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Information Technology — Data Centres — Key performance indicators —

Part 2:
Power usage effectiveness (PUE)

Titre manque

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Introduction

The global economy is now reliant on information and communication technologies and the associated generation, transmission, dissemination, computation and storage of digital data. All markets have experienced exponential growth in that data, for social, educational and business sectors and, whilst the internet backbone carries the traffic there are a wide variety of data centres at nodes and hubs within both private enterprise and shared/collocation.

The historical data generation growth rate exceeds the capacity growth rate of the information and communications technology hardware and with less than half (in 2014) of the world's population having access to an internet connection, that growth in data can only accelerate. In addition, with many governments having ‘digital agendas‘ to provide both citizens and businesses with ever faster broadband access, the very increase in network speed and capacity will, by itself, generate ever more usage (Javons Paradox). Data generation and the consequential increase in data manipulation and storage, is directly linked to increasing power consumption.

With this background it is clear that data centre growth, and power consumption in particular, is an inevitable consequence and that growth will demand increasing power consumption despite the most stringent energy efficiency strategies. This makes the need for Key Performance Indicators (KPIs) that cover the effective use of resources (including but not limited to energy) and the reduction of carbon emissions essential.

Within the ISO/IEC 30134 series, the term “*resource usage effectiveness*” is more generally used for KPIs in preference to “*resource usage efficiency*”, which is restricted to situations where the input and output parameters used to define the KPI have the same units.

In order to determine the overall resource effectiveness or efficiency of a data centre, a holistic suite of metrics is required. This International Standard specifies Power Usage Effectiveness (PUE), which has become a popular metric to determine the efficient utilisation and distribution of energy resources within a data centre.

NOTE: It is recognised that the term “efficiency” should be employed for PUE but “effectiveness” provides continuity with earlier market recognition of the term.

This International Standard is one of a series of standards for such KPIs and has been produced in accordance with ISO/IEC 30134-1, which defines common requirements for a holistic suite of KPIs for data centre resource usage effectiveness or efficiency.

At the time of publication of this International Standard the ISO/IEC 30134 series comprises the following

- ISO/IEC 30134-1,*Information Technology - Data Centres - Key Performance Indicators - Part 1: Overview and General Requirements*,
- ISO/IEC 30134-2,*Information Technology - Data Centres - Key Performance Indicators - Part 2: Power Usage Effectiveness (PUE)*,
- ISO/IEC 30134-3,*Information Technology - Data Centres - Key Performance Indicators - Part 3: Renewable Energy Factor (REF)*,
- ISO/IEC 30134-4,*Information Technology - Data Centres - Key Performance Indicators - Part 4: Equipment Energy Efficiency for Servers ($ITEE_{SV}$)*,
- ISO/IEC 30134-5,*Information Technology - Data Centres - Key Performance Indicators - Part 5: IT Equipment Utilization for Servers ($ITEU_{SV}$)*.

Additional standards in the series ISO/IEC 30134 will be developed, each describing a specific KPI for resource usage effectiveness or efficiency.

These International Standards do not specify limits or targets for any KPI and do not describe or imply, unless specifically stated, any form of aggregation of individual KPIs into a combined nor an overall KPI for data centre resource usage effectiveness or efficiency.

1 Scope

This International Standard specifies the Power Usage Effectiveness (PUE) as a Key Performance Indicator (KPI) to quantify the efficient use of energy in the form of electricity.

NOTE: It is recognised that the term “efficiency” should be employed for PUE but “effectiveness” provides continuity with earlier market recognition of the term.

This international Standard

a) defines the Power Usage Effectiveness (PUE) of a data centre,

b) introduces PUE measurement categories,

c) describes the relationship of this KPI to a data centre’s infrastructure, information technology equipment and information technology operations,

d) defines the measurement, the calculation and the reporting of the parameter,

e) provides information on the correct interpretation of the PUE.

PUE derivatives are described in Annex D.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 30134-1, *Information Technology - Data Centres - Key Performance Indicators - Part 1: Overview and General Requirements*

3 Terms, definitions, abbreviations and symbols

3.1 Terms and definitions

For the purposes of this document the definitions of ISO/IEC 30134-1 and the following apply.

3.1.1
information technology (IT) equipment energy consumption
energy consumed, measured in kilowatt hours (kWh), by equipment that is used to store, process, and transport data within the computer room, telecommunication room and control room spaces

Note 1 to entry: Examples are servers, storage equipment, and telecommunications equipment.

3.1.2
power distribution unit (PDU)
equipment that allocates or partitions power or other energy consuming equipment

3.1.3
Power Usage Effectiveness (PUE)
ratio of the data centre total energy consumption to information technology equipment energy consumption, calculated, measured or assessed across the same period.

Note 1 to entry: Sometimes the inverse value of PUE, referred to as Data Centre Infrastructure Efficiency (DCiE), is used.

3.1.4
partial Power Usage Effectiveness (pPUE)
derivative of PUE, which is the ratio of the total energy consumption within a defined boundary to the information technology equipment energy consumption

3.1.5
designed Power Usage Effectiveness (dPUE)
derivative of PUE, which is the a projected PUE determined by the design targets of the data centre

3.1.6
Interim Power Usage Effectiveness (iPUE)
derivative of PUE, which is measured over a specified time other than a year

3.1.7
total data centre energy consumption
total energy consumption for all energy types serving the data centre, measured in kWh at its boundary

Note 1 to entry: Energy measured with energy metering devices at the boundary of the data centre.

Note 2 to entry: This includes electricity, natural gas and district utilities such as supplied chilled water or condenser water.

3.2 Abbreviations

For the purposes of this document the abbreviations of ISO/IEC 30134-1 and the following apply:

CRAC	Computer Room Air Conditioner units
CRAH	Computer Room Air Handler units
dPUE	designed Power Usage Effectiveness
DX	Direct Expansion
iPUE	interimPower Usage Effectiveness
IT	information technology
PDU	Power Distribution Unit
pPUE	partial Power Usage Effectiveness
PUE	Power Usage Effectiveness
r.m.s	root mean square
ROI	return on investment
UPS	Uninterruptible Power Supply

3.3 Symbols

For the purposes of this document the following symbols apply:

E_{DC}	total data centre energy consumption (annual)
E_{IT}	IT equipment energy consumption (annual)

4 Applicable area of the data centre

Power Usage Effectiveness (PUE) as specified in this standard

a) is associated with the data centre infrastructure within its boundaries only,

b) describes the infrastructures energy efficiency relative to facilities with given environmental conditions, IT load characteristics, availability requirements, maintenance, and security requirement,

c) illustrates the energy allocation of a data centre,

d) measures the relationship between the total data centre energy consumed and the IT equipment energy consumed.

When viewed in the proper context, PUE provides effective guidance and useful insight into the design of efficient power and cooling architectures, the deployment of equipment within those architectures, and the operation of that equipment.

PUE provides a means to determine

1) opportunities for the improvement of the operational efficiency of a data centre,

2) the improvement of the designs and processes of a data centre over time,

3) a design target or goal for new data centres, which includes the anticipated IT load range.

PUE does not take into account the

- energy efficiency of the IT load, its utilization, or productivity,
- impact of on-site electricity generation,
- efficiency of other resources such as human resource, space or water,
- use of renewable energy resources or accounts for re-use of waste by-products, such as heat.

PUE is not a

- data centre productivity metric,
- a standalone, comprehensive resource efficiency metric.

Derivatives of PUE which are useful in certain circumstances as described in Annex D.PUE should not be used to compare different data centres.

5 Determination of Power Usage Effectiveness (PUE)

PUE is defined as:

$$PUE = \frac{E_{DC}}{E_{IT}} \tag{1}$$

where

E_{DC} = total data centre energy consumption (annual)

E_{IT} = IT equipment energy consumption (annual)

By definition, the calculated PUE is always greater than 1.

Where the only energy source is from the electrical utility, then E_{DC} is determined by the energy measured at the utility meter. PUE may be applied in mixed use buildings that allow of the differentiation between the energy used for the data centre and that for other functions. Alternatively, the derivative partial PUE (pPUE) may be applied (see Annex D).

E_{IT} includes but is not limited to

a) IT equipment (e.g. storage, processing and transport equipment),

b) supplemental equipment (e.g. keyboard/video/mouse (KVM) switches, monitors, and work-stations/laptops used to monitor, manage, and/or control the data centre).

E_{DC} includes E_{IT} plus all the energy that is consumed to support the following infrastructures

1) power delivery - including UPS systems, switchgear, generators, power distribution units (PDUs), batteries, and distribution losses external to the IT equipment,

2) cooling system - including chillers, cooling towers, pumps, computer room air handling units (CRAHs), computer room air conditioning units (CRACs), and direct expansion air handler (DX) units;

3) others including data centre lighting, elevator, security system, and fire suppression system.

6 Measurement of Power Usage Effectiveness

6.1 Measuring energy consumption

6.1.1 General

In order to calculate PUE, it is necessary to measure E_{DC} and E_{IT}. This is not a trivial task, especially within existing data centres which may require the installation of instrumentation to collect the data.

NOTE: Although measurement of E_{DC} and E_{IT} are adequate to calculate PUE for the defined equipment and supporting infrastructure, more monitoring data of logical subsets is necessary to assess areas for potential improvements and to evaluate the resulting improvements to PUE across the data centre.

6.1.2 Measurement period and frequency

The calculation of PUE requires the recording and documenting of E_{DC} and E_{IT} over a coincident period of twelve months. This standard does not specify the frequency of measurements of E_{DC} and E_{IT}, since PUE is calculated on an annual timeframe. However, the frequency of measurement employed will define the timing of subsequent PUE calculations on a rolling annual basis.

6.1.3 Meter and measurement requirements

Measurement of E_{DC} and E_{IT} shall be undertaken using either

a) watt meters with the capability to report energy usage

or

b) kilowatt-hour (kWh) meters that report the actual energy usage (true r.m.s), via the simultaneous measurement of the voltage, current, and power factor over time.

NOTE: Kilovolt-ampere (kVA), the product of voltage and current, is not an acceptable measurement. Though the product of volts and amperes mathematically results in watts, the actual energy consumption is determined by integrating a power factor corrected value of volts and amperes. The frequency, phase variance, and load reaction causes energy calculation difference between apparent energy and actual energy consumption. The error is inherently significant when power delivery includes alternating current (AC). Kilovolt-ampere (kVA) measurements may be used for other functions in the data centre, however, kVA is insufficient for efficiency measurements.

6.2 Categories of Power Usage Effectiveness

6.2.1 General

Three categories of PUE are defined:

a) Category 1 (PUE_1), which provides a basic level of resolution of energy performance data;

b) Category 2 (PUE_2), which provides an intermediate level of resolution of energy performance data;

c) Category 3 (PUE_3), which provides an advanced level of resolution of energy performance data.

The higher categories provide progressively

1) more accurate measurements of energy usage (as the measurements are made closer to the devices that consume the energy),

2) greater scope for energy efficiency improvements.

Table 1 provides a summary of the locations for the measurement of IT equipment energy consumption associated with each category. In all cases, the total data centre energy consumption is measured from the utility service entrance that feeds all of the electrical and mechanical equipment used to power cool and condition the data centre.

To properly assess PUE, it is critical to account for all systems that support the data centre, in addition to the environmental conditions, reliability, security and availability requirements independent of which PUE measurement Category is chosen (see ISO/IEC 30134-1:201X, Annex B).

Table 1 - PUE categories

	PUE_1	PUE_2	PUE_3
Location of IT equipment energy consumption measurement	UPS output[a]	PDU output[b]	IT equipment input[c]

[a] includes impact of fluctuating IT and cooling loads.

[b] excludes impact of losses associated with PDU transformers and static switches.

[c] excludes impact of losses associated with electrical distribution components and non-IT related devices.

6.2.2 Category 1 (PUE_1) – basic resolution

The IT load is measured at the output of the UPS (or equivalent) equipment and may be read

a) from the UPS front panel,

b) through a meter on the UPS output,

c) in cases of multiple UPS modules through a single meter on the common UPS output bus.

The incoming energy is measured from the utility service entrance that feeds all of the electrical and mechanical equipment used to power, cool, and condition the data centre.

If UPS or an equivalent power failure ride through or conditioning unit is not available, other categories may apply.

6.2.3 Category 2 (PUE_2) – intermediate resolution

The IT load is measured at the output of the PDUs within the data centre and is typically read from the PDU front panel or through a meter on the secondary of the PDU transformer. Individual branch circuit measurement is also acceptable for Category 2.

6.2.4 Category 3 (PUE_3) – advanced resolution

The IT load is measured at the IT equipment within the data centre. This can be achieved either by metered rack (e.g. plug strips) that monitors aggregate set of IT systems or at the receptacle level or by the IT device itself. Note that non-IT loads shall be excluded from these measurements.

6.2.5 Measurement placement

Each Category enables progressively improved accuracy of measurement of energy usage, as the measurements are taken closer to the IT devises that consume energy.

7 Reporting of Power Usage Effectiveness

7.1 Requirements

7.1.1 Standard construct for communicating PUE data

In order for a reported PUE to be meaningful, the reporting organization shall provide the following information

a) the data centre (including the boundaries of the structure) under inspection,
b) the PUE value,
c) the category,
d) the termination date of the period of measurement.

The PUE category shall be provided as a subscript to the name of the metric, e.g. PUE_2 for a category 2 value.

The PUE category should be appropriate to the expected value of PUE:

1) PUE > 1,5: Category 1 to Category 3;

2) 1,5 > PUE > 1,2: Category 2 or Category 3;

3) 1,2 > PUE: Category 3.

7.1.2 Example of reporting PUE values

Given the construct above, Table 2 provides examples of specific PUE designations and their interpretation.

Table 2 – Examples of PUE reporting

Sample 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 2012-07-01to 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) = 1,5	In the year 2013 the PUE value of data centre Z was 1,5. It was a category 2 PUE.

7.2 Supporting data for publicly reported PUE data

7.2.1 Required information

The following data shall be provided, when publicly reporting PUE data

a) contact information;

NOTE: Only the organization's name or contact should be displayed in public inquiries.

b) data centre location information (address, county or region),

NOTE: Only state or local region information should be displayed in public inquiries.

c) measurement results: PUE with appropriate nomenclature including category designation,

d) measurement completion date: completion date identifies the annual period of the assessment.

7.2.2 Required supporting evidence

Information on the data centre which shall be available upon request includes

a) organization's name, contact information and regional environmental description,

b) measurement results: PUE with appropriate nomenclature,

c) E_{DC} and E_{IT},

d) start and measurement(s) dates the assessments were completed,

e) the accuracy level (IEC 62052 series and IEC 62053 series provide a reference for measurement of electrical energy),

f) report on the size of computer room, telecom room and control room spaces,

g) external environmental conditions consisting of minimum, maximum and average temperature, humidity and altitude.

7.2.3 Optional data

The following information may be useful in tracking the PUE trends within a data centre

a) data centre size (facility square meters),

b) total data centre design load for the facility (e.g. 10,2 MW),

c) name of the possible auditor and method used for auditing,