ESG Technology

탄소중립을 위한 데이터센터 효율 표준기술

정상진, 기술총괄, 한국전자통신연구원

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01. 우리나라의 탄소중립 대응

< Source: IITP 백은경 PM, 탄소중립 ICT R&D 기획 >

01. 데이터센터 현황

데이터센터 현황

- 국내에는 약 160개 데이터센터가 존재 (2020년 기준)
- 국내 데이터센터 건물 사용 전력 약 400MW (2020년 기준)

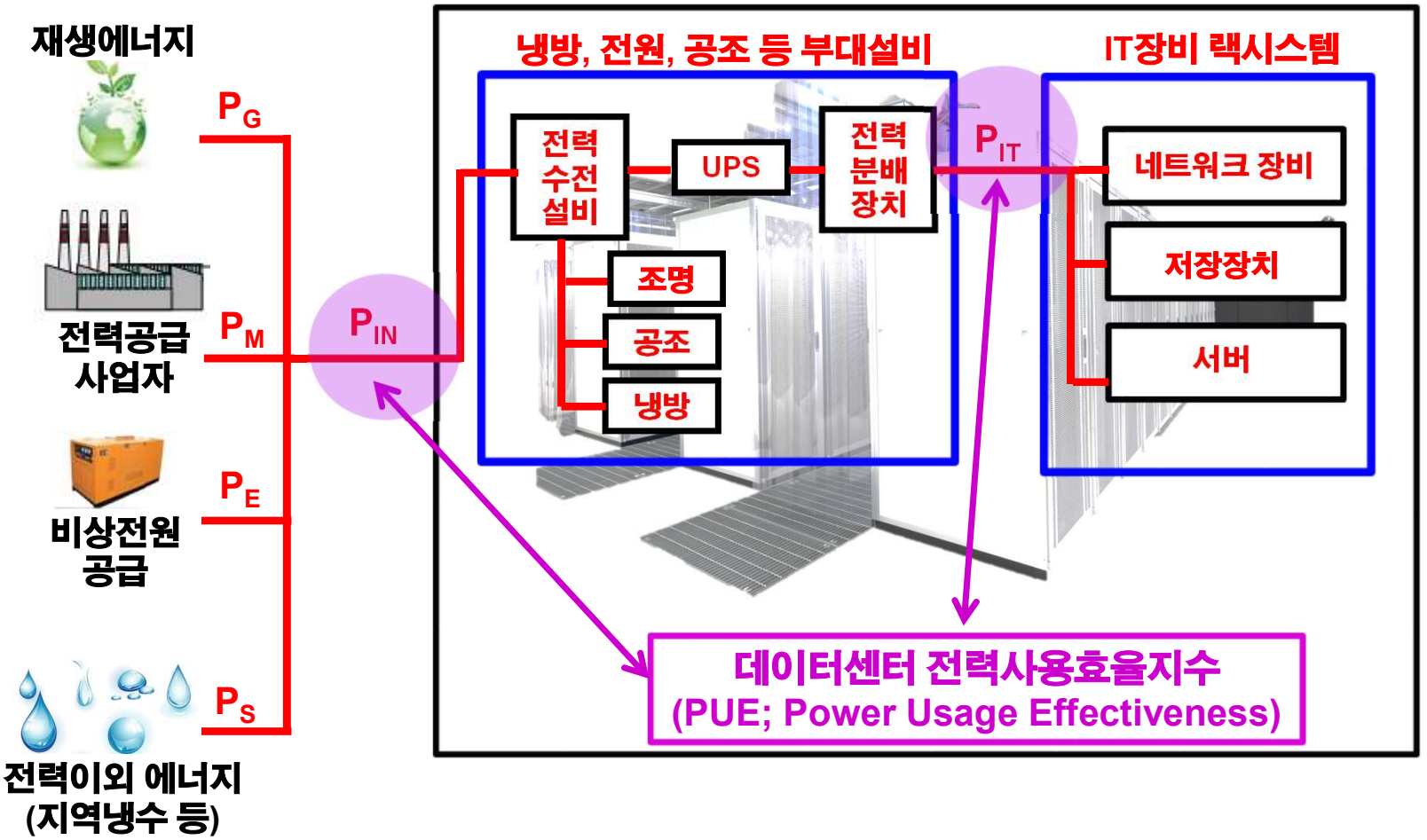
1 국내 160개 데이터센터 사용전력 약 400MW

2 국내 1개 원자력발전소 (신고리4호기) 평균 발전전력 870MW

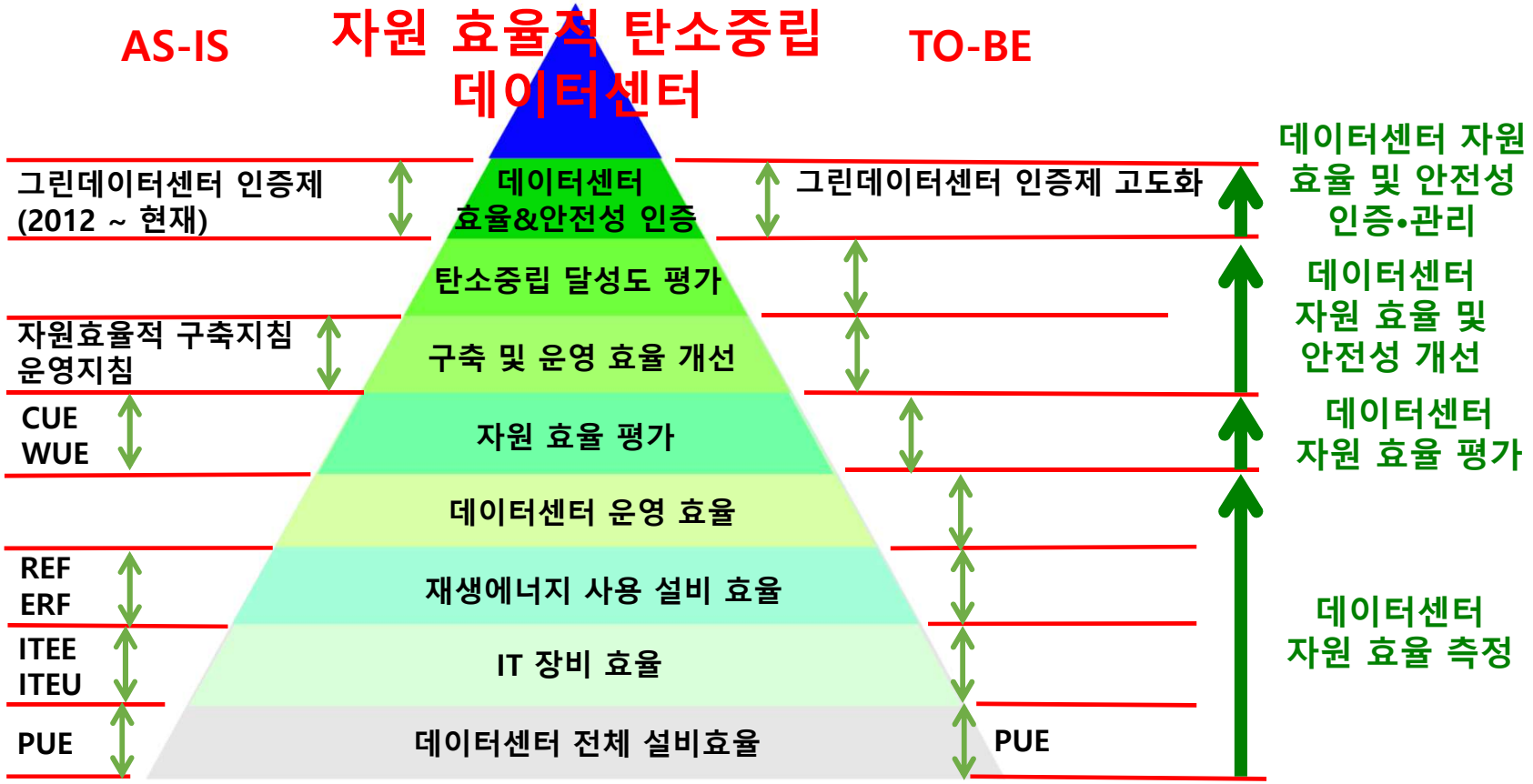
- 데이터센터 에너지 사용은 IT장비의 사용량과 데이터센터 설비의 사용량 (냉각, 공조, 조명 등)으로 구분
- 따라서, 데이터센터의 에너지 효율 향상을 위해서는 각 주요 구성요소의 에너지 사용의 측정/평가가 선결조건
  - 측정 → 평가 → 개선의 라이프사이클

관련 표준 부재

01. 데이터센터 에너지 흐름도



02. 데이터센터 효율 측정 및 평가 지표 개발 방향



02. 데이터센터 효율 관련 국제 표준화 기구

ISO/IEC JTC1 SC 39
(지속가능성, IT 및 데이터센터)
(의장: David Reiner, AMD, 미국
간사: Bill Ash, ANSI, 미국)

WG1
(자원 효율적인 데이터센터)
(의장: Henry Wong, 미국)

- ISO/IEC 30134-1 (데이터센터 KPI 요구사항)
- ISO/IEC 30134-2 (PUE)
- ISO/IEC 30134-3 (REF)
- ISO/IEC 30134-4 (ITEEsv)
- ISO/IEC 30134-5 (ITEUsv)
- ISO/IEC 30134-6 (ERF)
- ISO/IEC 30134-7 (CER) : 개발중
- ISO/IEC 30134-8 (CUE)
- ISO/IEC 30134-9 (WUE)
- ISO/IEC 20913 (데이터센터 효율 종합 평가방법)
- ISO/IEC 23544 (APEE)

WG3
(지속가능한 설비 및 인프라)
(의장: Jens Dittirich, 독일)

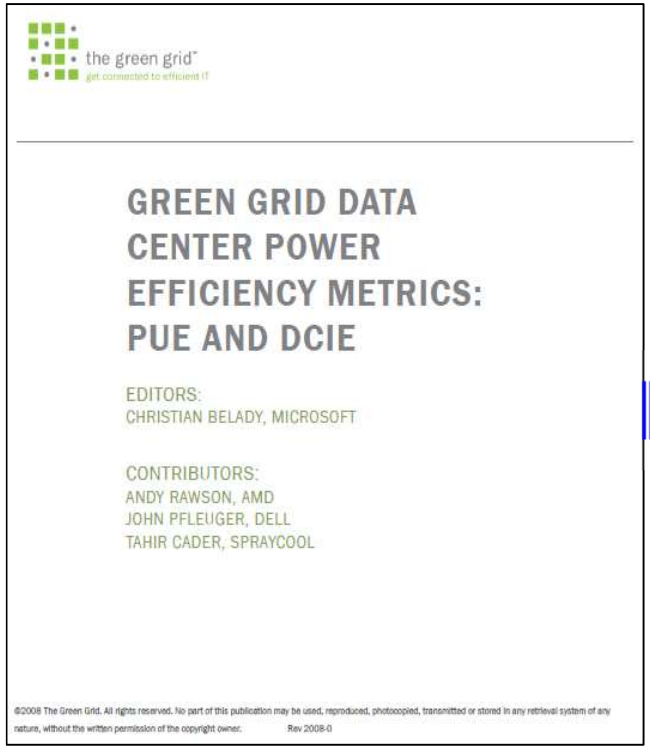
- ISO/IEC 22237 시리즈 (데이터센터 설비 및 인프라)

ITU-T SG5 WP3
(기후변화, 탄소중립)
(의장: Qi Shuguang, CAICT, 중국)

Q11 (기후변화 완화 및 스마트 에너지)
(라포터: 정상진, 한국, Qi Shuguang, 중국)

- ITU-T L.1300 (그린 데이터센터 구축지침)
- ITU-T L.1305 (데이터센터 인프라 관리시스템)
- ITU-T L.1381 (데이터센터 스마트 에너지 솔루션)
- ITU-T L. MM&BP_DC (데이터센터 탄소저감 측정방법 및 모범사례)
- ITU-T L.1306 (에지 데이터센터 인프라 규격)

02. 데이터센터 전력사용효율지수 (PUE: Power Usage Effectiveness) (1/5)


the green grid
get connected to efficient IT

GREEN GRID DATA CENTER POWER EFFICIENCY METRICS: PUE AND DCIE

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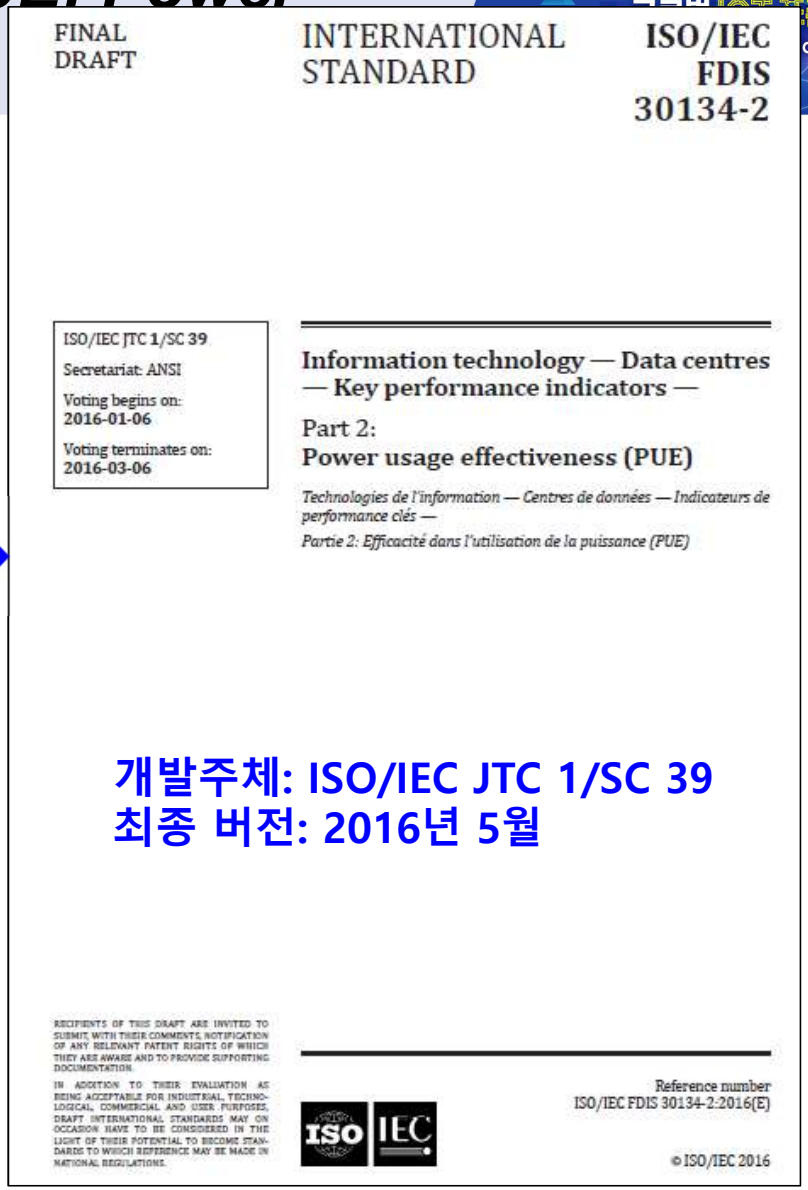
최초 버전: 2007년 10월

개발권한 위임


FINAL DRAFT

INTERNATIONAL STANDARD

ISO/IEC FDIS 30134-2

ISO/IEC JTC 1/SC 39
Secretariat: ANSI
Voting begins on: 2016-01-06
Voting terminates on: 2016-03-06

Information technology — Data centres — Key performance indicators —

Part 2:
Power usage effectiveness (PUE)

Technologies de l'information — Centres de données — Indicateurs de performance clés —
Partie 2: Efficacité dans l'utilisation de la puissance (PUE)

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Reference number
ISO/IEC FDIS 30134-2:2016(E)

개발주체: ISO/IEC JTC 1/SC 39
최종 버전: 2016년 5월

02. 데이터센터 전력사용효율지수 (PUE; Power Usage Effectiveness) (2/5)

❖ 데이터센터 전력사용효율지수 **국제표준 개발완료** (ISO/IEC 30134-2)

$$PUE = \frac{E_{DC}\ (kWh)}{E_{IT}\ (kWh)} = \frac{\text{① Total 건물 전력 (IT전력 + IT동력 + IT손실)}}{\text{③ UPS 출력단 전력 (IT전력)}}$$

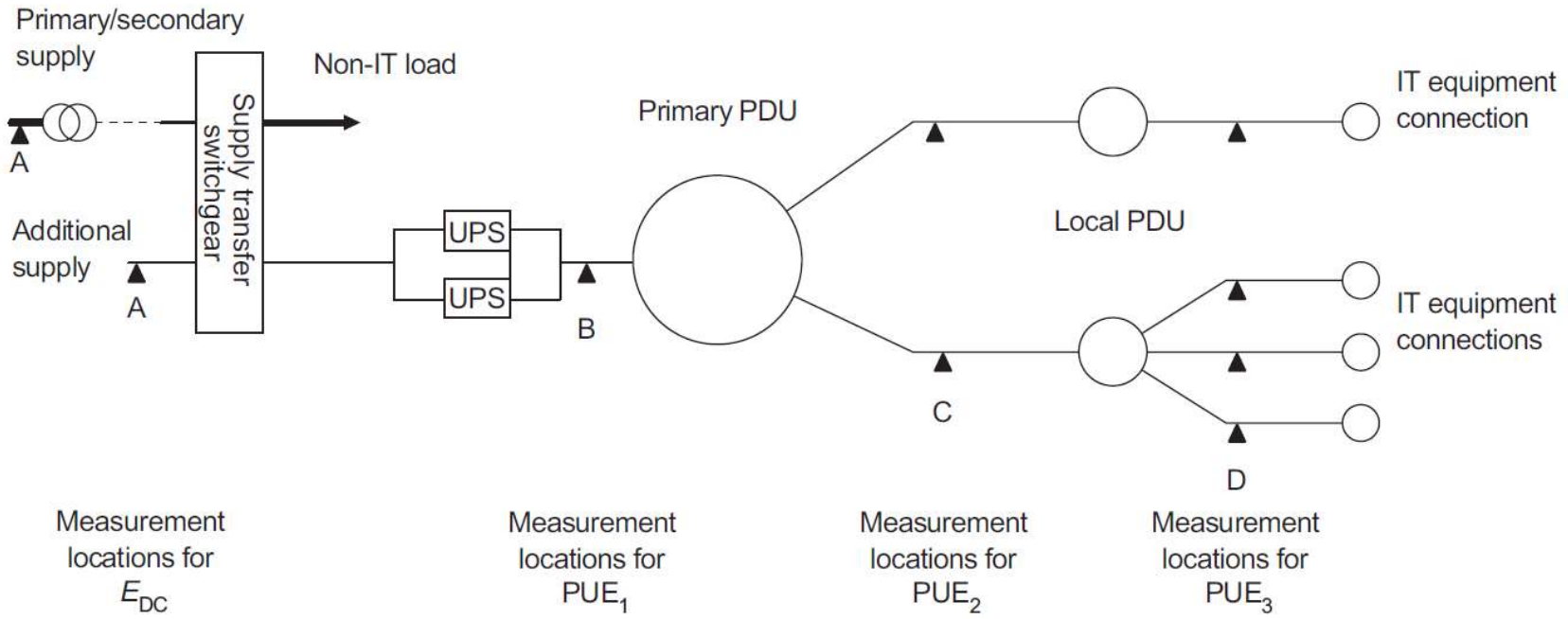
❖ PUE는 데이터센터 설비의 **에너지 효율을 정량적으로 측정**할 수 있는 측정 지표로, 데이터센터 구성 설비 중 **어떤 설비가 에너지 효율이 낮은 가를 판별**하여 개선하기 위한 **핵심 기술**임

02. 데이터센터 전력사용효율지수 (PUE; Power Usage Effectiveness) (3/5)

- PUE Category
  - Category 1 (PUE_1): basic resolution
  - Category 2 (PUE_2): intermediate resolution
  - Category 3 (PUE_3): advanced resolution
- Recommendation of use of PUE category
  - PUE > 1.5: Category 1 ~ Category 3
  - 1.2 < PUE ≤ 1.5: Category 2 or Category 3
  - PUE ≤ 1.2: Category 3
- PUE measurement frequency
  - Continuous real-time is desirable (if not applicable, justifiable & repeatable frequency)
- PUE measurement period
  - 1-year average value
  - *iPUE* for less than 1-year measurement

02. 데이터센터 전력사용효율지수 (PUE; Power Usage Effectiveness) (4/5)

❖PUE measurement location



	PUE_1	PUE_2	PUE_3
E_{IT} 측정 위치	UPS output	PDU output	IT equipment input
고려사항	Includes impact of fluctuating IT and cooling loads	Excludes impact of losses associated with PDU transformers and static switches	Excludes impact of losses associated with electrical distribution components and non-IT related devices

02. 데이터센터 전력사용효율지수 (PUE; Power Usage Effectiveness) (5/5)

❖PUE reporting

- Data centre (including the boundaries of the structure) under inspection
- PUE value
- Category

Example PUE designations	Interpretation
Data centre X, PUE_1 (2012–12–31) = 2,25	In the year 2012, the PUE value of data centre X was 2,25. It was a Category 1 PUE.
Data centre Y, PUE_1 (2013–06–30) = 1,75	In the period 2012–07–01 to 2013–06–30, the PUE value of data centre Y was 1,75. It was a Category 1 PUE.
Data centre Z, PUE_2 (2013–12–31) = 1,50	In the year 2013, the PUE value of data centre Z was 1,50. It was a Category 2 PUE.

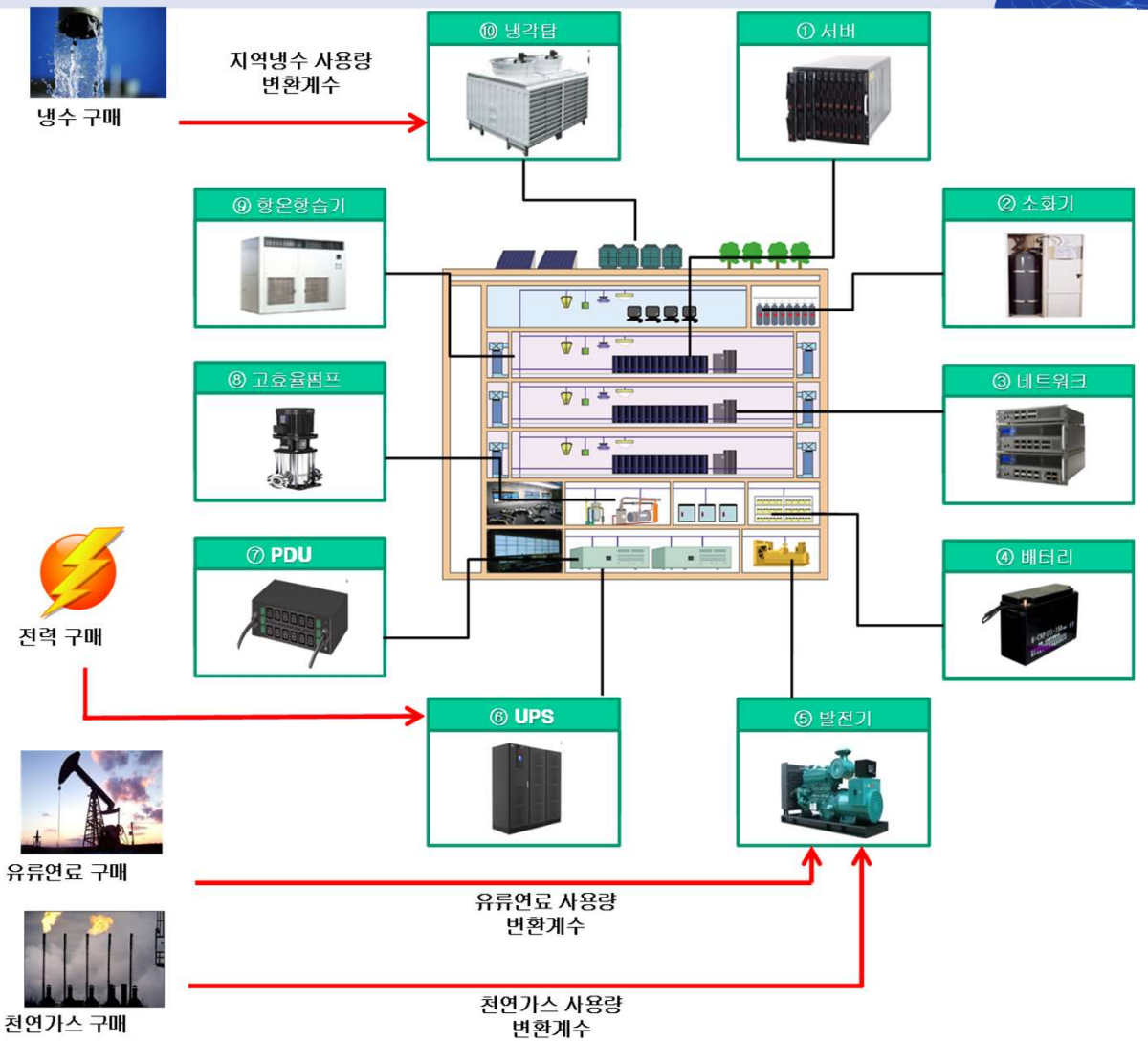
❖PUE reporting for public

- Contact information
- Data centre location information (address, county or region)
- Measurement results with Category

❖PUE supporting evidence (감사 권한 보유 기관에 제공 추가 정보)

- E_{DC} and E_{IT}
- Start and end date of measurement
- Accuracy level for measurement of electrical energy (IEC 62052, IEC 62053)
- Size of computer room, telecom room, control room spaces
- External environmental conditions (최소/최대/평균 기온, 습도, 고도)

02. Multiple Energy Sources for Data Center



02. PUE calculation with mixed energy sources

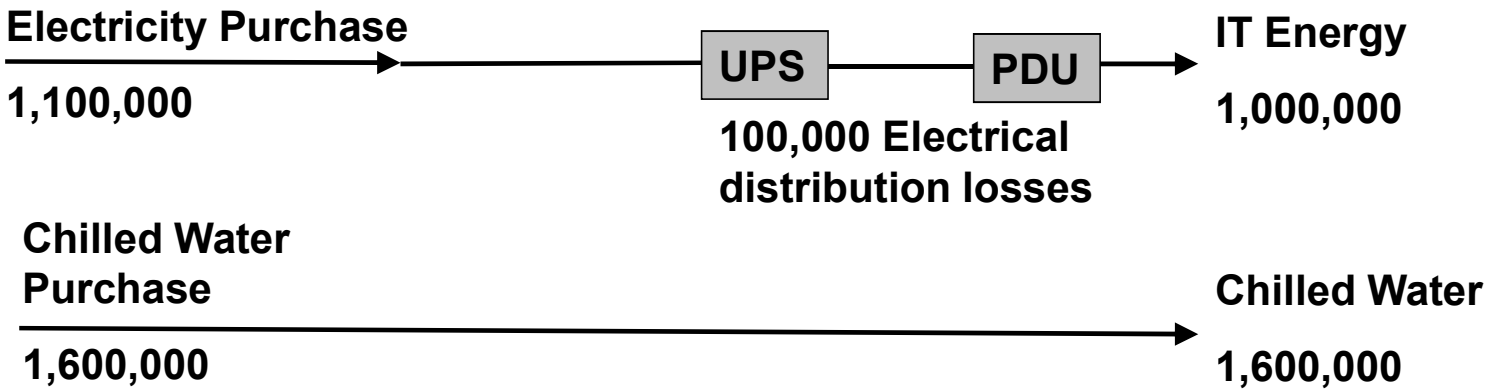
$$PUE = \frac{E_{DC}}{E_{IT}} = \frac{(Electricity\ Purchase) \times 1.0 + (Other\ Energy\ Source) \times (Conversion\ Factor)}{E_{IT}}$$

Standard energy conversion factors

Energy type	Conversion factor
District chilled water	0.4
District hot water	0.4
District steam	0.4
Fuel (for absorption type chiller)	0.35

02. PUE calculation with mixed energy sources

Case B – Electricity & Chilled Water Purchase



PUE = (1,100,000*1+1,600,000*0.4) / (1,000,000*1)
PUE = 1.74

*All units are kWh

02. Considerations for PUE Interpretation

A 센터
서울시 강남구
지상 6층

Cold weather

Water for cooling

Renewable energy

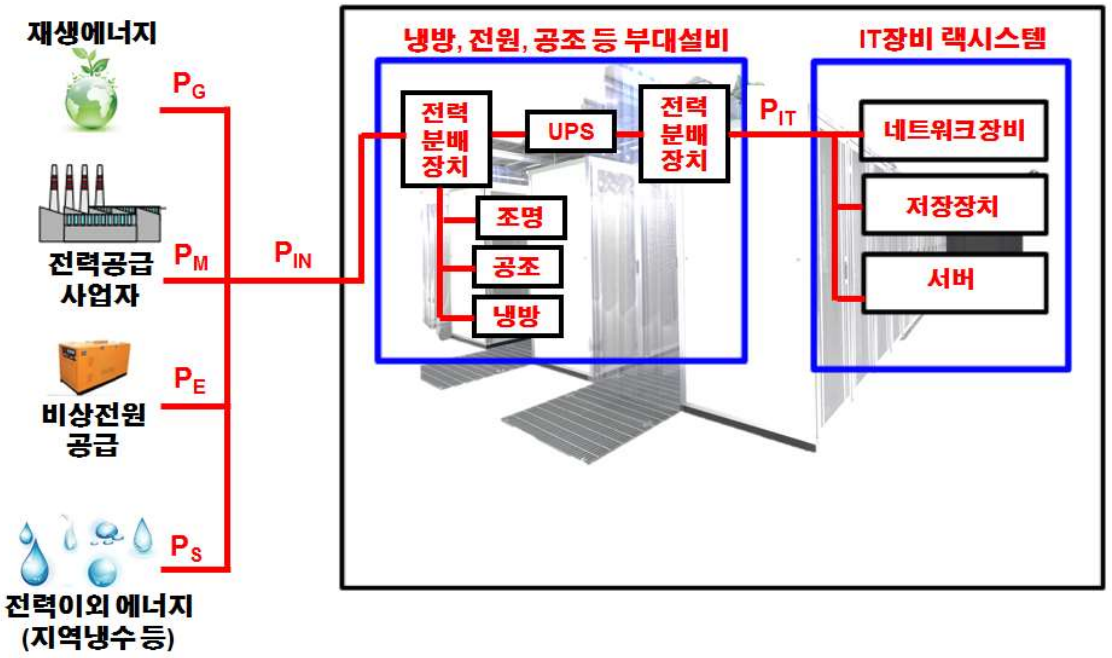
❖ PUE values should not be compared directly among data centers

02. 재생에너지 사용 효율 지표 (REF; Renewable Energy Factor) (1/2)

❖재생에너지 사용 효율 (REF; Renewable Energy Factor)

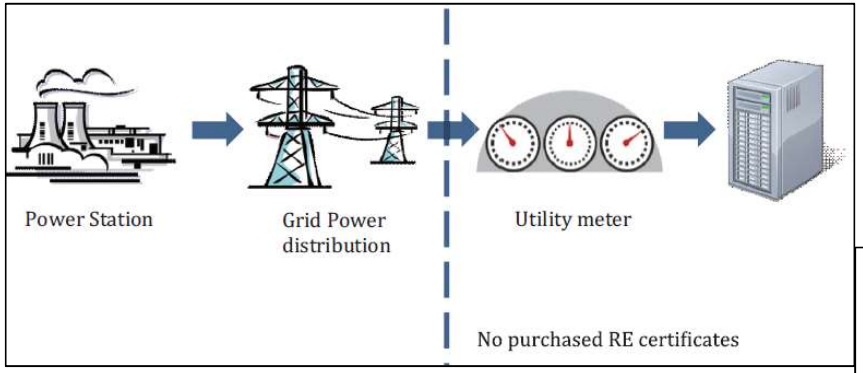
❖전력 공급자로부터 공급받는 전력 이외의 자체 생산 에너지 사용가능 (태양광 발전, 풍력 등)

- 데이터센터 전체가 공급받는 전력량의 감소를 통한 에너지 절감

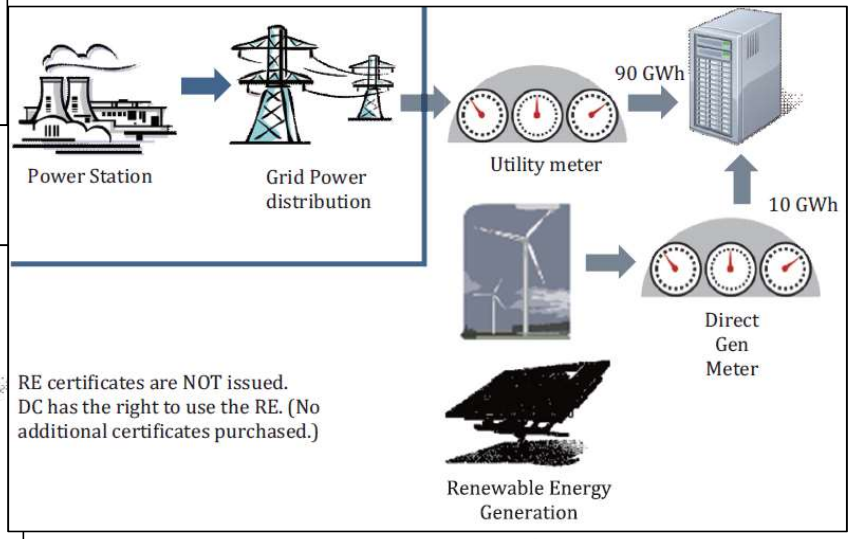


$$\text{재생에너지 사용 효율 (REF)} = \frac{\text{재생에너지 사용량 } (kWh)}{\text{데이터센터 전체에너지사용량 } (kWh)}$$

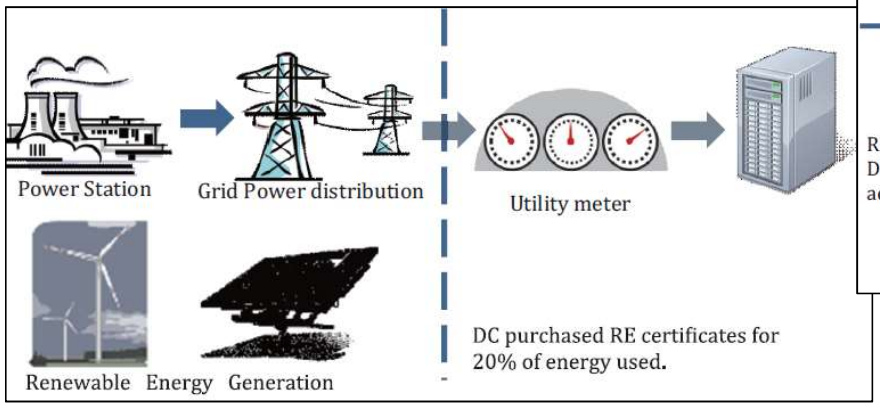
02. 재생에너지 사용 효율 지표 (REF; Renewable Energy Factor) (2/2)



$$REF = 0$$



$$REF = \frac{10}{100} = 0.1$$



$$REF = 0.2$$

02. IT 서버 효율 측정지표 ($ITEE_{SV}$) (1/2)

❖IT 서버 효율 측정 지표 ($ITEE_{SV}$; Information Technology Equipment Efficiency for Servers)

- 데이터센터 내 탑재된 IT 서버장비의 성능대비 에너지 효율을 측정하는 지표
- 서버가 사용하는 에너지 대비 성능이 높은 서버를 판정하기 위한 용도로 사용
- 서버의 신규 구매시 활용

$$ITEE_{SV} = \frac{\sum_{i=1}^{n} SMPE_i}{\sum_{i=1}^{n} SMPO_i}$$

✓ $ITEE_{SV}$: 서버의 에너지 효율
✓ $SMPE_i$: 서버 i 의 최대 성능
✓ $SMPO_i$: 서버 i의 최대 에너지 사용량 (kW)

	서버 A	서버 B
최대성능	0.03 WT	0.06 WT
최대 전력 사용량	0.1 kW	0.15 kW
$ITEE_{sv}$	0.3	0.4

에너지 사용량 대비 높은 성능

02. IT 서버 효율 측정지표 ($ITEE_{SV}$) (2/2)

❖Measuring maximum performance

- Use well-known server performance benchmark tools

서버 최대 성능 측정 방법	설명
SERT	$ITEE_{SV}$(SERT)
LINPACK	$ITEE_{SV}$(LINPACK)
APP	$ITEE_{SV}$(AAP)
SPECpower_ssj2008	$ITEE_{SV}$(SPECpower_ssj2008)

- Servers can be grouped (same specification and same benchmark tool)

❖Category level of $ITEE_{SV}$

Level	Level 1 ($ITEE_{SV1}$)	Level 2 ($ITEE_{SV}$)
Calculation method of SMPE (최대 성능)	SERT, LINPACK, APP, or SPECpower_ssj2008	SERT, LINPACK, APP, or SPECpower_ssj2008
Calculation method of SMPO (최대 전력 사용량)	Use of published data of maximum power	Measurement of the power at the maximum performance state

02. IT 서버 가동율 측정지표 ($ITEU_{SV}$)

❖IT 서버 가동율 측정 지표 ($ITEU_{SV}$; Information Technology Equipment Utilization for Servers)

- 데이터센터 내 탑재된 IT 서버장비의 가동율을 측정하는 지표
- 운용 시간이 긴 서버를 판정하기 위한 용도로 사용
- 교체 대상 서버의 판정을 위해 활용

$$ITEU_{SV}(t) = \frac{\sum_{i=1}^{N} CUS_i(t)}{N}$$

Measuring method of CUS_i	Description
WMI (Windows Management Instrument)	$ITEU_{SV}$(WMI)
SAR (System Admin Reporter in Linux/Unix)	$ITEU_{SV}$(SAR)

✓ $CUS_i(t)$ = CPU utilization ratio of server i at time t (%)
✓ N = number of servers in a data centre or in a group of servers
✓ $ITEU_{SV}(t)$ =average CPU utilization of all servers in a data centre at time t

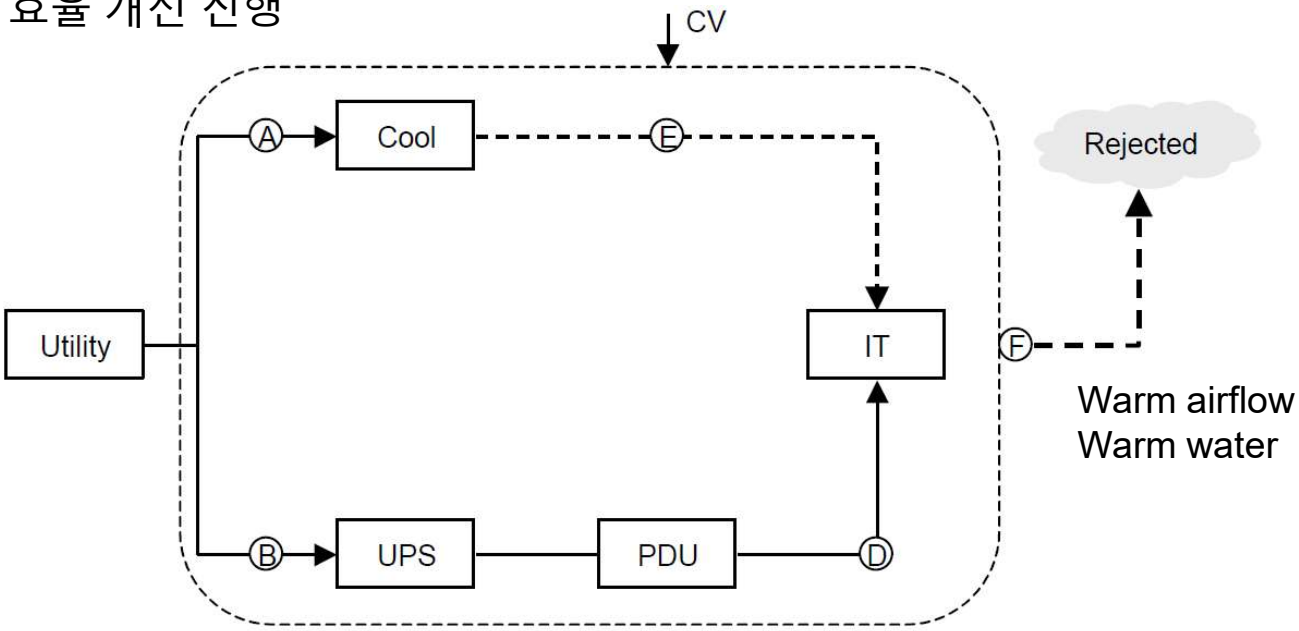
$$ITEU_{SV} = \frac{1}{a}\sum_{i=1}^{a}[ITEU_{SV}(t_0 + e \times i)]$$

✓ **a** = number of $ITEU_{SV}(t)$ measurements intervals over a year
✓ t_0 = starting time of measurement
✓ **e** = interval of measurement t_0+e ×a= *one year*

02. 에너지 재활용율 지수 (ERF; Energy Reuse Factor) (1/2)

❖에너지 재활용율 지수 (ERF; Energy Reuse Factor)

- 데이터센터에서 발생한 열을 재활용 하는 정도를 측정하는 지표
- CV (Control Volume) : 데이터센터의 인프라와 非인프라를 구분하는 가상의 구역
- CV내에서 데이터센터 효율 개선 진행



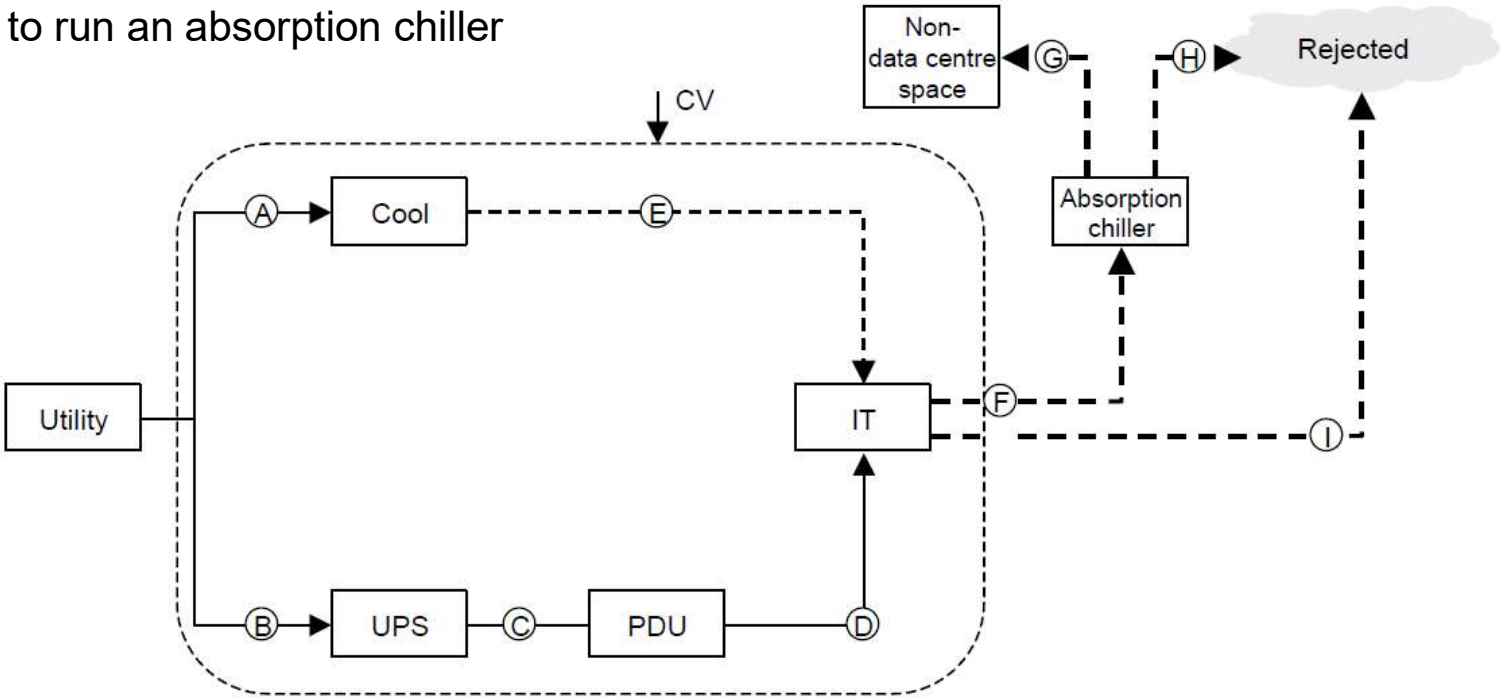
$$ERF = \frac{E_{Reuse}}{E_{DC}}$$

E_{Reuse} = the excess energy from the data center (annual) that is used outside of the data center

02. 에너지 재활용율 지수 (ERF; Energy Reuse Factor) (2/2)

❖Use of ERF

- Heat from the data center being used to heat adjacent, non-data center spaces
  - ✓ Heating water or heating air by reusing energy
- Heat to run an absorption chiller



$$PUE = \frac{A + B}{D}$$

$$ERF = \frac{F}{A + B}$$

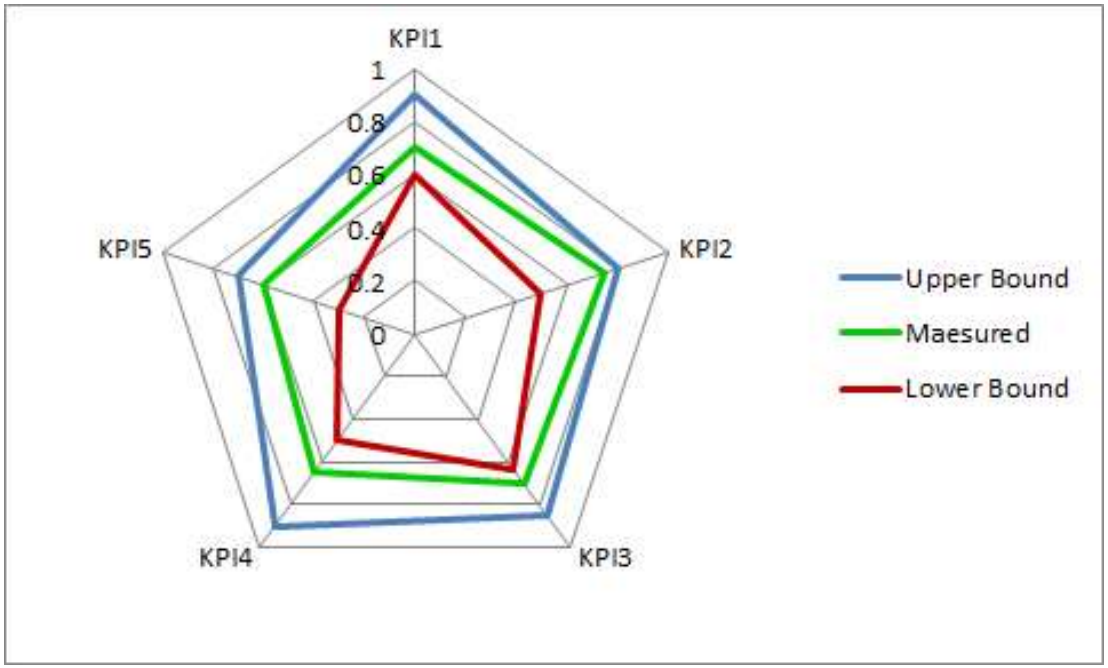
03. Holistic Approach for Data Center KPIs (1/6)

❖Many KPIs are developed/under development

- Data center overall efficiency (PUE)
- Energy efficiency of IT server equipment (ITEEsv)
- Operational utilization of IT server equipment (ITEUsv)
- Renewable energy usage to reduce carbon emission (REF)
- Amount of energy reuse (ERF)
- Cooling efficiency and performance of cooling equipment (CER & CPR)
- Water usage (WUE)
- and more

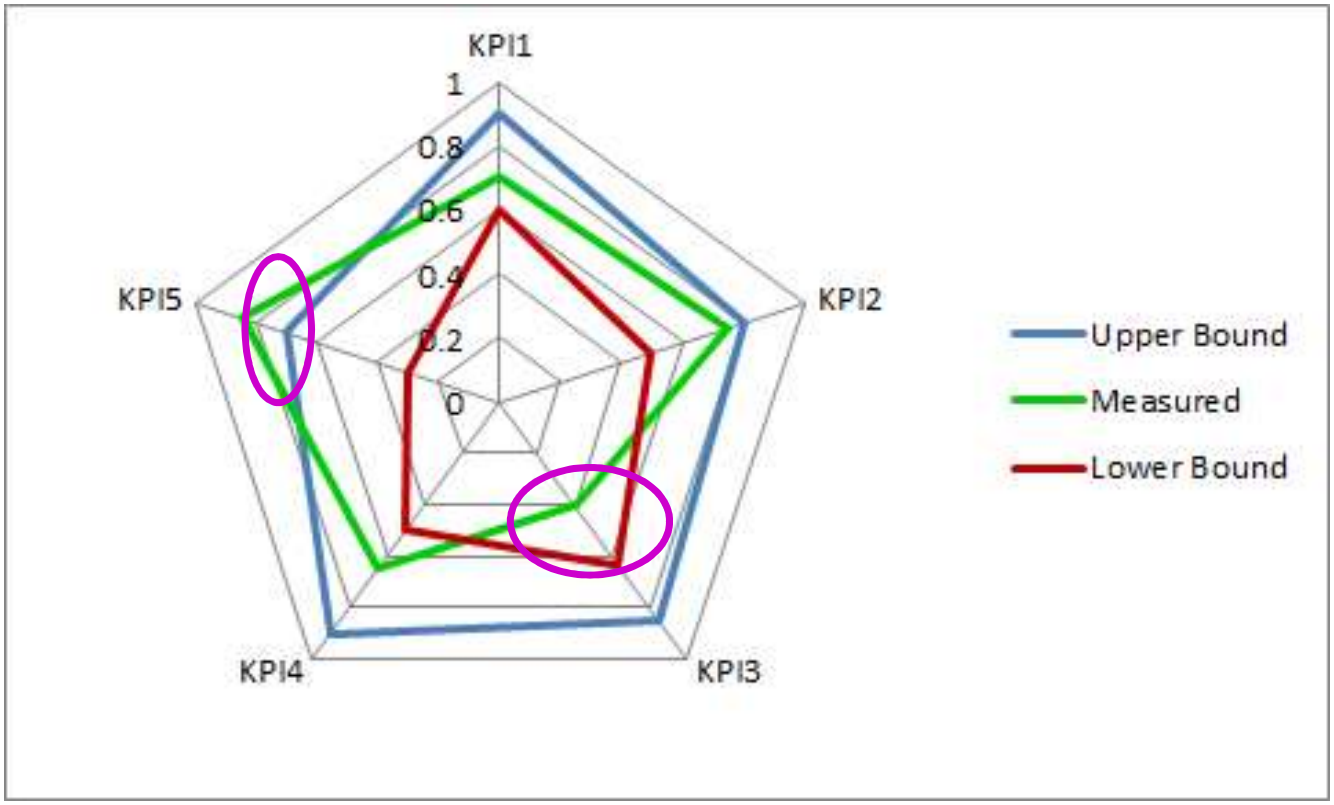
03. Holistic Approach for Data Center KPIs (2/6)

- Base methodology: radar chart
- Required information: control chart including upper bound and lower bound of the status of KPIs
  - Administrator manages a datacenter's operational status using control chart
- Value of each index: shows operational achievement of each KPI (0 to 1)



- ✓ Measured value: operational achievement of a KPIs to the Upper Bound
- ✓ Value of KPI: operational achievement (0 to 1)
- ✓ Integrated value: overall operational achievement

03. Holistic Approach for Data Center KPIs (3/6)



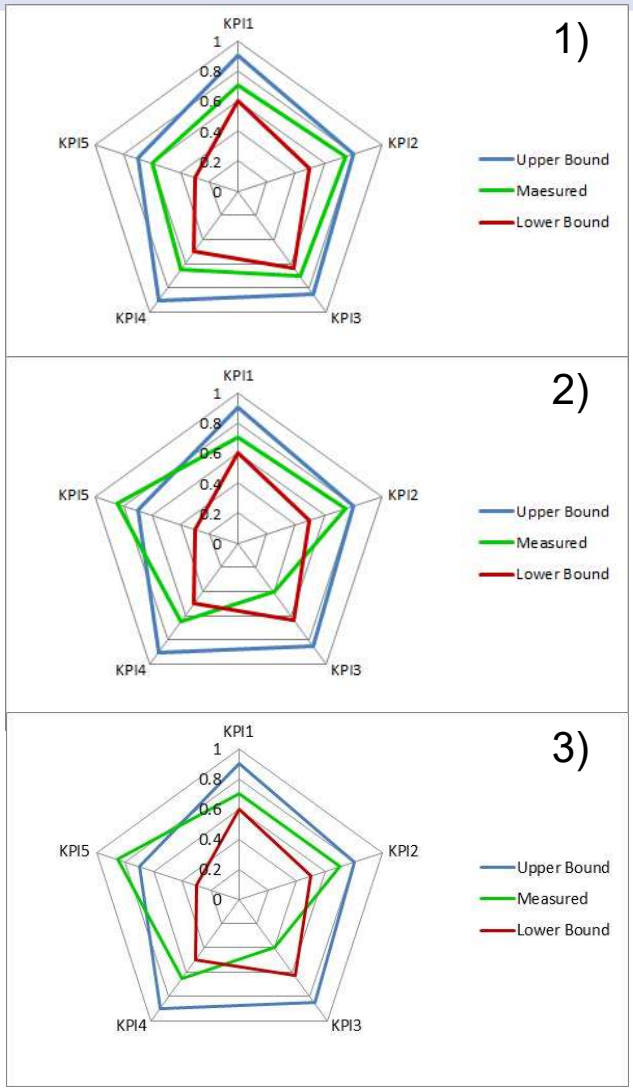
- Outlier or inlier: exceeding the upper/lower bound
- Integrated value of outlier & inlier: sum quantifies the amount of uncontrolled operation
  - Minimizing the integrated value is desirable

03. Holistic Approach for Data Center KPIs (4/6)

- Case 1) current measurement chart is within control range
  - The ratio of the area of current measurement chart to the area of upper bound chart
    - Indicate the overall operational achievement with respect to the target
  - The area of outlier / inlier are 0

- Case 2) current measurement chart has outlier / inlier of control chart
  - The ratio of the area of current measurement chart to the area of upper bound chart
  - The area of outlier / inlier quantify the amount of uncontrolled KPI operation
    - Desirable to minimize outlier / inlier

03. Holistic Approach for Data Center KPIs (5/6)



✓ Overall operational achievement: 80% (for example)

✓ Quantity for uncontrolled operation: 0%

✓ Overall operational achievement: 70%

✓ Quantity for uncontrolled operation: 3% (for example)

✓ Overall operational achievement: 80% (for example)

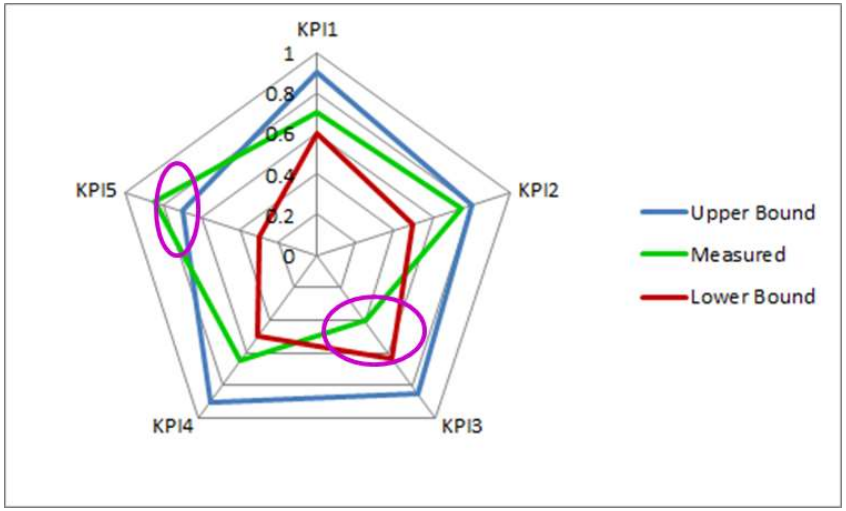
✓ Quantity for uncontrolled operation: 4% (for example)

✓ Not controlled than 2)

03. Holistic Approach for Data Center KPIs (5/6)

- AV_{ef} : average rate of non-achievement of the energy management efficiency of a data center
- x_i : operational achievement for the i_{th} KPI measurement value ($0 \leq x_i \leq 1$)
- LB_i : lower bound for the operational achievement of i_{th} KPI ($0 \leq LB_i \leq 1$)
- UB_i : upper bound for the i_{th} KPI ($0 \leq UB_i \leq 1$)

$$AV_{ef}^{5} = \frac{\sum_{i=1}^{5} (MAX(|x_i - UB_i|, |x_i - LB_i|))^2}{5}$$

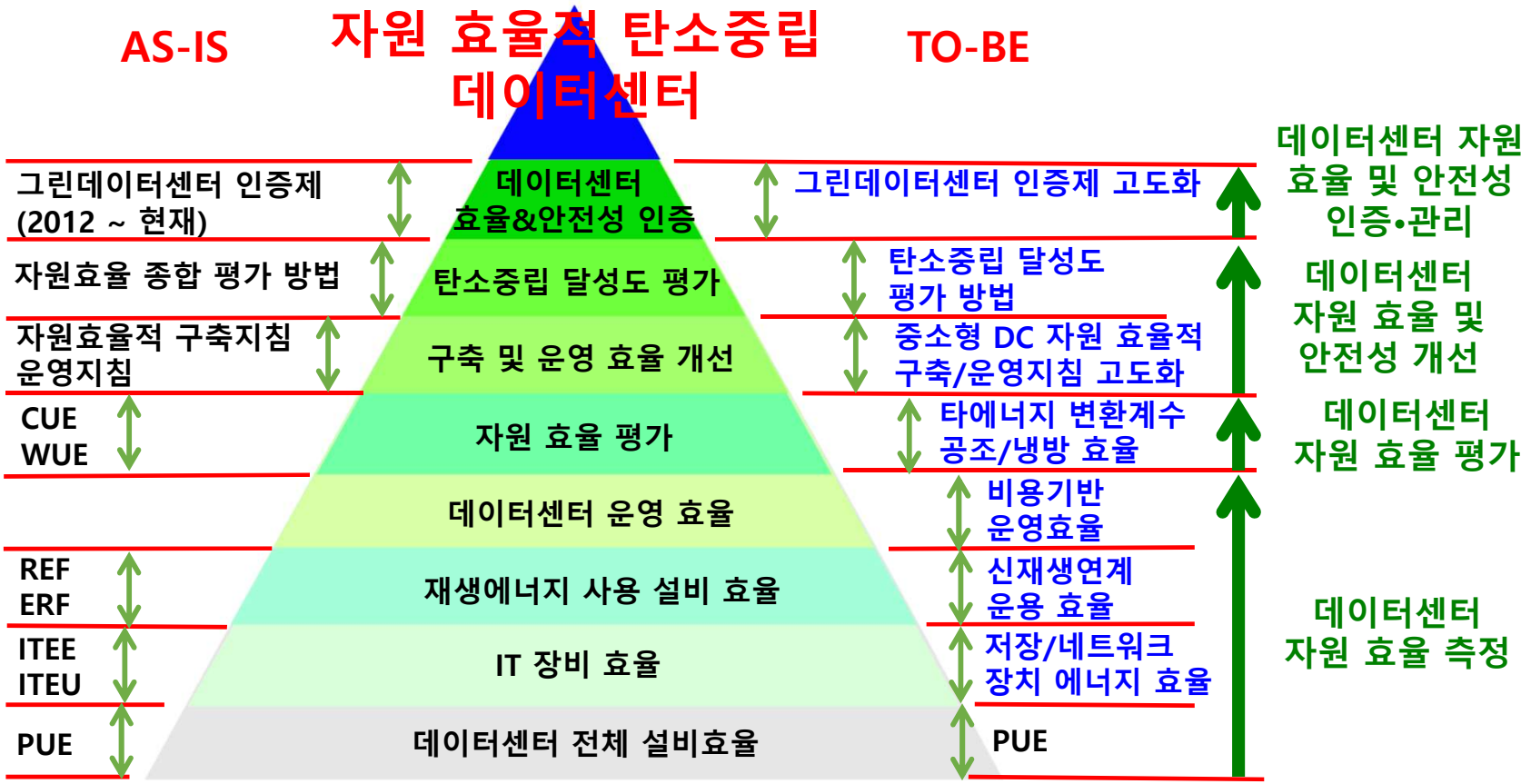


Example values of KPIs

	KPI1	KPI2	KPI3	KPI4	KPI5
Upper bound value	0.9	0.8	0.85	0.9	0.7
Measured value	0.7	0.7	0.4	0.65	0.85
Lower bound value	0.6	0.5	0.63	0.5	0.3

Average rate of non-achievement of the operational achievement of the DC : 6.75%

04. 결론


AS-IS
자원 효율적 탄소중립 데이터센터
TO-BE
그린데이터센터 인증제 (2012 ~ 현재)
데이터센터 효율&안전성 인증
그린데이터센터 인증제 고도화
데이터센터 자원 효율 및 안전성 인증•관리
자원효율 종합 평가 방법
탄소중립 달성도 평가
탄소중립 달성도 평가 방법
데이터센터 자원 효율 및 안전성 개선
자원효율적 구축지침 운영지침
구축 및 운영 효율 개선
중소형 DC 자원 효율적 구축/운영지침 고도화
CUE
WUE
자원 효율 평가
타에너지 변환계수 공조/냉방 효율
데이터센터 자원 효율 평가
데이터센터 운영 효율
비용기반 운영효율
REF
ERF
재생에너지 사용 설비 효율
신재생연계 운용 효율
ITEE
ITEU
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데이터센터 자원 효율 측정
PUE
데이터센터 전체 설비효율
PUE

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Thank you

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