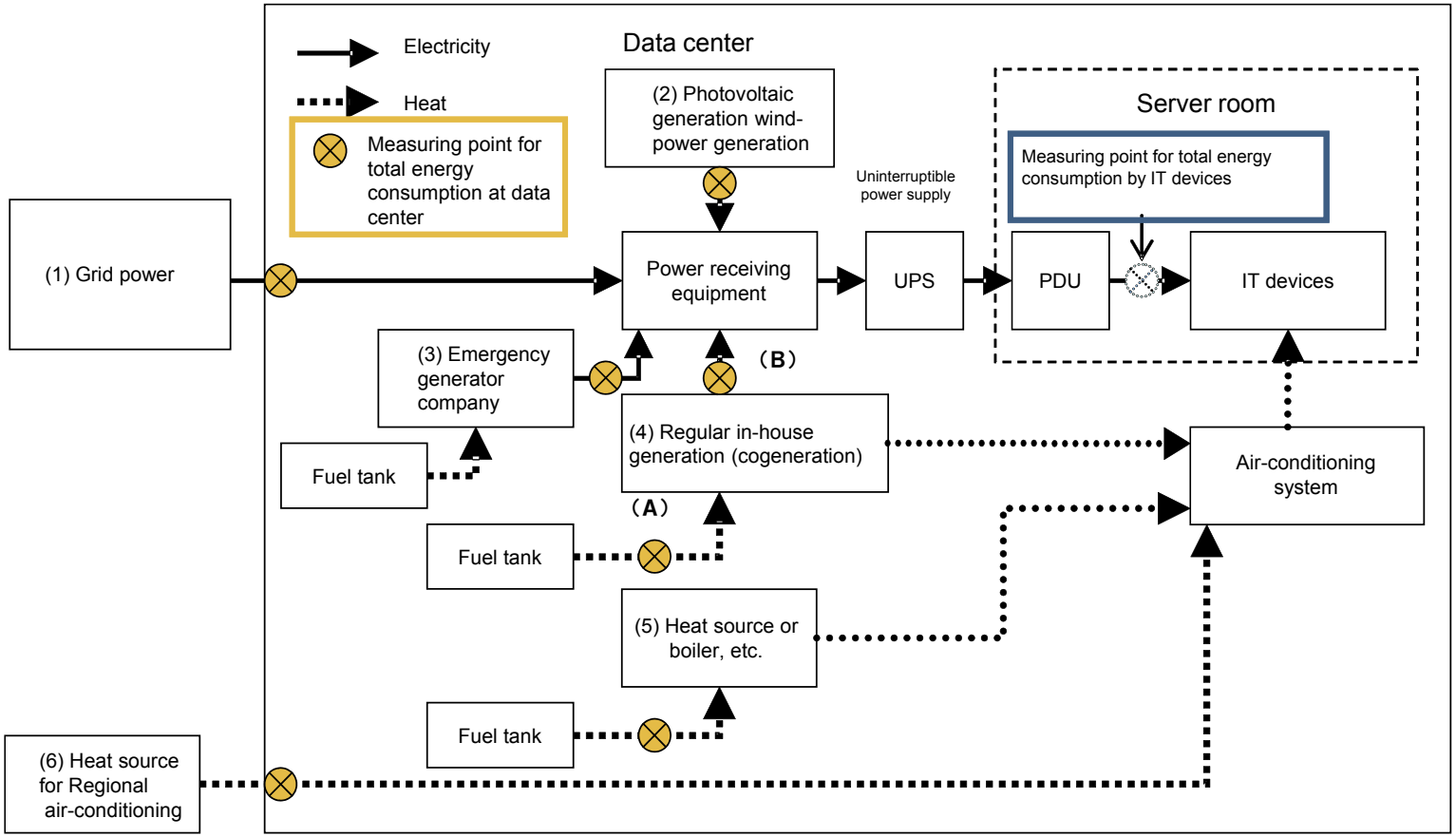
PUE Power Usage Effectiveness

- All energy related to the data center
- Use uniform GJ unit to accumulate measurements of electricity and other energy (fuel, etc.)
- Convert using 1 kWh = 0.0036 GJ



Details of PUE Measurement Points

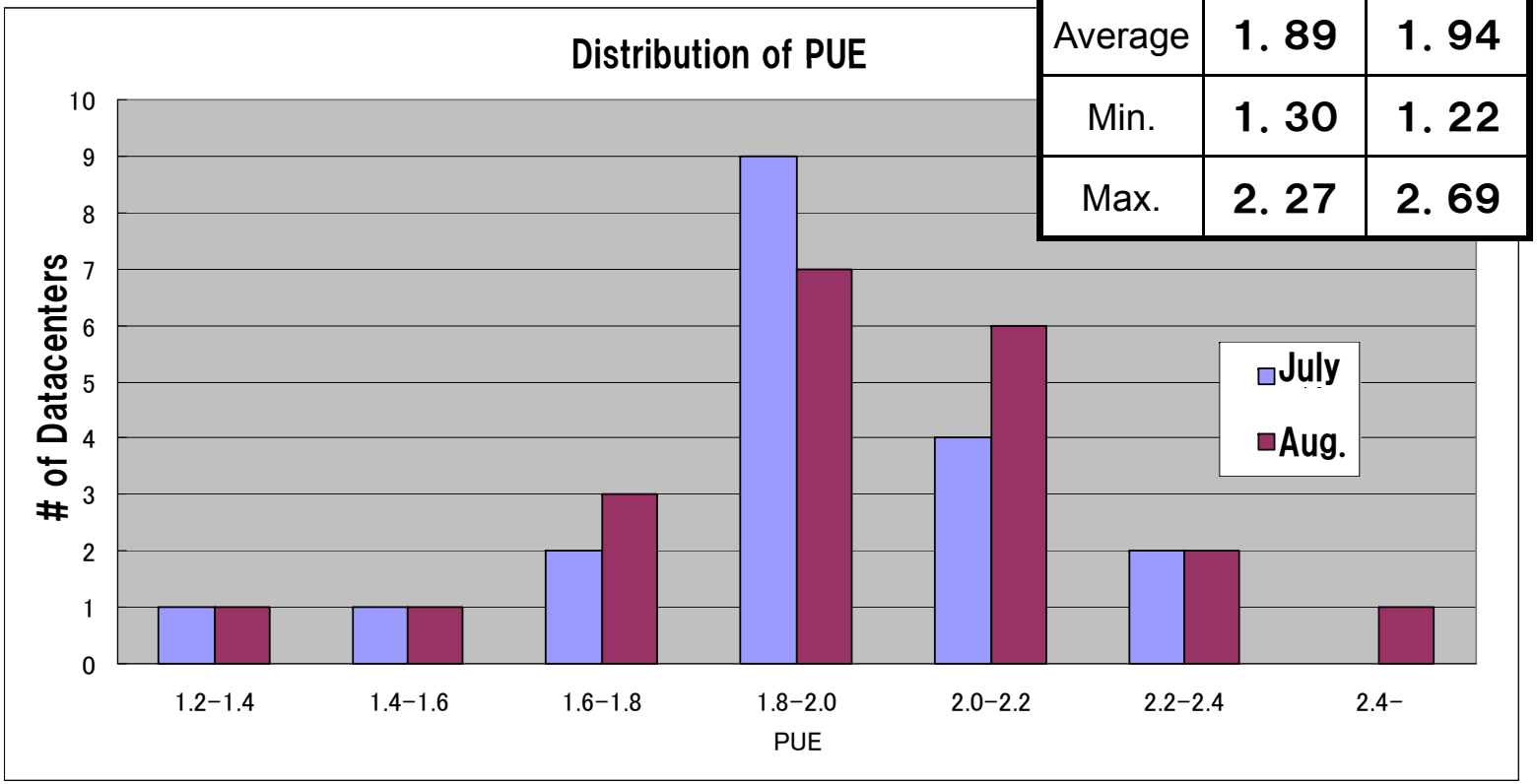
- Measure electric power for grid power, solar power and emergency power generation ((1), (2), (3)). Measure fuel consumption and electricity generated for in-house power generation, boilers and district heating/cooling ((4), (5), (6)).
- Measure accumulated energy consumption and fuel consumption over 1 month.



Results of PUE Measurement

The average of PUE is about 1.9 in Japan.

	July	Aug
Average	1. 89	1. 94
Min.	1. 30	1. 22
Max.	2. 27	2. 69



Definition of ITEE

■ITEE: IT Equipment Energy Efficiency

$$\text{ITEE} = \frac{\alpha \times \Sigma\,(\text{server capacity}) + \beta \times \Sigma\,(\text{storage capacity}) + \gamma \times \Sigma\,(\text{NW equipment capacity})}{\text{Total rated power [W] of IT equipment (servers, storage, NW equipment)}}$$

α = 7.72 [W / GTOPS]
β = 0.0933 [W / Gbyte]
γ = 7.14 [W / Gbps]

■Measuring ITEE

- Total rated capacity of IT equipment = Total of the capacity specifications (server capacity, storage capacity, network equipment capacity) from the energy consumption efficiency stipulated in the “Energy Conservation Law”, multiplied by a coefficient
- The mean capacity of server/storage/network equipment in 2005 is defined as unit [Work].
- Total rated power of IT equipment = Catalog rated power [W]
- Calculated based only on servers, storage and network equipment (does not include other equipments).
- The equipment configuration used in calculations is the configuration as of the end of each month.

Calculation Sheet of ITEE

The value of ITEE is calculated from the data inputted into the worksheet.

Data Input

Server	"Energy consumption efficiency" and "Energy consumption efficiency division name" are the values that were set by "Conservation of Energy Law", and published in														
No	Model Name	maximum spec electric power	unit	Energy consumption efficiency	unit	Energy consumption efficiency division name		Ability	Unit	unit数	Unit	Total of the maximum spec electric power	Unit	Total of Ability	Unit
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						※1GTOPS=1000MTOPS			Total	420	unit	87,780	W	54,863	GTOPS

Results

ITEE of this System																			
	Ability conversion coefficient																		
	Alfha =	7.72														423,539			
	Beta =	0.0933														724,157			
	Gamma =	7.14														10,710			
D	Total ability of this system															1,158,406	Work	->to the DPPE filling in sl	
E	Total maximum rated power of this system (without Other equipment)= Server maximum rated power + Storage maximum rated power + Network Equipment maximum rated power)															295,450	W	->to the DPPE filling in sl	
F	ITEE of this system = Total avility of this system / Total maximum rated power of this system (without other equipment)															3.92		ITEE value of each syster	

Energy Consumption Efficiency

Energy Consumption Efficiency of Energy Conservation Law is available in specification sheets in Japan.

HP Integrity rx2800 i2

最新のクアッドコア インテル® Itanium® プロセッサー 9300番台搭載のHP Integrity rx2800 i2は、コンパクトな2Uの筐体に8コアまで可能にし、小規模のみならず中規模データベースまでをカバーする拡張性を実現。

製品名		HP Integrity サーバー rx2800 i2		
プロセッサー		インテル® Itanium® プロセッサー 9310 1.6GHz/10MB Level 3キャッシュ	インテル® Itanium® プロセッサー 9320 1.33GHz/16MB Level 3キャッシュ	インテル® Itanium® プロセッサー 9340 1.6GHz/20MB Level 3キャッシュ
オンチップ・キャッシュ	Level 1 キャッシュ	32KB/コア		
	Level 2 キャッシュ	512KB/コア(命令キャッシュ)+256KB/コア(データキャッシュ)		
	Level 3 キャッシュ	10MB/プロセッサー	16MB/プロセッサー	20MB/プロセッサー
SMP構成		最大2プロセッサー/4コア	最大2プロセッサー/8コア	
メモリ/最大		ECC機能付きDDR3/96GB		
I/Oスロット		PCI Express×6		
省エネ法に基づくエネルギー消費効率※1		未定※2	b区分 0.012	b区分 0.010
サイズ(H×W×D)		86.4mm×482.6mm×673.1mm		
質量(最大)		30.0kg		

※1 エネルギー消費効率とは省エネ法で定める測定方法により測定された消費電力を、省エネ法で定める複合理論性能で除したものです。
※2 2010年夏頃販売開始予定、販売時の仕様は異なる場合がございます。

Source) HP Japan HP

Example of Capacity Calculation

- Sample Calculation of Server Capacity/ Storage Capacity

  - Server — Max Rated Power 209 [W], Energy Consumption Efficiency 0.0016 [d]
    209 [W] / 0.0016 [MTOPS/W] / 1000 = 131 [GTOPS] / server

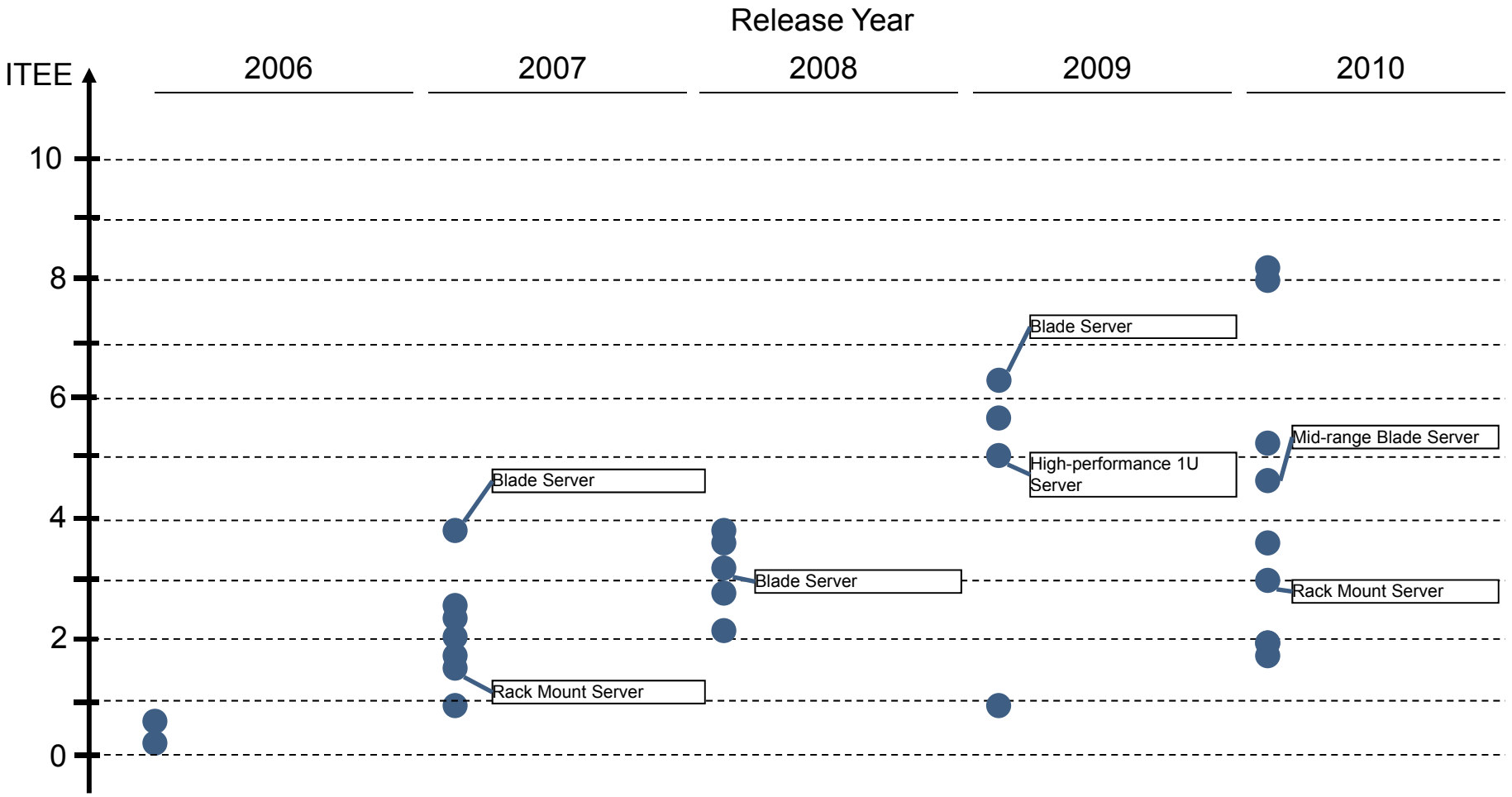
  - Storage — Max Rated Power 4620 [W], Energy Consumption Efficiency 0.025 [AAA]
    4,620 [W] / 0.025 [Gbyte/W] = 184,800 [Gbyte] / storage

- Sample Calculation of Network Equipment Capacity

  - NW — Max Rated Power 145 [W], Max transfer capacity 1 [G bps]
    Ports / NW equipment: 24
    (All ports can be set as 10/100 M bps. 14 ports can be set as 1 G bps)
    10 x 0.1[Gbps] + 14 x 1[Gbps] = 15 [Gbps] / NW equipment

Examples of ITEE (Server)

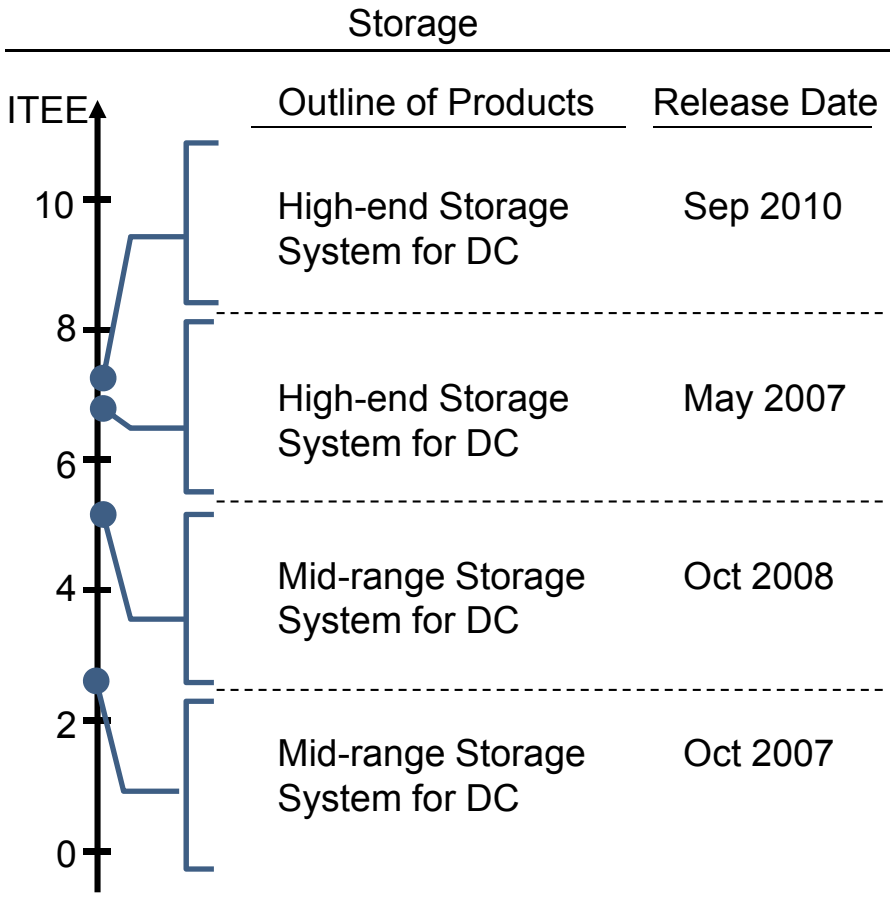
The value of ITEE depends on both type of servers and release year.

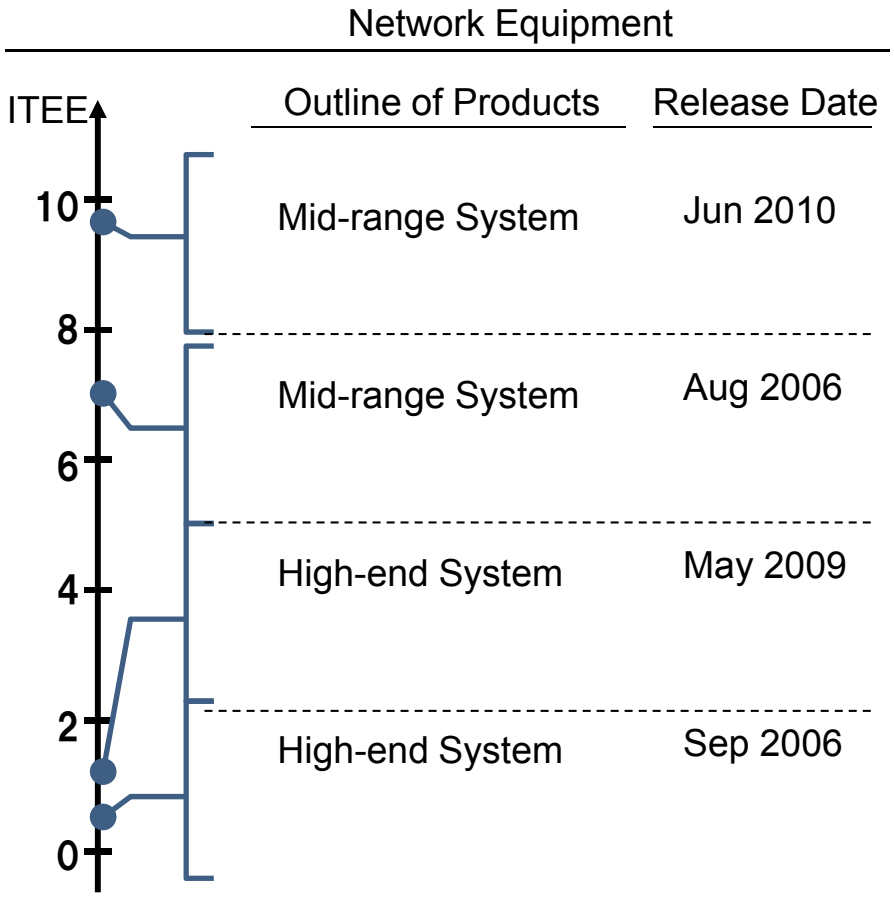


Note) Calculated from Energy Consumption Efficiency of servers
Source) Catalogue of each product provided by server vendors

Examples of ITEE (Storage / NW Equipment)

The range of ITEE values for Storage and Network Equipment is comparable as that of servers.





Note) Calculated from Energy Consumption Efficiency of storages and NW equipment
Source) Catalogue of each product provided by vendors

Results of ITEE Measurement

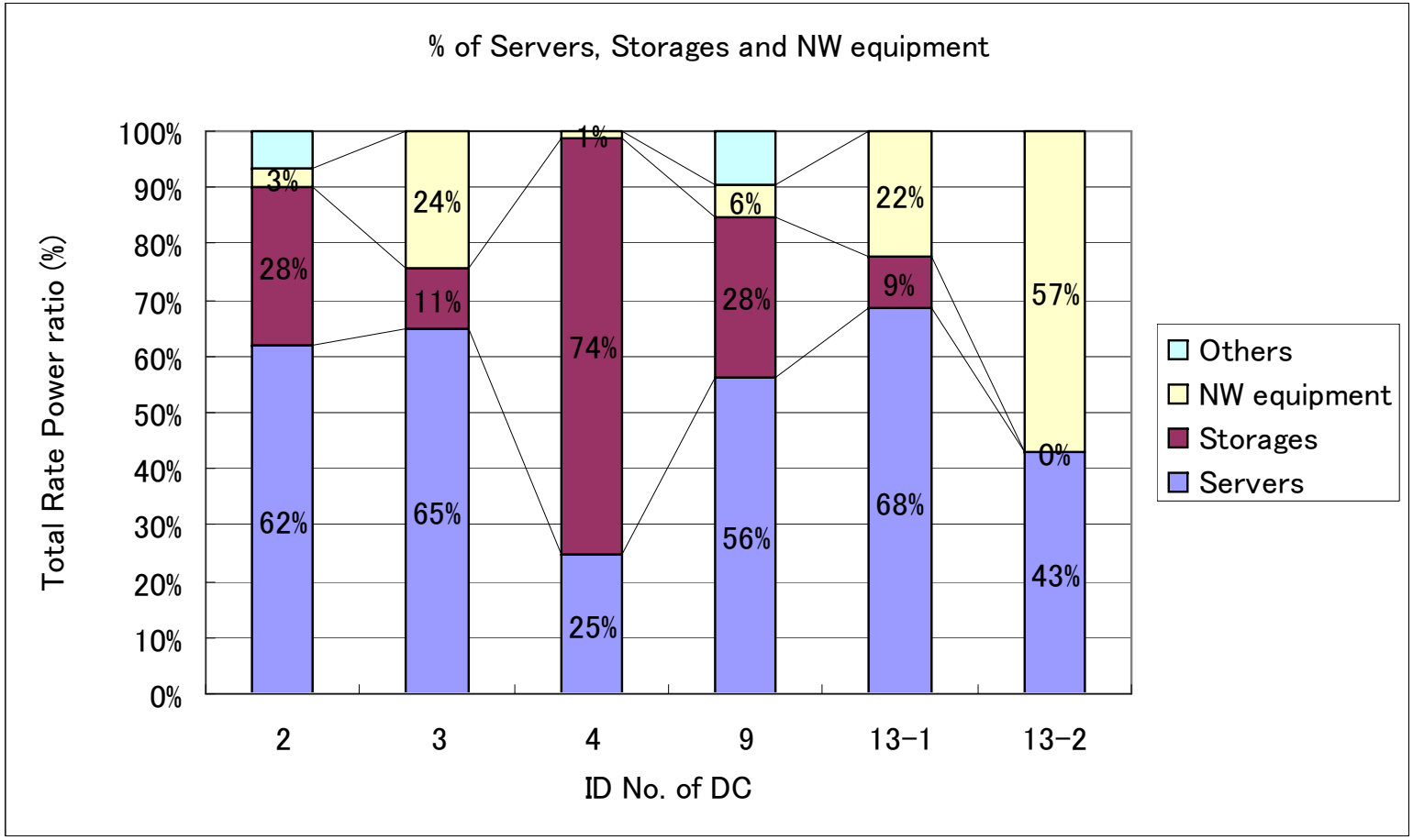
ITEE, successfully measured, shows a higher value at DCs providing finance service and hosting service.

ID No. of DC		2	4	8	9	13
System application		Finance	Showroom, solutions evaluation/ testing	Cloud	Hosting	IDC integrated surveillance system
ITEE	July	2.14	1.08	1.55	3.49	1.18
	Aug	2.14	1.08	1.55	3.70	1.18
Corresponding ITEU	July	0.56	0.31	0.36	0.30	0.35
	Aug	0.56	0.26	0.36	0.33	0.34

	July	Aug.
Average	1.97	1.93
Min.	1.08	1.08
Max.	3.49	3.70

Ratio of Server, Storage and NW equipment

As % of Servers, Storages, and NW equipment is different depending on DC's characteristics, all of these IT equipment should be considered in evaluating DC's IT capacity.



Source) GIPC measurement project

Definition of GEC

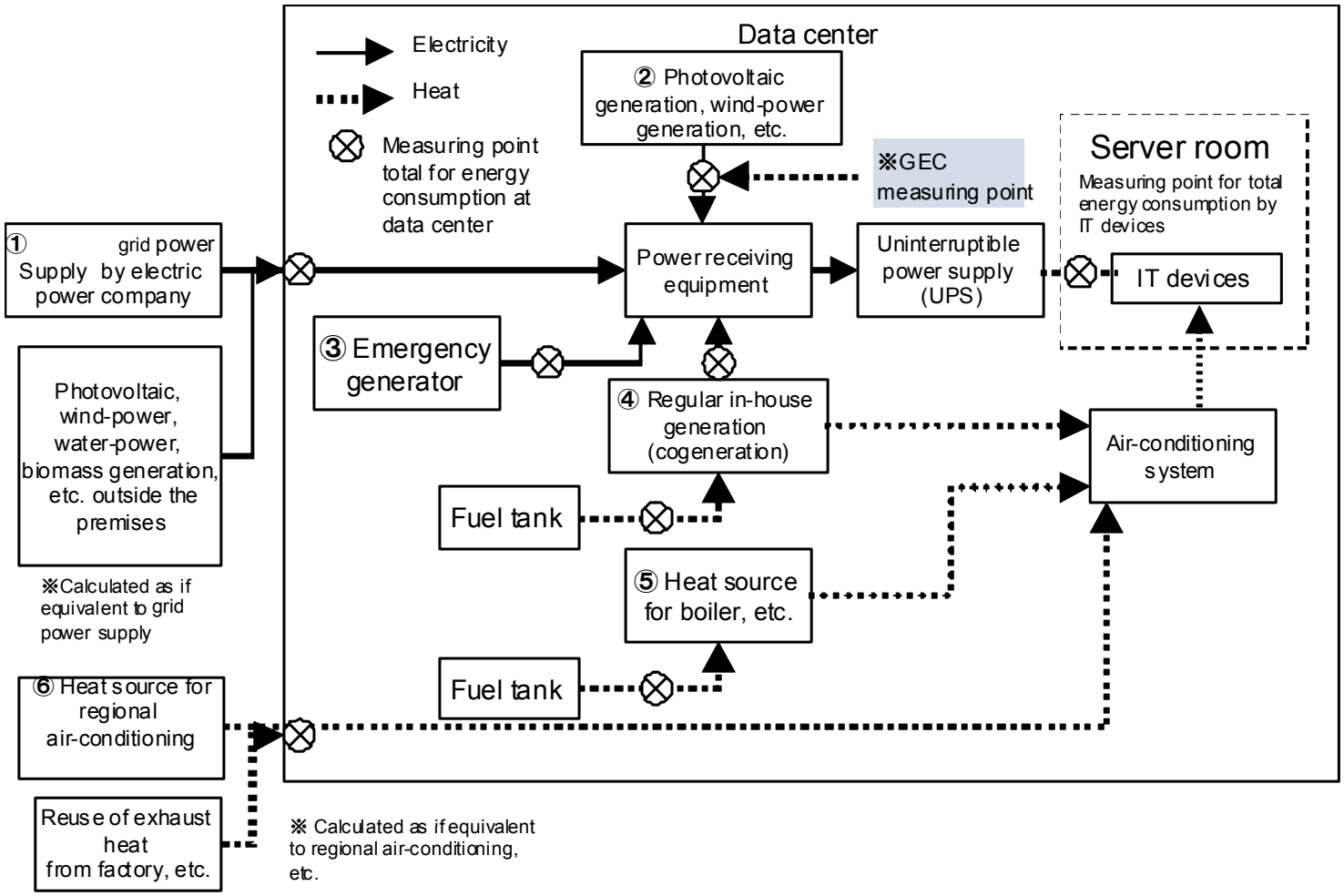
- Green Energy Coefficient (GEC)

$$\text{GEC} = \frac{\text{Green energy generated and consumed at data center [GJ or kWh]}}{\text{Data center's total consumed energy [GJ or kWh]}}$$

- Outline of Measurement
  - Calculate the quantity of energy from green energy (photovoltaic power, etc.) generated at the data center site and convert to accumulated energy consumption for 1 month.
  - The portion of off-site generated green energy purchased is not included in the metric.
  - The portion consumed by the data center is included (the portion used for general office purposes, etc. is not included).
    - In the case of generated power being consumed by non-data-center functions, estimate the portion consumed by the data center according to the proportional allocation rules.

GEC Measurement Points

- Measure the output of power-generating equipment within the data center



Results of GEC Measurement

The ratio of renewable energy consumed by DCs is still small

			8	15	5	9	9
20	Building use/purpose		Data center/office	Data center	Computer-only building	Data center only	Data center only
68	Type of renewable energy	Data center only	PV	PV	PV	PV	PV
110		Shared	PV		PV		
152		Non-data-center only					
303	Total renewable energy consumed by DCs (kWh)	July	-	1,990	1,984	1,198	2,470
		August	6,784	2,302	2,264	1,414	2,640
305	GEC	July	-	0.0038	0.0023	0.0001	0.0051
		August	0.0212	0.0043	0.0025	0.0002	0.0052
		Average	0.0212	0.0041	0.0024	0.0002	0.0052

The estimated range of DPPE and sub-metrics

Estimated potential range of DPPE in 2010 is consistent with the observation.

Assumed range of sub metrics for 2010

	Worst	Best
ITEU	0.2	0.7
ITEE	1.00*	6.41**
PUE	2.5	1.2
GEC	0	0.3

Estimated range of DPPE in 2010

Worst		Best
0.08	-	5.34
0.2×1.00 ×1/2.5 ×1/(1-0)		0.7×6.41 ×1/1.2 ×1/(1-0.3)

＊ the mean value of ITEE in 2005 is assumed. ＊＊ the mean value of ITEE in 2010 (CAGR of 45 % is assumed.)

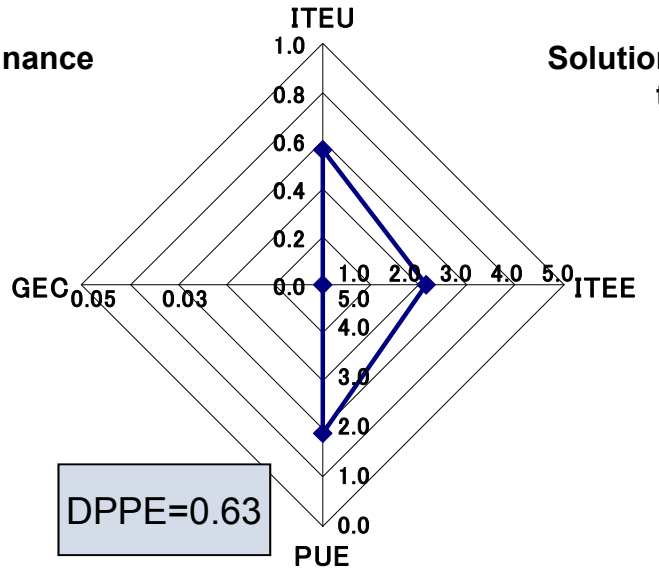
Summary of DPPE Measurement

DPPE and sub-metrics are properly measured and seem to show significant values.

System No.		2	4	8	9	13	Average value
System application		Finance	Showroom, solutions evaluation/ testing	Shared IT-based service (Cloud)	Hosting	ASP system	
PUE	July	1.91	1.42	-	2.58	1.97	1.97
	Aug.	1.93	1.42	1.72	2.38	2.00	1.89
GEC	July	0.00	0.00	-	0.01	0.00	0.00
	Aug.	0.00	0.00	0.02	0.01	0.00	0.01
ITEU	July	0.56	0.31		0.30	0.50	0.42
	Aug.	0.56	0.31	0.36	0.33	0.48	0.41
ITEE	July	2.14	1.08	-	3.49	1.42	2.03
	Aug.	2.14	1.08	1.55	3.70	1.42	1.98
DPPE	July	0.63	0.24	-	0.41	0.29	0.39
	Aug.	0.62	0.24	0.33	0.52	0.27	0.40

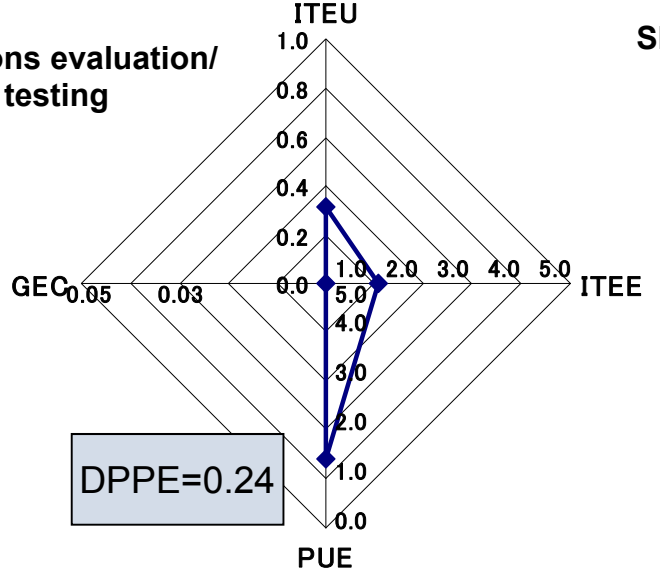
Results of DPPE Measurement

Finance



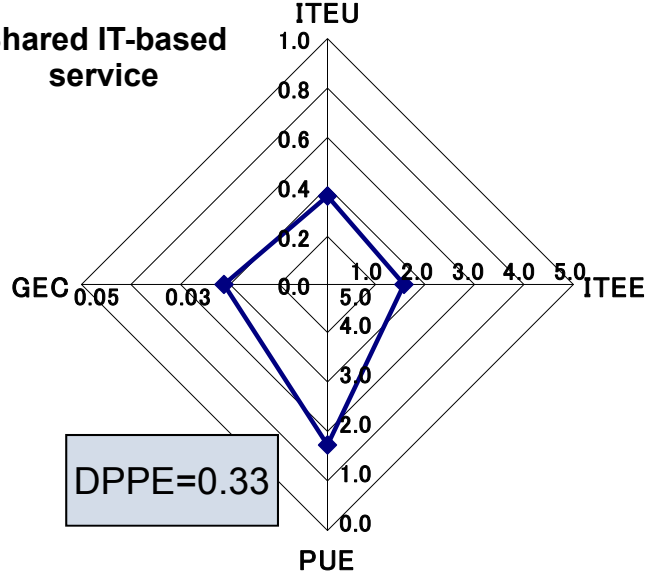
DPPE=0.63

Solutions evaluation/ testing



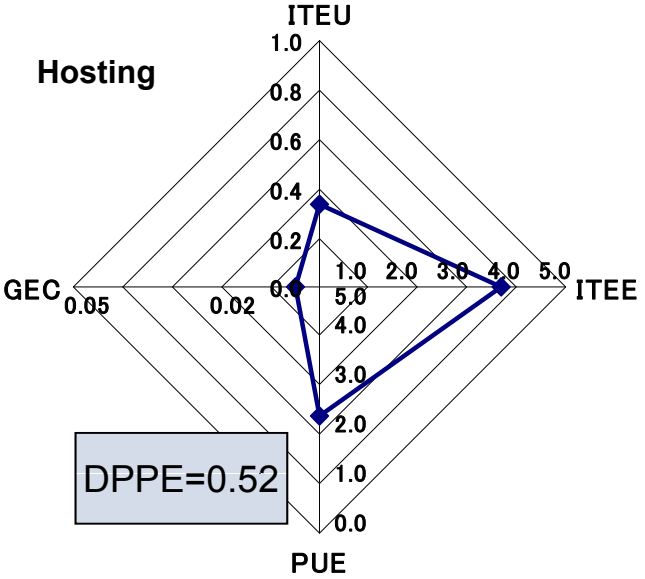
DPPE=0.24

Shared IT-based service



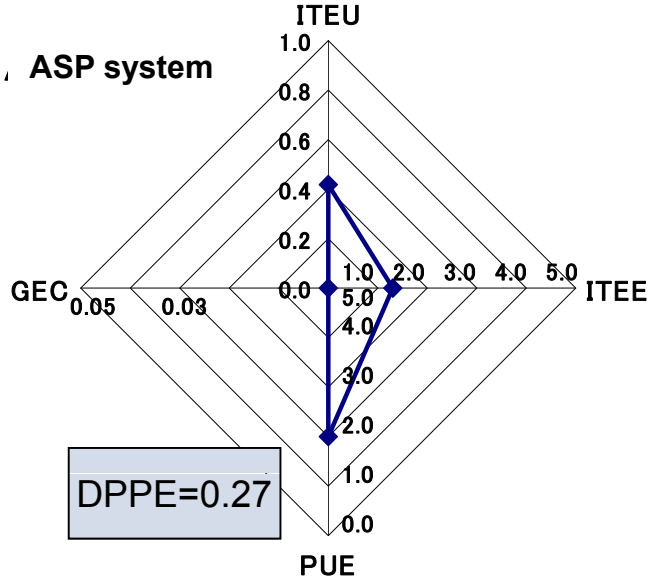
DPPE=0.33

Hosting



DPPE=0.52

ASP system



DPPE=0.27

3. Japan-US-EU Workshop

Japan-US-EU Workshop

GIPC and US/EU organizations (both private and public sectors) continuously hold the Japan-US-EU workshops for global harmonization of metrics of data center energy efficiency. GIPC has proposed DPPE in the workshops.

Members

JAPAN: METI , GIPC , JEITA
US: DOE , EPA , TGG
EU: EC , BCS

Discussions on DPPE

1st WS 2009.3 Washington DC
Introduction of DPPE outline
2nd WS 2010.2 San Jose
Introduction of calculation procedure of DPPE
3rd WS 2010.10 Milan
Introduction of DPPE measurement guideline and results of the trial measurement
Agreement on PUE measurement.
4th WS 2011.2 Tokyo (Scheduled)
DPPE Feedback (TGG, EU, DOE, EPA) and Discussion
PUE Calculations Final

Thank you

Contact List

If you have interests in our survey, please feel free to contact to the following addresses.

NTT DATA CORPORATION
Data Center Business Unit

TAKESHI UEORO

E-mail:ueorot@nttdata.co.jp

Reference: **Concept of New Metrics for Data Center Energy Efficiency**

http://www.greenit-pc.jp/e/topics/release/100316_e.html