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Information technology - Data centre facilities and infrastructures - Part 4-2: Power Usage Effectiveness

Technologie de l'information - Installation et infrastructures de centres de traitement de données - Partie 4-2 : Efficacité de l'utilisation de l'énergie

Informationstechnik - Einrichtungen und Infrastrukturen von Rechenzentren - Teil 4-2: Kennzahl zur eingesetzten Energie

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TÜRK STANDARDI

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Milli Önsöz

Bu standard, CLC/TC 215 "Electrotechnical aspects of telecommunication equipment - Telekomünikasyon ekipmanlarının elektroteknik yönleri" Teknik Komitesi tarafından hazırlanmış, CENELEC tarafından 10.10.2016 tarihinde onaylanmış ve Türk Standardları Enstitüsü Teknik Kurulu'nun 20.03.2017 tarihli toplantısında Türk Standardı olarak kabul edilerek yayımına karar verilmiştir.

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Information technology - Data centre facilities and infrastructures - Part 4-2: Power Usage Effectiveness

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European foreword

This document (EN 50600-4-2:2016) has been prepared by CLC/TC 215 “Electrotechnical aspects of telecommunication equipment”.

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	[2017-07-10]
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	[2019-10-10]

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This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

Regarding the various parts in the EN 50600 series, see the Introduction.

Introduction

The unrestricted access to internet-based information demanded by the information society has led to an exponential growth of both internet traffic and the volume of stored/retrieved data. Data centres are housing and supporting the information technology and network telecommunications equipment for data processing, data storage and data transport. They are required both by network operators (delivering those services to customer premises) and by enterprises within those customer premises.

Data centres need to provide modular, scalable and flexible facilities and infrastructures to easily accommodate the rapidly changing requirements of the market. In addition, energy consumption of data centres has become critical both from an environmental point of view (reduction of carbon footprint) and with respect to economic considerations (cost of energy) for the data centre operator.

The implementation of data centres varies in terms of:

a) purpose (enterprise, co-location, co-hosting, or network operator facilities);

b) security level;

c) physical size;

d) accommodation (mobile, temporary and permanent constructions).

The needs of data centres also vary in terms of availability of service, the provision of security and the objectives for energy efficiency. These needs and objectives influence the design of data centres in terms of building construction, power distribution, environmental control and physical security. Effective management and operational information is required to monitor achievement of the defined needs and objectives.

This series of European Standards specifies requirements and recommendations to support the various parties involved in the design, planning, procurement, integration, installation, operation and maintenance of facilities and infrastructures within data centres. These parties include:

1) owners, facility managers, ICT managers, project managers, main contractors;

2) architects, consultants, building designers and builders, system and installation designers;

3) facility and infrastructure integrators, suppliers of equipment;

4) installers, maintainers.

At the time of publication of this European Standard, the EN 50600 series will comprise the following standards and documents:

— EN 50600-1, *Information technology — Data centre facilities and infrastructures — Part 1: General concepts*;

— EN 50600-2-1, *Information technology — Data centre facilities and infrastructures — Part 2-1: Building construction*;

— EN 50600-2-2, *Information technology — Data centre facilities and infrastructures — Part 2-2: Power distribution*;

— EN 50600-2-3, *Information technology — Data centre facilities and infrastructures — Part 2-3: Environmental control*;

— EN 50600-2-4, *Information technology — Data centre facilities and infrastructures — Part 2-4: Telecommunications cabling infrastructure*;

— EN 50600-2-5, *Information technology — Data centre facilities and infrastructures — Part 2-5: Security systems*;

— EN 50600-3-1, *Information technology — Data centre facilities and infrastructures — Part 3-1: Management and operational information*;

— EN 50600-4-1, *Information technology — Data centre facilities and infrastructures — Part 4-1: Overview of and general requirements for key performance indicators*;

— EN 50600-4-2, *Information technology — Data centre facilities and infrastructures — Part 4-2: Power Usage Effectiveness*;

— EN 50600-4-3, *Information technology — Data centre facilities and infrastructures — Part 4-3: Renewable Energy Factor*;

— CLC/TR 50600-99-1, *Information technology — Data centre facilities and infrastructures — Part 99-1: Recommended practices for energy management*.

The inter-relationship of the standards within the EN 50600 series is shown in Figure 1.

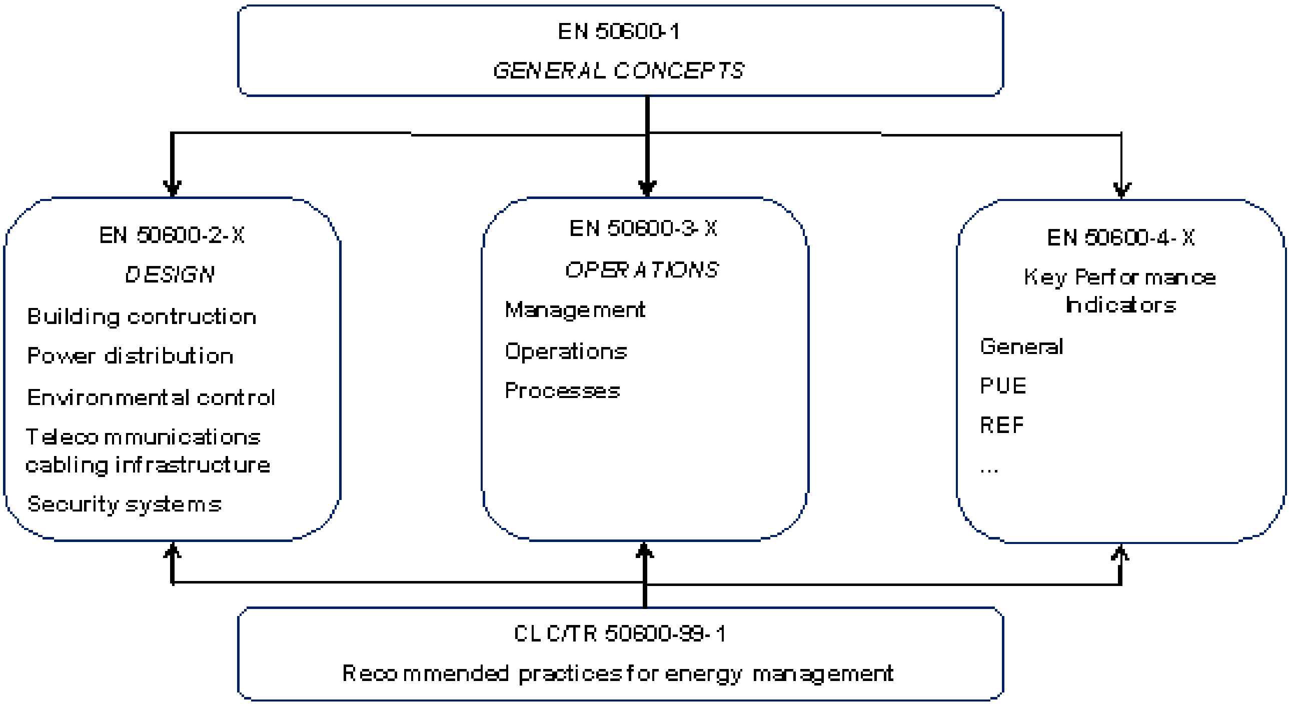


Figure 1 — Schematic relationship between the EN 50600 series of documents

EN 50600-2-X standards specify requirements and recommendations for particular facilities and infrastructures to support the relevant classification for “availability”, “physical security” and “energy efficiency enablement” selected from EN 50600-1.

EN 50600-3-X documents specify requirements and recommendations for data centre operations, processes and management.

EN 50600-4-X documents specify requirements and recommendations for key performance indicators (KPIs) used to assess and improve the resource usage efficiency and effectiveness, respectively, of a data centre.

In today’s digital society 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 that cover the effective use of resources (including but not limited to energy) and the reduction of CO_2 emissions essential.

NOTE Within the EN 50600–4-X 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 enable the optimum resource effectiveness of data centres a suite of effective KPIs is needed to measure and report on resources consumed in order to develop an improvement roadmap.

These standards are intended to accelerate the provision of operational infrastructures with improved resource usage effectiveness.

This European Standard specifies Power Usage Effectiveness (PUE), which has become a popular metric to determine the efficient utilization and distribution of energy resources within a data centre.

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

Additional standards in the EN 50600-4-X series will be developed, each describing a specific KPI for resource usage effectiveness or efficiency.

The EN 50600-4-X series does not specify limits or targets for any KPI and does 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.

This European Standard is intended for use by and collaboration between data centre managers, facility managers, ICT managers, and main contractors.

This series of European Standards does not address the selection of information technology and network telecommunications equipment, software and associated configuration issues.

1 Scope

This European 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 See the Note 1 to entry in Definition 3.1.3.

This European 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 C.

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.

EN 50600-1, *Information technology — Data centre facilities and infrastructures — Part 1: General concepts*

EN 50600-4-1:2016, *Information technology — Data centre facilities and infrastructures — Part 4-1: Overview of and general requirements for key performance indicators*

EN 62052 (all parts), *Electricity metering equipment (AC) — General requirements, tests and test conditions (IEC 62052 series)*

EN 62053 (all parts), *Electricity metering equipment (a.c.) — Particular requirements (IEC 62053 series)*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 50600-1 and the following apply.

3.1.1
information technology equipment energy consumption
energy consumed, measured in kilowatt-hour (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
equipment that allocates or partitions power for other energy consuming equipment

3.1.3
Power Usage Effectiveness
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: It is recognized that the term “efficiency” should be employed for PUE but “effectiveness” provides continuity with earlier market recognition of the term.

Note 2 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
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
derivative of PUE, which is a projected PUE determined by the design targets of the data centre

3.1.6
interim Power Usage Effectiveness
derivative of PUE, which is measured over a specified time other than a year

3.1.7
total annual 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 is measured with energy metering devices at the boundary of the data centre or points of generation within the boundary.

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

Note 3 to entry: Total annual energy includes supporting infrastructure.

3.2 Abbreviations

For the purposes of this document, the abbreviations given in EN 50600-4-1 and the following apply.

CRAC	Computer Room Air Conditioner/Conditioning
CRAH	Computer Room Air Handler units
dPUE	designed Power Usage Effectiveness
DX	Direct Expansion
idPUE	interim designed Power Usage Effectiveness
iPUE	interim Power Usage Effectiveness
PDU	Power Distribution Unit
pPUE	partial Power Usage Effectiveness
PUE	Power Usage Effectiveness
r.m.s.	root mean square
ROI	Return On Investment

3.3 Symbols

For the purposes of this document the following symbols apply.

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

E_{IT} IT equipment energy consumption (annual) in kWh

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 infrastructure's 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.

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 across the anticipated IT load range.

PUE does not take into account the:

— energy efficiency of the IT load, its utilization or productivity;

— efficiency 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 are described in Annex C. PUE should not be used to compare different data centres.

5 Determination of Power Usage Effectiveness

5.1 General

PUE is defined as:

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

where

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

E_{IT} = IT equipment energy consumption (annual) in kWh.

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 location of 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 C).

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 workstations/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 detection/suppression system.

5.2 Total data centre energy consumption

The data centre under consideration shall be viewed at as a system defined by interfaces through which energy flows.

The following forms of energy shall be metered at the interfaces:

a) electricity;

b) gaseous fuel;

c) fluid fuel;

d) fluids for cooling (comprising water usage when returned fluid and not evaporated).

The following forms of energy are not required be metered at these interfaces:

1) air for cooling;

2) water from natural sources (i.e. requiring no energy consumption in its provision).

All forms of electrical energy at interfaces shall be metered to kWh. If any of the required forms of energy are not accounted for at the interfaces then E_{DC} is not determined and PUE cannot be calculated.

Gaseous or liquid fuels shall be metered in kWh or converted into kWh using the heat of combustion values for the fuel used. Where information on combustion values is not available the following values shall be applied:

— diesel: 9,9 kWh/l;

— gas: 10,5 kWh/m^3;

— hydrogen: 38,9 kWh/kg;

— bioethanol: 6 kWh/l.

The energy contribution of fluids for cooling shall be measured using heat meters (providing information on flow rate and differential temperature) and multiplied by the relevant conversion factor of the system used to provide the fluid used.

If technical subsystems, e.g. on-site co-generation of heat and electricity, have meters at their output, they are considered external to the system. If technical subsystems have meters at their input or only have partial metering at their outputs, they are considered internal to the system.

5.3 Total data centre energy consumption in mixed-use buildings

The total data centre energy consumption for data centres in mixed-used buildings shall be calculated on the energy use of the data centre as system only if metering of all shared technical subsystems allows separation of energy usage.

If energy use of shared technical subsystems cannot be separated, total data centre energy usage shall comprise the building in total. The impact on PUE should be counteracted by implementing the necessary meters for separation.

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 can require the installation of instrumentation to collect the data.

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 12 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 determine 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 cause 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 can 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 EN 50600-4-1:2016, Annex A).

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.

If UPS or an equivalent power failure ride through or conditioning unit is not available, other categories can 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 PDU output (with or without transformer, the measurement point is then after the 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 a metered rack (e.g. plug strips) that monitors an 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 IT equipment energy consumption, as the measurements are taken closer to the IT devices 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.

7.1.2 Example of reporting PUE values

Using the construct of 7.1.1, 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 2012–07–01 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.

7.1.3 Data for public reporting PUE

7.1.3.1 Required information

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

a) contact information - only the organization's name or contact should be displayed in public inquiries;

b) data centre location information (address, county or region) - only state or local region information should be displayed in public inquiries;

c) measurement results - PUE with appropriate nomenclature including category designation.

7.1.3.2 Supporting evidence (where required by authorities having jurisdiction)

Information on the data centre which shall be available upon request as a minimum 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 (the EN 62052 series and EN 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 Recommendations

7.2.1 Use of PUE Category

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

1) *PUE* > 1,50: Category 1 to Category 3;

2) 1,50 > *PUE* > 1,20: Category 2 or Category 3;

3) *PUE* < 1,20: Category 3.

7.2.2 Trend tracking data

The following information can 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,

d) data centre contact information,

e) data centre environmental conditions,

f) data centre’s mission,

g) data centre archetype percentages (e.g. 20 % web hosting, 80 % email),

h) data centre commissioned date,

i) numbers of servers, routers, and storage devices,

j) average and peak server CPU utilization,

k) percentage of servers using virtualization,

l) average age of IT equipment by type,

m) average age of facility equipment by type (cooling and power distribution equipment),

n) data centre availability objectives (see EN 50600-4-1:2016, Annex A),

o) cooling and air-handling details.

NOTE Other KPIs within the EN 50600–4-X series can assist in the recording of the above information.

Annex A
(normative)

Energy measurements

A.1 Measuring energy and calculating Power Usage Effectiveness

In Figure A.1, total data centre energy consumption is measured at or near the data centre's utility meter(s) to accurately reflect the energy entering the data centre (see 5.2 for other energy sources) in order that the measurement represents the total energy consumed in the data centre.

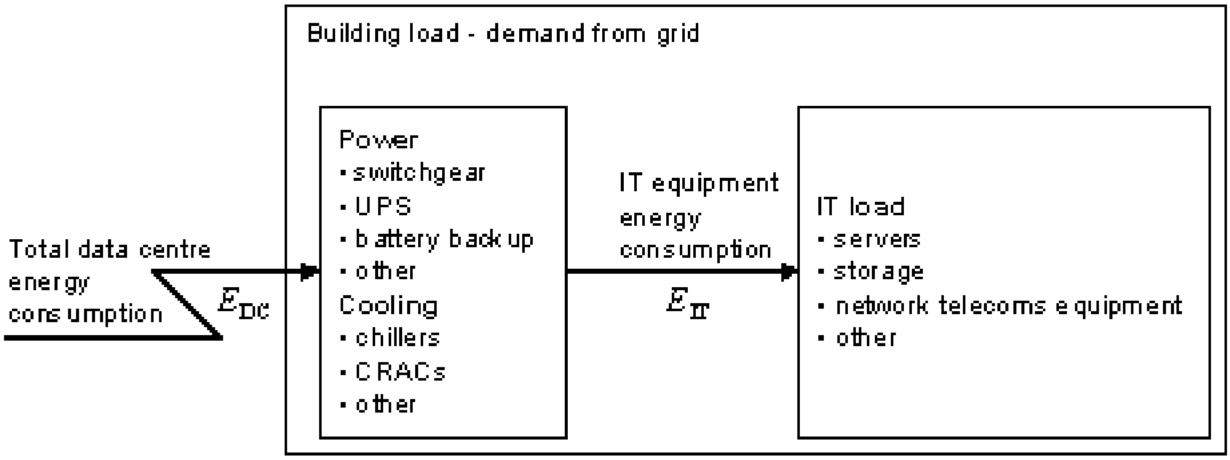


Figure A.1 — Schematic of PUE calculation from measurements

Only the data centre portion of a facility's utility consumption meter relevant to the data centre shall be measured, since including in the calculation any energy that is not intended to be consumed in the data centre would result in a non-compliant PUE calculation. For example, if a data centre resides in an office building, the total energy drawn from the utility will be the sum of the total facility energy consumption for the data centre and the total energy consumed by the non-data centre offices in the building. In this case, the data centre administrator shall measure and subtract the amount of energy being consumed by the non-data centre offices in order to calculate an accurate PUE.

A.2 Measurement locations

Figure A.2 shows measurement points to support the determination of E_{DC}. E_{DC} is measured after the utility feed at the utility metering point (i.e. point A). This measurement is consistent across all Categories. The additional measurement points shown in Figure A.2 relate to the three PUE Categories. The measurement points to allow determination of Category 1 PUE (PUE_1), Category 2 PUE (PUE_2) and Category 3 PUE (PUE_3), are indicated by B, C and D respectively.

NOTE The measurement points do not correspond to granularity level 1 of EN 50600–2-2:2014.

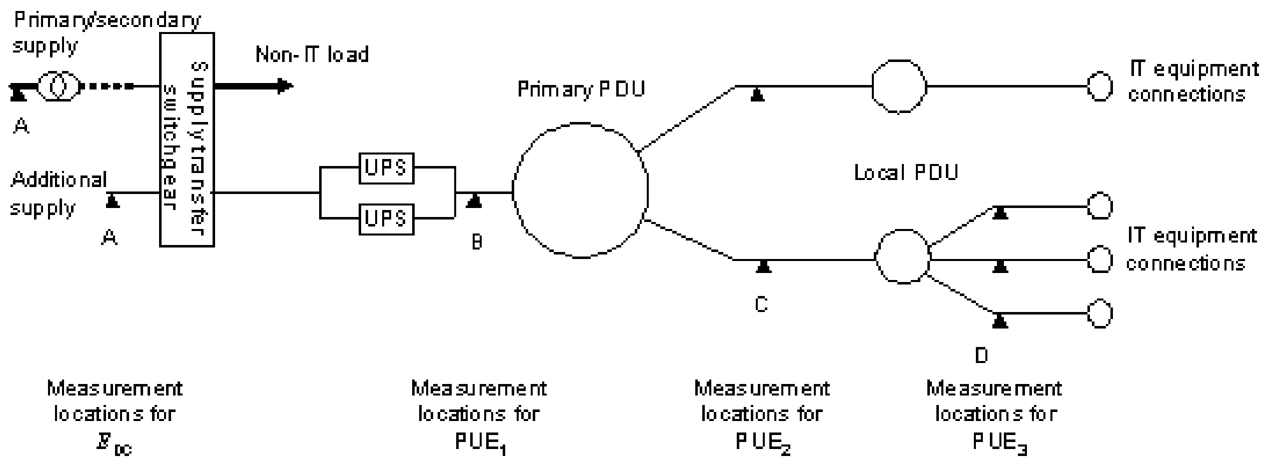


Figure A.2 — Monitoring and measurement points

Monitoring energy consumption involves many aspects that can prevent it from being easy and straightforward for the data centre operator. Costs can be quite high to install measuring instruments at every point in the critical power path. Collecting, processing, and interpreting all the data also can be complex.

There is also some degree of error inherent in each of the meters measuring energy consumption, which can affect results.

For a practical and achievable approach to monitoring, data centre operators should identify where it is most beneficial to measure, taking into account associated improvements in PUE accuracy.

A.3 Assessment frequencies

Increasing the minimum frequency of the assessment cycle provides a larger and more accurate data set to analyse.

To fully understand and successfully manage the energy performance of a data centre, continuous real-time monitoring should be used so that historical trending and statistical analysis can be done to determine where efficiencies can be gained. This approach also enables early detection of unexpected variations that could indicate system issues.

In cases where continuous real-time monitoring is not practical or economically justifiable, some form of repeatable, defined process should be in place to capture measurements enabling the calculation of PUE as often as possible for internal comparison purposes. If automated systems are employed the minimum assessment frequency should be daily.

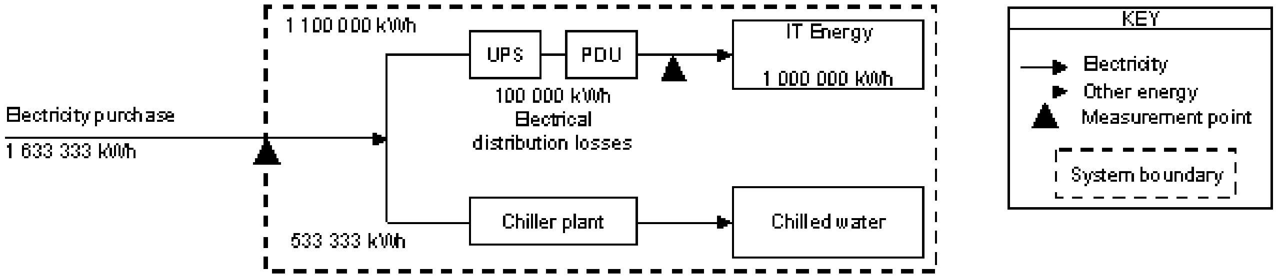
In all cases, the measurement methodology shall be consistent with the Categories and locations defined in 6.2.

Annex B
(informative)

Calculation of PUE using various energy supplies

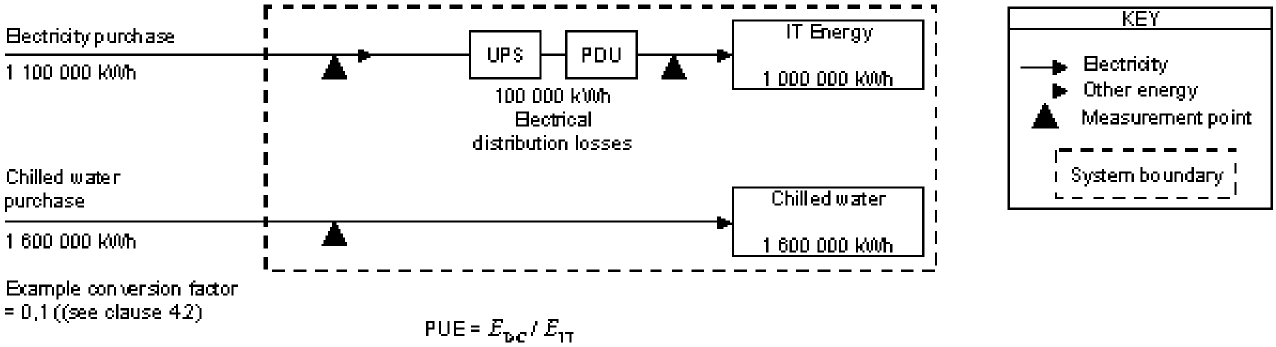
B.1 Examples of PUE calculation with various energy supplies

Figures B.1 to B.4 show examples of PUE calculation with various energy supplies.



$$PUE = E_{DC} / E_{IT}$$
$$= (1\,633\,333)/(1\,000\,000)$$
$$= 1{,}63$$

Figure B.1 — Example for a data centre purchasing all electricity



$$PUE = E_{DC} / E_{IT}$$
$$= (1\,100\,000 \times 1 + 1\,600\,000 \times 0{,}1)/(1\,000\,000)$$
$$= 1{,}26$$

Figure B.2 — Example for a data centre purchasing electricity and chilled water

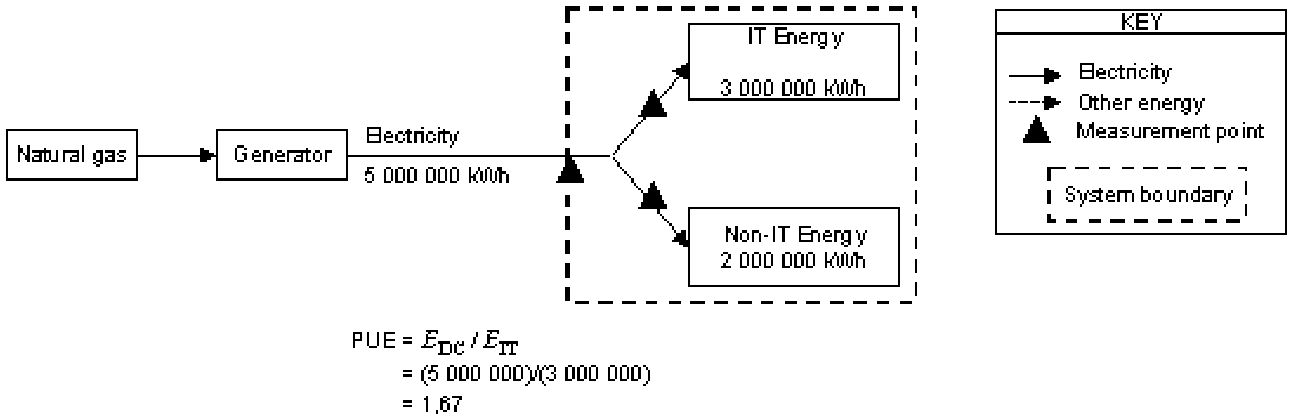


Figure B.3 — Example for a data centre purchasing natural gas

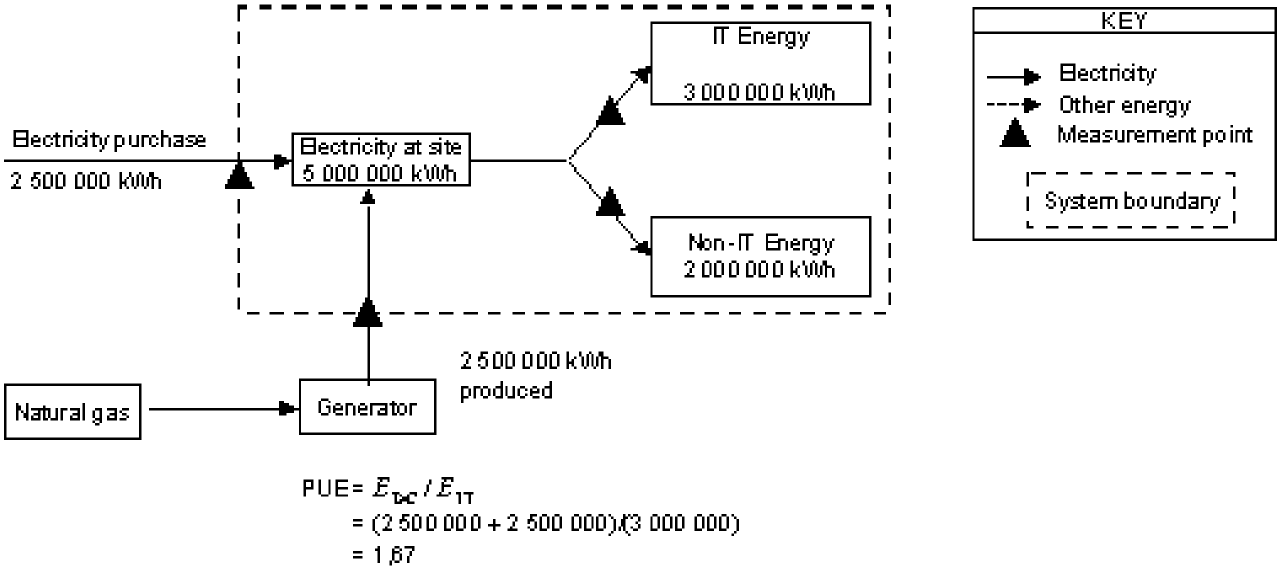
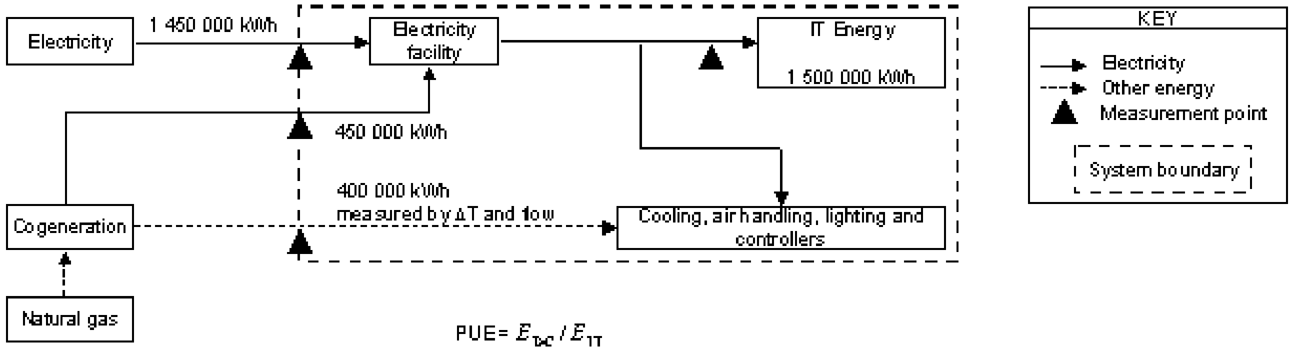


Figure B.4 — Example for a data centre purchasing electricity and natural gas

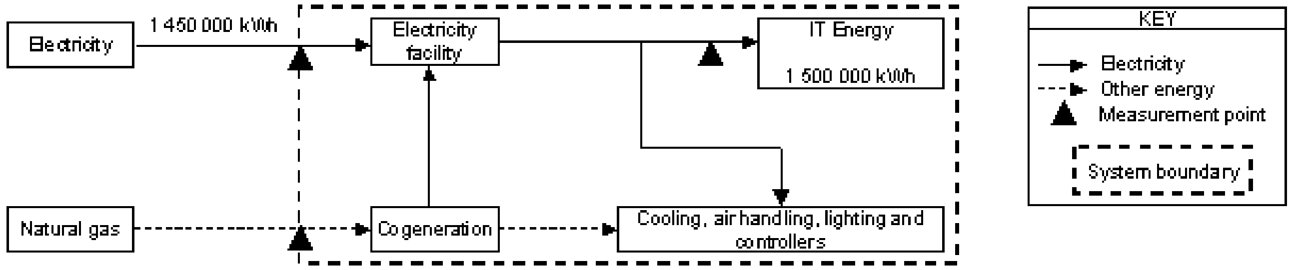
B.2 Examples of PUE calculation with cogeneration using electricity and natural gas

Figures B.5 and B.6 show examples of PUE calculation with cogeneration using electricity and natural gas.



$$PUE = E_{DC} / E_{IT}$$
$$= (1\,450\,000 + 450\,000 + 400\,000)/(1\,500\,000)$$
$$= 1{,}53$$

Figure B.5 — Method 1: Measured by chilled water flow

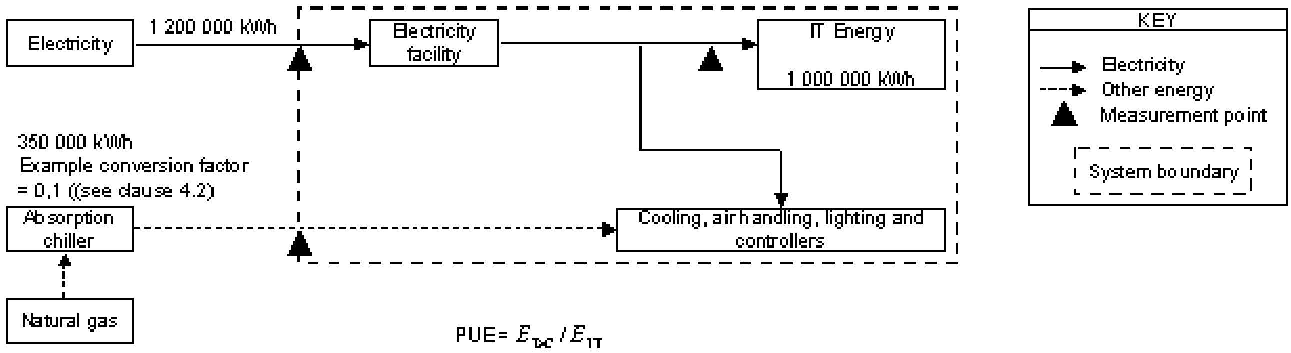


$$PUE = E_{DC} / E_{IT}$$
$$= (1\,450\,000 + 1\,000\,000)/(1\,500\,000)$$
$$= 1{,}63$$

Figure B.6 — Method 2: Calculated from energy required to produce chilled water

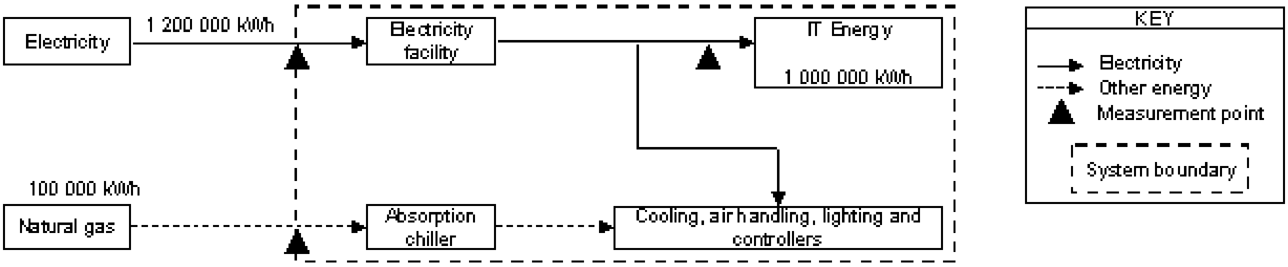
B.3 Examples of PUE calculation with absorption type chiller

Figures B.7 and B.8 show examples of PUE calculation with absorption type refrigerator.



$$PUE = E_{DC} / E_{IT}$$
$$PUE = (1\,200\,000 + 350\,000 \times 0{,}2)/(1\,000\,000)$$
$$PUE = 1{,}27$$

Figure B.7 — Method 1: Measured by chilled water flow



PUE= E_{DC} / E_{IT}

PUE= (1 200 000 + 100 000)/(1 000 000)

PUE= 1,3

Figure B.8 — Method 2: Measured by input gas

Annex C
(normative)

PUE derivatives

C.1 General

C.1.1 Purpose of PUE derivatives

PUE derivatives are useful to support an effective energy management process such as those described in EN 50600-3-1. Each derivative shall be accompanied with specific information that describes the specific situation.

C.1.2 Using PUE derivatives

The PUE derivatives shall be designated and shall be documented as one of the following.

Partial PUE (pPUE) describes the power usage effectiveness of a data centre infrastructure subset. pPUE shall include but is not limited to the following supporting data:

a) the boundaries of the data centre including resiliency level,

b) an explicit list of shared resources,

c) assessment method used to determine the amount of shared resources included,

d) all other PUE supporting evidence.

Interim PUE (iPUE) describes a PUE measured for a period less than a year (see C.2). iPUE shall include but is not limited to the following supporting data:

— the boundaries of the data centre including resiliency level;

— time interval(s) under assessment;

— all other PUE supporting evidence which exists during the defined intervals.

Designed PUE (dPUE) describes a predicted PUE for a data centre prior to its operation or to a specified change in operation (see C.4). dPUE shall include but is not limited to the following supporting data:

1) the boundaries of the data centre including resiliency level;

2) a schedule of interim PUE and PUE based on target IT loads and environmental conditions;

3) all other PUE supporting evidence available prior to operation including target commissioning date.

iPUE may be used to validate dPUE parameters.

Combined use of the terms is permitted to describe specific situations and values. An example use of these derivatives is:

- d/i/pPUE (20XX-08-01:20XX-08-31) = 3,1 [ref. jjj];
- [jjj]: [boundaries of the data centre, shared cooling, space, physical security];
- 40 % IT load; environmental conditions; etc.

C.2 Interim PUE

The definition of PUE clearly indicates that it is an annual figure and requires continuous measurement of IT energy and total data centre energy for at least one year. Reporting requires accompanying every PUE value with its category and the period of measurement.

For energy management purposes it can be useful to measure and report periods smaller than a full year. These values shall be designated as “interim PUE” (iPUE). They shall also be accompanied by its category, the period of measurement, and the other context and reporting information required for annualized PUE.

By decreasing the measurement interval to a minimum, a real-time iPUE may be established.

C.3 Partial PUE (pPUE)

C.3.1 General

While PUE is defined using total data centre energy, pPUE is determined on the energy use of particular and specified subsystems of the data centre’s infrastructure. The boundaries of these subsystems are within the data centre and pPUE may be applied for all kinds of data centres.

Partial PUE (pPUE) is calculated as follows:

$$pPUE_{\mathrm{sub}} = \frac{E_{\mathrm{sub}} + E_{\mathrm{IT}}}{E_{\mathrm{IT}}} \tag{C.1}$$

where:

E_{sub} = energy consumption (annual) of the subsystem in kWh;

E_{IT} = IT equipment energy consumption (annual) in kWh.

As with the PUE, pPUE is related to IT energy use and is an annual figure that requires a full year of measurement. Reporting pPUE requires the same disclosures as PUE, in addition to a clear delineation of the sub-system or zone under investigation. A zone comprises a meaningful set of infrastructure components that are using energy and the energy efficiency of which needs to be examined.

To be useful in an energy management process, the zones for the subsystems shall be defined in every individual data centre. Electrical distribution (including UPS), air handling and cooling are typical subsystems that apply to most of the data centres nowadays. They are defined as by Formulae (C.2) to (C.4):

$$pPUE_{\mathrm{power}} = \frac{E_{\mathrm{electrical}} + E_{\mathrm{IT}}}{E_{\mathrm{IT}}} \tag{C.2}$$

where:

$E_{\mathrm{electrical}}$ = energy consumption (annual) of the electrical systems in kWh

$$pPUE_{\mathrm{HVAC}} = \frac{E_{\mathrm{HVAC}} + E_{\mathrm{IT}}}{E_{\mathrm{IT}}} \tag{C.3}$$

where:

E_{HVAC} = energy consumption (annual) of the heating, ventilation and air conditioning systems in kWh

$$pPUE_{\text{cooling}} = \frac{E_{\text{cooling}} + E_{\text{IT}}}{E_{\text{IT}}} \tag{C.4}$$

where:

E_{cooling} = energy consumption (annual) of the cooling systems in kWh

This standard allows other zones to be defined as required with the purpose of gaining useful pPUE to analyse and understand the contribution of a data centre subsystem to the total energy use and to improve the energy efficiency of the sub-system under inspection.

The pPUE concept (and any reported value) is only applicable to the zones of a data centre under study.

It is meaningless to apply a pPUE to a part of the building that is not a zone of the data centre.

Specifically, there is no meaning in pPUE for zones that do not contain IT load (other KPIs can be applicable).

pPUE may also be employed to evaluate specific regions in the data centre or facilities where the IT equipment resides but share resources with other regions. The other regions not under investigation may or may not contain IT equipment, but, those regions are not considered part of the evaluation. The boundaries of the region under evaluation shall be described per EN 50600-4-1.

C.3.2 Zoning

The normal use of pPUEs is within the boundaries of a data centre. As a step of the energy management process, the zones of infrastructure subsystems inside the data centre shall be defined. This zoning depends on the technical design of the data centre.

For most of the data centres in post-commissioning and in operation, the zoning in Figure C.1 applies.

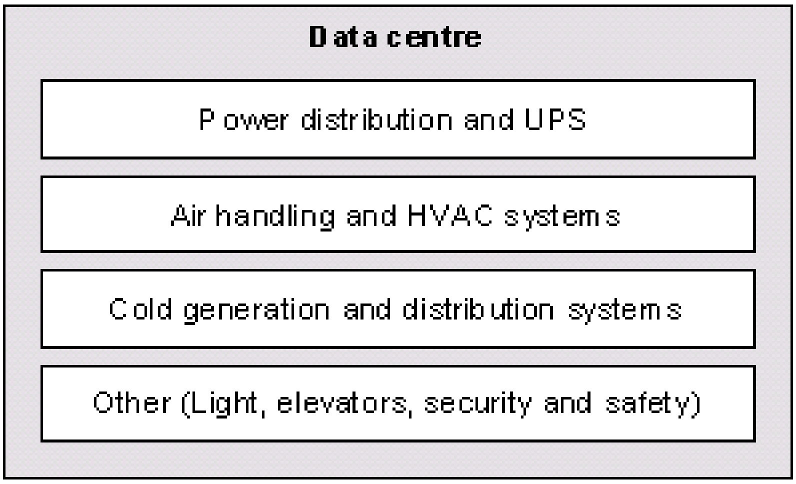


Figure C.1 — Zoning for a data centre

Whether or not the zone “other” shall be included depends on the significance of the energy use of that zone. It may be ignored in the beginning and included at a later stage of the energy management process, when the efficiency of the main zones has reached a level that the zone “other” becomes relevant.

In case the cooling is provided by DX systems, air handling and cooling cannot be separated. Therefore, the zoning of Figure C.2 might be a better approach.

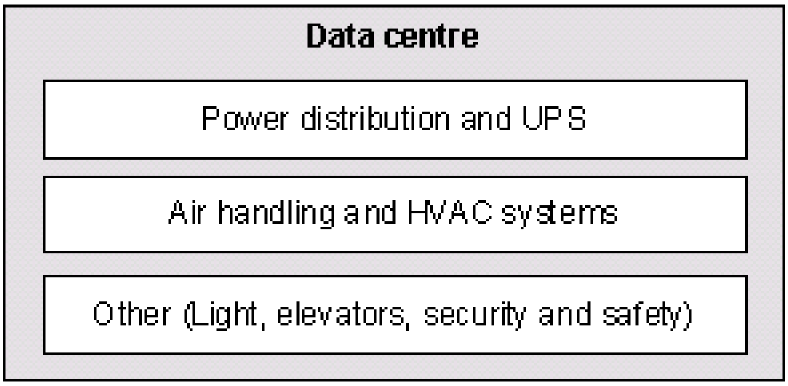


Figure C.2 — Zoning for a data centre using DX cooling

In case water is used for an additional cooling system and water transportation and treatment uses a significant amount of energy, the zoning of Figure C.3 is a good approach.

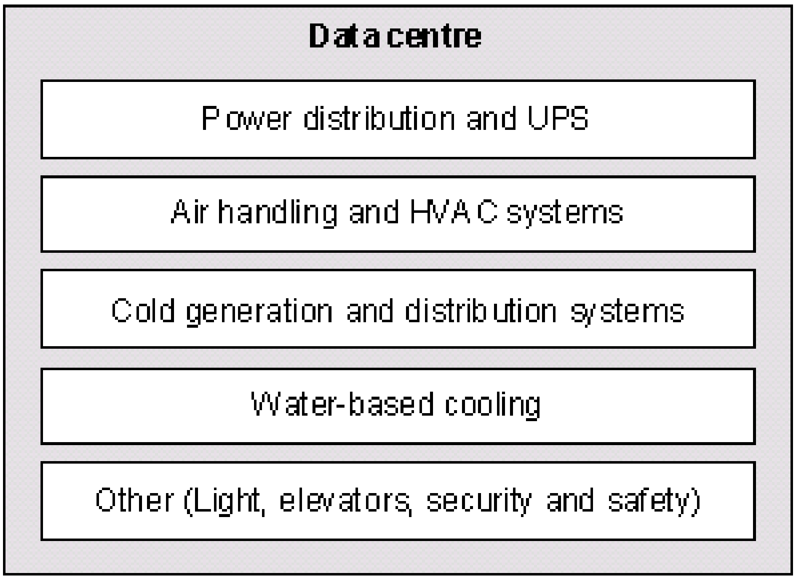


Figure C.3 — Zoning for a data centre using water

This standard does not specify a method of defining a zone, but any zone shall be:

a) suitable for the task of the desired energy management process,

b) where appropriate, adjusted according to the progress of maturity of the energy management process.

C.3.3 Metering requirements for pPUE

In order to obtain an appropriate measure of E_{sub} it is typically required to install meters at each outlet of the main PDU.

Measurements shall be in accordance with Clause 6.

C.3.4 Reporting of pPUE

See Clause 7.

C.3.5 Use of pPUE in energy management

The main purpose of pPUE use is to analyse and identify potential energy savings by detection of inefficient zones and infrastructure subsystems. In addition, pPUE can be used to verify effectiveness of improvement measures. As an example, Figure C.4 shows a data centre with zones for HVAC and cooling. The arrows indicate points in time where measures were taken to improve the efficiency of the related infrastructure components.

Furthermore, pPUE can be used to estimate the potential of an improvement measure and calculate upfront a return on investment (ROI) of the costs associated with it. Once the operational conditions and their related pPUE are known, the effect of a measure can be expressed as a reduction of the pPUE. The annual savings are the result of the pPUE reduction multiplied with the annual costs for IT equipment energy use. The ROI is the necessary investment divided by the annual savings and expresses the number of years needed to get the return on the investment.

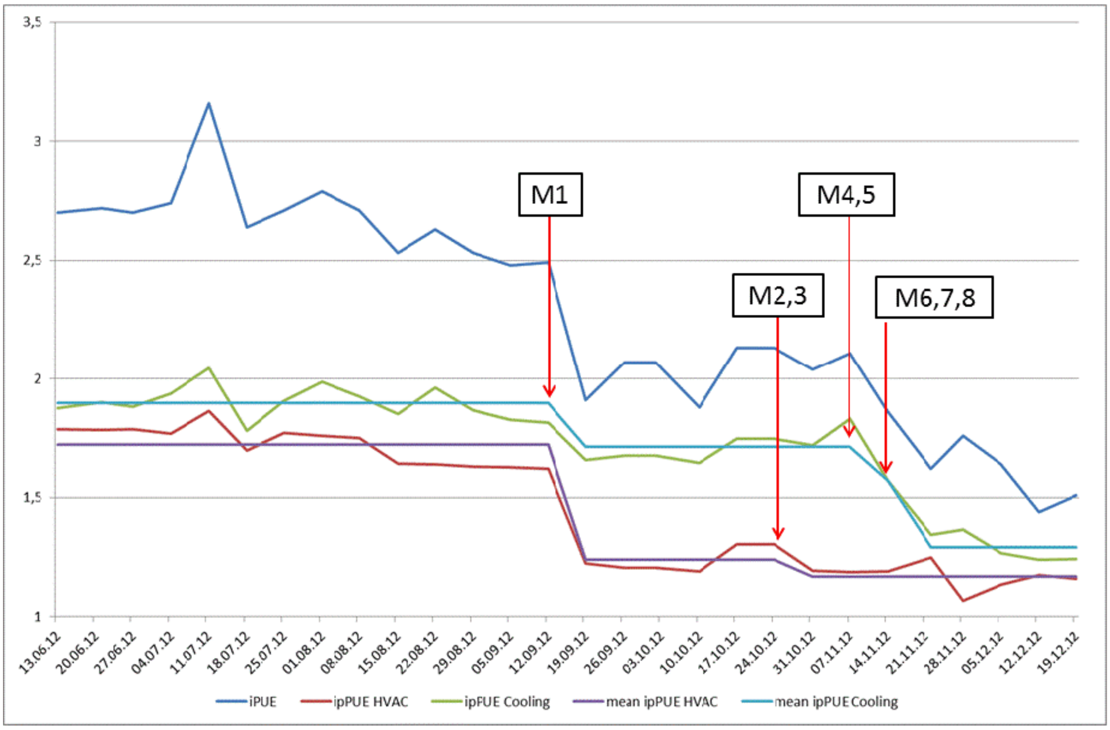


Figure C.4 — Example of utilizing the combination of PUE derivatives: ipPUE

C.3.6 Use of pPUE in mixed use buildings

For data centres in mixed use buildings, the sharing of infrastructure components can prevent the determination of the PUE, as not all energy use can be dedicated either to the building or to the data centre. In this case, it is still possible to determine a pPUE for those zones of the data centre that can be separated.

For example, where the cooling infrastructure of a mixed use building serves both data centre space and office space and the installed meters are unable to separately measure the energy used for each space, it is not possible to calculate PUE. However, it is possible to calculate pPUE for power distribution and HVAC, although the benefit of these pPUEs without knowledge of the PUE is limited. Therefore, it is recommended to implement the necessary metering to provide a separation for the main infrastructure components using most of the energy in a mixed use building.

In this approach, accepted exceptions to calculating pPUE in mixed use building are ancillary energy loads required for shared spaces, such as:

a) offices,

b) laboratories,

c) cubicles,

d) conference rooms,

e) elevators,

f) lobbies,

g) kitchens/break rooms,

h) parking areas,

i) toilets,

j) corridors,

k) stairs,

l) convenience stores.

C.4 Designed PUE

The energy efficiency of a data centre can be predicted at the design stage based on:

a) the scenario for growth or expectation of occupancy,

b) the timeline for increases and/or decreases in energy consumption.

Table C.1 shows an example, for a containerized data centre, of such predictions using expected loads based on target occupation of a data centre leading to a designed PUE (dPUE) for each stage - and resulting in an annualized value of dPUE of 1,20.

Table C.1 — Example of dPUE calculation

Month		IT equipment		Cooling/ventilation/ humidification		Power distribution	UPS	Lighting	Remaining support	Total data centre in	
Nr	Dura- tion	Average load	Energy used [a]	Average load [a]	Energyused	Energy used	Energy used	Energy used	Energy used	Energy used	idPUE
#	Days	kW	kWh	kW	kWh	kWh	kWh	kWh	kWh	kWh	
1	31	50	37 200	6	4 464	221	3 720	248	744	46 597	1,25
2	28	100	67 200	10	6 720	769	4 704	224	672	80 289	1,19
3	31	125	93 000	11	8 184	1 301	5 580	248	744	109 057	1,17
4	30	135	97 200	14	10 080	1 511	5 832	240	720	115 583	1,19
5	31	140	104 160	18	13 392	1 756	5 729	248	744	126 029	1,21
6	30	140	100 800	19	13 680	1 720	5 544	240	720	122 704	1,22
7	31	140	104 160	20	14 880	1 800	5 729	248	744	127 561	1,22
8	31	160	119 040	25	18 600	2 407	5 952	248	744	146 991	1,23
9	30	160	115 200	24	17 280	2 304	5 760	240	720	141 504	1,23
10	31	160	119 040	20	14 880	2 278	5 952	248	744	143 142	1,20
11	30	160	115 200	16	11 520	2 108	5 760	240	720	135 548	1,18
12	31	160	119 040	15	11 160	2 154	5 952	248	744	139 298	1,17
□											dPUE
Σ	365		1 191 240		144 840	20 329	66 214	2 920	8 760	1 434 303	1,20

[a] Forecasted use or estimate.

When used in the design phase, dPUE represents a target based on optimal operation as defined by the designer and should take into account the climate (outside air temperature and humidity) to be experienced due to the location of the data centre.

When used in the operational phase, dPUE represents an expected PUE value based on a resource capacity forecast (such as that of EN 50600-3-1) using the expected energy consumption of the installed and planned data centre infrastructures and the IT equipment. The fluctuating demand of the infrastructure supporting systems over the forecast period is estimated based on the characteristics of the system components and external fluctuations like weather and system load. Table C.1 gives an example of such a capacity forecast over a period of one year. The forecast period is divided in smaller sub-periods in this example in months. For each period the impact of the expected changes and circumstances are estimated and the results are placed in a Table. The assumptions for January are in Table C.2.

For each sub-period the assumptions in the capacity planning process will provide values, for that sub-period, of E_{DC} and E_{IT}. The assumptions made as exemplified in Table C.2 are part of the dPUE reporting. The summation of the sub-period values of E_{DC} and E_{IT} is used to calculate the annualized dPUE.

Where the forecast period exceeds one year, multiple annual dPUE values may be reported.

Table C.2 — Example of context description

No.	Sub-period	What	Change/external fluctuations
1	January	IT equipment	Start-up of data centre IT load 50 kW
		Cooling ventilation/ humidification	Data centre is situated in the northern hemisphere latitude 40 N and uses free cooling
		Power distribution installation	With a low load the mainly i^2 related power distribution losses are low
		UPS	The UPS system is on load, efficiency about 90 %
		Lighting and remaining supporting equipment	Constant consumption only varying with the number of days per month

Annex D
(informative)

Interpretation of PUE and its derivatives

D.1 General

The PUE nomenclature, proper and transparent public reporting guidelines, and the availability of key information about reported results in accordance with this European Standard enhance both the credibility and usefulness of the PUE metric.

This annex provides guidelines and consideration points for correctly interpreting PUE results.

Individuals making claims should be aware of the following issues and ensure they are reporting and interpreting valid numbers prior to making any public claims.

Data centres have different:

a) characteristics, capabilities, and operational policies (e.g. government regulations and policy, climate, location and customer's requirements),

b) primary applications such as:

   1) main usage: testing, manufacturing, internal processes, networking, scientific modelling or calculations, database management, communications, etc.,

   2) primary business supported by the data centre: financial services, healthcare, telecommunications, research and development, environmental monitoring, industrial manufacturing, etc.,

   3) criticality of service: emergency services, civic infrastructure, health and safety, security, and similar,

   4) availability objectives: disaster recovery, periodic loss of service, resource backup requirements, auxiliary resource requirements, and similar (see EN 50600-4-1:2016, Annex A);

c) capabilities with respect to collecting and analysing energy consumption data.

These factors affect the performance of the data centre and shall be taken into account in the interpretation of any PUE value. Without additional information about the reported results, interpretations of data collected by different organizations using different approaches over different timeframes can be meaningless or misleading.

As a result, PUE in accordance with this European Standard should principally be used to assess trends in an individual facility over time and to determine the effects of different design and operational decisions within a specific facility. PUE values of different data centres should not be compared directly subject to the advice of D.2 and D.3.

D.2 Data centre infrastructure versus IT equipment

Each load in a data centre is designated as either an IT load, an infrastructure load, or not included in the calculation. Many data centres are in mixed use buildings where there are significant offices or other loads that are not related to the data centre function. Mixed use buildings can also have shared systems such as cooling towers, switchgear, or ventilation systems. In these cases, PUE reporting shall explicitly describe how the loads have been incorporated into the calculation. For the purpose of improving a single, specific data centre, what remains important is not the exact allocation of shared loads to the PUE calculation, but rather that the calculations be performed in a consistent manner.

A reduction of PUE implies a reduction in the energy overhead needed to house its IT equipment. However, PUE does not provide any guidance or insight into the operation or productivity of IT equipment. It is likely that changes in the deployment or operation of IT equipment will affect PUE results.

As examples:

a) Organizations implementing virtualization in their data centres can reduce overall IT load but see an increase in PUE. In these instances, the fixed overhead for power distribution and cooling has not changed, but the reduction in IT load delivers a seemingly poorer PUE result. PUE users should document and consider the factors that contributed to the PUE increase as further opportunities for improvements.

b) Older data centres can accommodate older servers without energy saving technology. By comparison, more recent data centres can contain “energy proportional” servers with high levels of dynamic range, where the energy consumption fluctuates significantly based on the IT load. In such case, the older data centres can exhibit better PUE results.

Changes in PUE are meaningful when they are seen as the data centre’s response to changes in infrastructure equipment or infrastructure operations. Studies investigating the effect on PUE of changes in infrastructure equipment or operations should ensure that any changes occurring to the IT load over the study’s period of time are properly accounted for.

D.3 Comparing PUE results between data centres

As highlighted in D.1, PUE values of different data centres should not be compared directly.

However, data centres with similar conditions can learn from the changes made to another data centre provided the measurement guidelines, reporting guidelines, and the additional data attributes are obtained. To enable equitable comparison of PUE results among data centres, attributes such as age, geographic location, capacity loading, resiliency, service availability, size of facility, and other load aspects should be taken into consideration (see EN 50600-4-1:2016, Annex A).

In such cases, PUE can be used to improve data centre infrastructure efficiency and provide insight for similar data centres.

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