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Bilgi teknolojisi - Veri merkezi tesisleri ve altyapıları - Bölüm 4-7: Soğutma Verimliliği Oranı

Information technology - Data centre facilities and infrastructures - Part 4-7: Cooling Efficiency Ratio

Technologie de l'information - Installation et infrastructures de centres de traitement de données - Partie 4-7: Taux d'efficacité de refroidissement

Informationstechnik - Einrichtungen und Infrastrukturen von Rechenzentren - Teil 4-7: Wirkungsgrad der Kühlung (CER)

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Milli Önsöz

Bu standard, CLC/TC 215 “Electrotechnical aspects of telecommunication equipment - Telekominikasyon cihazlarının elektroteknik yönleri” Teknik Komitesi tarafından hazırlanmış, CENELEC tarafından 10.02.2020 tarihinde onaylanmış ve Türk Standardları Enstitüsü Teknik Kurulu'nun 02.07.2020 tarihli toplantısında Türk Standardı olarak kabul edilerek yayımına karar verilmiştir.

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Information technology - Data centre facilities and infrastructures - Part 4-7: Cooling Efficiency Ratio

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European Committee for Electrotechnical Standardization
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European foreword

This document (EN 50600-4-7:2020) 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)	2021-02-10
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2023-02-10

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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 document, 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 supply and 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*;

— FprEN 50600-4-6, *Information technology — Data centre facilities and infrastructures — Part 4-6: Energy Reuse Factor*

— FprEN 50600-4-7, *Information technology — Data centre facilities and infrastructures — Part 4-7: Cooling Efficiency Ratio;*

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

— CLC/TR 50600-99-2, *Information technology — Data centre facilities and infrastructures — Part 99-2: Recommended practices for environmental sustainability;*

— CLC/TR 50600-99-3, *Information technology — Data centre facilities and infrastructures — Part 99-3: Guidance to the application of EN 50600 series*

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

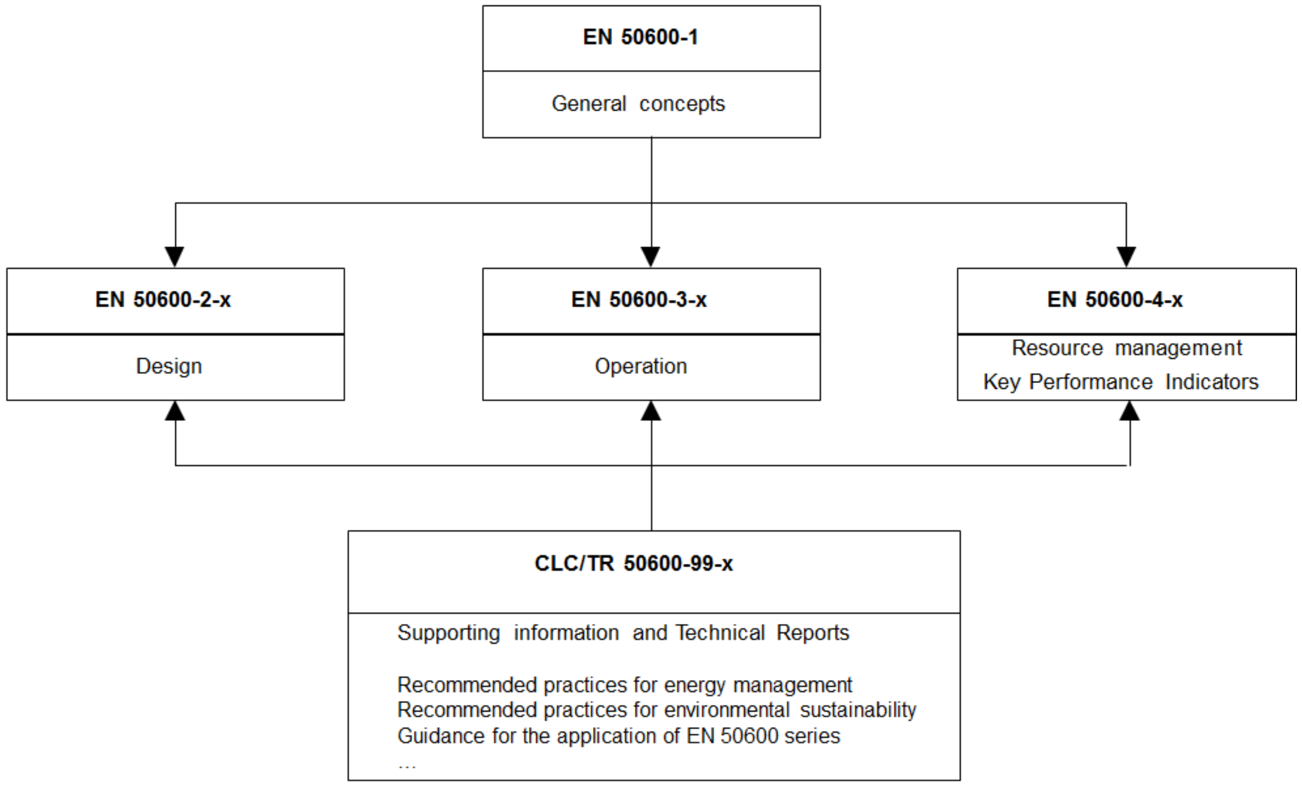

Figure 1 — Schematic relationship between the EN 50600 series of documents

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 document specifies Cooling Efficiency Ratio to determine the efficient utilization of energy resources to provide the temperature control required by spaces of the data centre.

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 document 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 document specifies the Cooling Efficiency Ratio (CER) as a Key Performance Indicator (KPI) to quantify the efficient use of energy to control the temperature of the spaces within the data centre.

This document:

a) defines the Cooling Efficiency Ratio (CER) of a data centre;

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

c) defines the measurement, the calculation and the reporting of the parameter;

d) provides information on the correct interpretation of the CER.

Annex A describes the correlation of CER and other KPIs.

Annex B provides examples of the application of CER.

Annex C introduces the parameters that affect CER.

Annex D describes requirements and recommendations for derivatives of KPIs associated with CER.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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, *Information technology - Data centre facilities and infrastructures - Part 4-1: Overview of and general requirements for key performance indicators*

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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
Cooling Efficiency Ratio
ratio of total heat removed and electrical energy used by a cooling system

3.1.2
Cooling Performance Ratio
ratio of actual heat load and electrical power used by a cooling system

3.2 Abbreviations

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

CEF	Cooling Efficiency Factor
CER	Cooling Efficiency Ratio

CPR	Cooling Performance Ratio
HVAC	Heating, Ventilation, Air Conditioning
iCER	interim Cooling Efficiency Ratio
KPI	Key Performance Indicator
PUE	Power Usage Effectiveness
pCEF	partial Cooling Efficiency Factor
pPUE	partial Power Usage Effectiveness
$\text{pPUE}_{\text{HVAC}}$	partial Power Usage Effectiveness for heating, ventilation and air conditioning systems

3.3 Symbols

For the purposes of this document, the following symbols apply.

E_{Cooling}	Electrical Energy used by cooling systems
E_{CoolDC}	Part of E_{Cooling} that is accounted to the data centre
E_{heat}	Electrical Energy transferred to heat
$E_{\text{HVAC,DC}}$	Electrical Energy used by air conditioning systems
E_{IT}	Electrical Energy used by IT equipment
E_{UPSloss}	Electrical Energy loss in UPS
E_{total}	Total energy used by the data centre calculated from CER
Q	actual heat load from data centre
Q_{removed}	heat quantity removed by the cooling system
P_{Cooling}	actual electrical power of the cooling systems

4 Applicable area of the data centre

Cooling Efficiency Ratio (CER) as specified in this document:

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

b) describes the efficiency of a cooling system with respect to its electrical energy use.

Derivatives of CER which are useful in certain circumstances are described in Annex D (Cooling Performance Ratio (CPR), interim CER (iCER)).

5 Determination of Cooling Efficiency Ratio

5.1 Definition of CER

The Cooling Efficiency Ratio (CER) is defined as follows:

$$CER = \frac{Q_{\text{removed}}}{E_{\text{cooling}}} \quad (1)$$

Where

Q_{removed} = total heat removed from data centre in kWh

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

Both Q_{removed} and E_{cooling} shall be measured in kWh and for the same period T.

NOTE In EN 50600-3-1:2016, Formula (1) is designated as EER. This will be corrected with the revision of EN 50600-3-1.

5.2 Determining total energy use in multi-purpose buildings using CER

Calculation of PUE for data centres located in multi-purpose can be a challenge, when parts of the infrastructure are shared between the data centre and e.g. the office building. Separating electrical energy use can be easily arranged with sub-meters in the power trail. When the offices are equipped with UPS secured sockets, UPS losses need to be split up for offices and data centre. This can be accomplished by determination of the UPS loss with a meter before the UPS and meters on every line behind the UPS. For a large data centre in a small office building the loss attributed to the offices may even be ignored.

The major challenge is to account for the electrical energy for cooling when the cooling infrastructure is shared between data centre and offices as shown schematically in Figure 2. In most cases, the piping system is not separated between data centre and offices. Therefore, the heat loads of data centre and offices cannot be separated and measured. In addition, the heat load in offices strongly depends on the weather conditions and thus is much more variable than the heat load of the data centre.

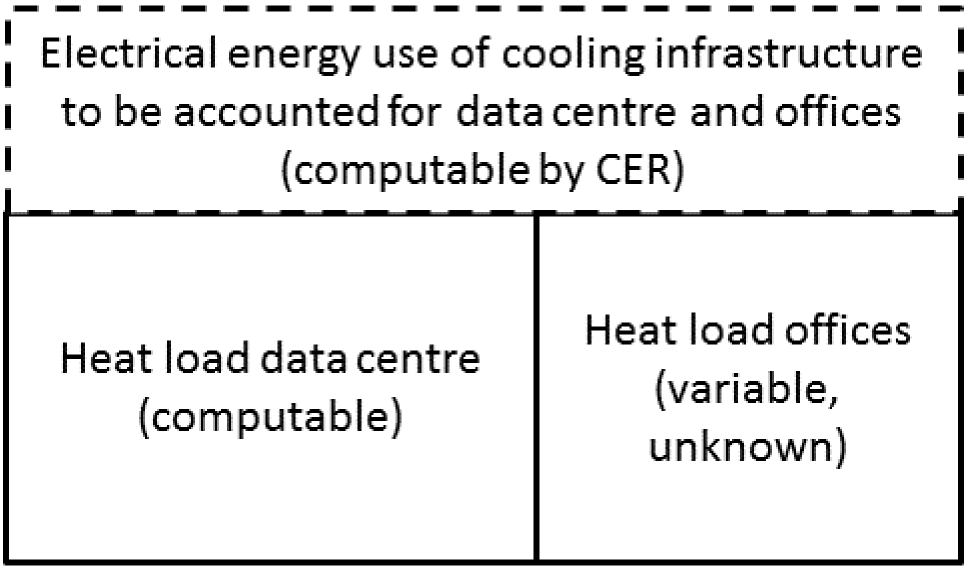

Figure 2 — Heat loads in multipurpose buildings and energy used for cooling

The calculation of the heat load of the data centre is based on the assumption that all electrical energy used in the data centre is transferred to heat: IT energy, UPS losses, and electrical energy for HVAC.

$$E_{\text{heat}} = E_{\text{IT}} + E_{\text{UPSloss}} + E_{\text{HVAC,DC}} \quad (2)$$

Provided that the CER of the cooling infrastructure is known, i.e. the total heat removed and the electrical energy used by the cooling infrastructure is measured, the electrical energy used to remove heat can be calculated as follows:

$$E_{\text{cooling}} = \frac{Q_{\text{removed}}}{CER} \quad (3)$$

To calculate the electrical energy used for cooling of the data centre, the heat removed in the formula above needs to be replaced by E_{heat}.

$$E_{\text{cooling}} = \frac{E_{\text{heat}}}{CER} = E_{\text{coolDC}} \quad (4)$$

The total energy usage of the data centre is the sum of all parts:

$$E_{\text{total}} = E_{\text{IT}} + E_{\text{UPSloss}} + E_{\text{HVAC,DC}} + E_{\text{CoolDC}} = E_{\text{heat}} + E_{\text{CoolDC}} = E_{\text{heat}} * (1 + {}^{1}\!/_{CER}) \quad (5)$$

Based on this calculation it is possible to determine the PUE of a data centre in a multi-purpose building, because IT energy use is known and total energy use can be calculated. Pre-requisites are the measurement of the energy use of the sub-systems HVAC, UPS and cooling and the total heat removed by the cooling infrastructure.

Uncertainties in the calculation result from heat losses of the data centre part into the building and disregarded heat intake to the computer room, e.g. through windows. Both effects can be considered neglectable for most of the multi-purpose buildings.

6 Measurement of Cooling Efficiency Ratio

6.1 General

The calculation of CER requires the recording and documenting of total heat removed and electrical energy used for cooling over a coincident period of 12 months. This document does not specify the frequency of measurements of total heat removed and electrical energy used for cooling, since CER is calculated on an annual timeframe. However, the frequency of measurement employed will define the timing of subsequent CER calculations on a rolling annual basis.

6.2 Requirements

The measurement of CER requires the measurement of the total heat removed and the electrical energy used in the same period.

In order to measure the heat removed, the volume of the coolant and its heat capacity shall be measured. In cases like direct free cooling, every parameter influencing the heat capacity (like humidity) shall be measured for an acceptable accuracy of the calculation of the heat removed. In case of redundant pipes, every pipe shall be measured.

For the electrical energy use all components of the cooling infrastructure, like pumps, valves etc., shall be measured and included in the energy used. Electrical metering shall be based on kWh, not on power in kW.

6.3 Recommendations

Data centres should implement meters with remote reading and data history storage capabilities.

7 Reporting of CER

7.1 General

In order for a reported CER (or CPR, see D.2) 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 CER value (or CPR value, see D.2);

c) the termination date of the period of measurement;

7.2 Requirements

In general, the CER shall be reported to one decimal place. However, depending on the accuracy of both measurements, the heat removed and the electrical usage, more than one decimal place may be reported.

Reporting of CER for external communication shall be accompanied by additional cooling conditions, like usage of direct free cooling or water. As far as KPI exist for these conditions, they should be determined and reported together with the CER.

7.3 Recommendations

For usage in energy management and verification of measures of improvement, a report of iCER (see D.1) can be plotted against the outside air temperature and humidity, if applicable. As there is a strong dependency of the iCER from outside air temperature and other conditions like humidity for most energy efficient cooling systems, every improvement can be detected in a shift of the iCER value at the same outside air temperature.

Annex A
(informative)

Correlation of CER and other KPIs

A.1 General

Cooling is one of the most important aspects of energy use in a data centre, and one with the largest potential for optimization of energy efficiency. The partial PUE (pPUE) of the cooling infrastructure provides insight into that potential in comparison to the other parts of the infrastructure, but it is less helpful in energy management to verify the effect of improvements of the cooling infrastructure, as the value of a pPUE in general is between 1 and the PUE of the data centre:

$$1 < pPUE < PUE \qquad (A.1)$$

See EN 50600-4-2 for the definition and further information on the usage of PUE and pPUE.

Measuring the heat removed divided by the electrical energy used by the cooling infrastructure provides a much more sensitive KPI.

A.2 Discussion of existing terms for performance rating

There are already multiple terms defined for performance rating of heat pumps and cooling equipment, e.g. in ANSI/AHRI Standard 210/240-2008, see Table A.1:

Table A.1 — Terms of efficiency for cooling machines

Term	Abbreviation	Infrastructure	Comments
Coefficient of Performance	**COP**	**Heat pumps**	**Machine characteristic, defined under fixed conditions**
Energy Efficiency Ratio	**EER**	**Cooling machines**	**Machine characteristic, defined under fixed conditions**
Seasonal EER	**SEER**	**Cooling machines**	**Defined for the period of one year**

The Coefficient of Performance (COP) is a value based on actual heat load and electrical power. It describes the performance under controlled, optimal conditions, thus giving a maximum value for performance, not a realistic one for operation in a real data centre. Furthermore, it is defined for heat pumps, not for cooling infrastructure.

According to ANSI/AHRI Standard 210/240-2008 the EER is “A ratio of the cooling capacity in Btu/h to the power input value in watts at any given set of Rating Conditions expressed in Btu/(Wh)”. It also describes the performance under controlled conditions, but it already acknowledges the influence of part load operation of a cooling infrastructure.

According to ANSI/AHRI Standard 210/240-2008 the SEER is “The total heat removed from the conditioned space during the annual cooling season, expressed in Btu’s, divided by the total electrical energy consumed by the air conditioner or heat pump during the same season, expressed in watt-hours”. It describes the performance of a cooling infrastructure under real conditions based on a period of a full year. It therefore accounts for the dependency of the EER on climate conditions, or – to be more precise – on the outside air temperature.

Annex B
(normative)

Examples of usage of CER

B.1 Determining PUE in data centres with different computer rooms using CER

Operators of data centres with multiple rooms that have different characteristics, e.g. in energy density of the racks or air flow strategies, possibly wish to compare the energy efficiency of these rooms. Similar to 5.2 the calculation of a PUE value for each room can be a challenge when infrastructure is shared within the data centre. On the power trail – again – this issue can be solved by an appropriate set of sub-meters providing ability to account for IT energy and UPS losses.

Accounting for the usage of electrical energy for a central cooling infrastructure requires calculating the heat load of every room by the formula introduced in B.1:

$$E_{\text{heat}} = E_{\text{IT}} + E_{\text{UPSloss}} + E_{\text{HVAC,DC}} \tag{B.1}$$

Following the same conclusion as in 5.2 the total energy used by each room can be calculated based on the CER of the cooling infrastructure and the value of E_{heat} for each room:

$$E_{\text{total}} = E_{\text{IT}} + E_{\text{UPSloss}} + E_{\text{HVAC,DC}} + E_{\text{CoolDC}} = E_{\text{heat}} + E_{\text{CoolDC}} = E_{\text{heat}} * (1 + 1/_{CER}) \tag{B.2}$$

Knowing IT energy for every room, a PUE value can be determined.

Besides the uncertanties discussed in 5.2, the calculated PUE in this clause ignores potential advantages of the different air flow strategies. Enclosed environments usually lead to a higher temperature spreading over IT and lead to higher temperatures at the HVAC inlet and thus to a higher temperature of the cooling fluid. When routes of cooling pipes of different computer rooms with different temperatures are combined, the temperature before the cooling system is a mixture of these temperatures. The CER measured in such a data centre is based on the mixed temperature, but could be better when cooling would be seperated for each room. As this clause is about a situation with multiple rooms using a shared cooling infrastructure, it remains a valid approach to compare different rooms *in this special data centre*. It does not provide a general PUE value for the different air flow strategies.

B.2 Determining CER in cases of energy re-use

Re-use of energy is an important strategy for overall energy efficiency. Data centres can contribute significantly to energy re-use by providing heat to premises that need heat. Therefore, heat transferred beyond the border of a data centre can be measured and accounted for in the KPI Energy Re-use Factor (see FprEN 50600-4-6).

Using data centre heat in a multi-purpose building is the most obvious form of re-use and raises the question, whether electrical energy used to transport heat transfer medium in the building shall be accounted for in CER calculation.

CER is a KPI to characterize the efficiency of a data centre sub-system, i.e. the cooling infrastructure. The infrastructure to distribute heat in a building is not considered as a part of the data centre. Therefore, all energy needed to transfer the heat out of the borders of the data centre shall be accounted for in the denominator of CER formula. Any additional systems to distribute heat in the building and their energy use shall be accounted for in building management and its related KPI.

Annex C
(informative)

Parameters influencing CER

C.1 Adjustment of temperature

Air handling units, if technically capable, can be configured regarding two important parameters:

a) fan speed, defining the amount of air circulated in the computer room;

b) lower temperature of the coolant, defining the cooling power.

While the first one has major impact on the $pPUE_{HVAC}$, the latter one has impact on CER.

The higher the lower temperature for the air handling units, the lower is their cooling power, but for part load operation a lower cooling power can be sufficient. Rising the lower temperature is beneficial for systems using free cooling, as the period of sufficient difference of outside air temperature to lower temperature can be extended. Using free cooling over a longer period throughout the year leads to a higher CER for a full year.

Therefore, adjusting lower temperature for coolant in air handling units influences CER.

C.2 Demand of cooling

Inside the cooling infrastructure, a set of pumps ensures the flow of coolant through the pipes to the air handling units. A reduction of the volume of coolant down to the demand of cooling avoids unnecessary pumping. This directly improves the value of CER as less electrical energy is used by the cooling infrastructure, serving the same IT load and thus heat load.

Annex D
(normative)

Derivatives of CER

D.1 Interim Cooling Efficiency Ratio (iCER)

The definition of CER clearly indicates that it is an annual figure and requires continuous measurement of IT energy and total heat removed from data centre for at least one year. Reporting requires accompanying every CER value with its category and the period of measurement (see 6.2).

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 CER” (iCER). They shall also be accompanied by the period of measurement, and the other context and reporting information required for annualized CER.

D.2 Determination of Cooling Performance Ratio

D.2.1 Calculation of CPR

For small periods iCER evolves into the direction of a COP for cooling infrastructure, but under conditions of real operations as a parameter dependent on the load and the outside air temperature.

The Cooling Performance Ratio (CPR) is defined as follows:

$$CPR = \frac{Q}{P_{\text{cooling}}} \tag{D.1}$$

Where

Q	=	Actual heat load from data centre in kW
P_{cooling}	=	Actual electrical power of the cooling systems in kW

Both nominator and denominator shall be measured in kW and at the same time T.

D.2.2 Measurement of CPR

D.2.2.1 Requirements

Determining CPR requires determination of heat load and power usage on a small time frame. The size of this time frame depends on the intended use of CPR, e.g. in the process of Capacity Management, and the technical capabilities of the meters and the monitoring infrastructure.

For an acceptable accuracy of the CPR, it is necessary to ensure a precise alignment of the measurement period of both factors of the CPR, i.e. the heat removed and the electrical usage.

D.2.2.2 Recommendations

Data centres should implement automation of meter reading and data processing in order to cope with the expected amount of data.

D.2.3 Reporting of CPR

D.2.3.1 Requirements

Reporting of CPR requires the point in time of determination, e.g. “on July 15th at 13:30 h CPR was 2,3” or “on January 12th, at 5:15 h CPR was 12,7”. In general, the CPR shall be reported to one decimal place. However, depending on the accuracy of the measurement of CPR, more than one decimal place may be reported, but not more decimal places than reported for CER.

As there is a strong dependency of the CPR from outside air temperature and other conditions like humidity for most energy efficient cooling systems, reporting of CPR shall contain these conditions.

D.2.3.2 Recommendations

For usage in Capacity Management, CPR should be plotted against outside air temperature and humidity, if applicable. The minimum of CPR is usually a better indication for the maximum power requirement of the cooling infrastructure than the data given on the name plates of all components.

D.2.4 Using CPR in Capacity Management

Determining the utilization of main power supply and generators requires knowledge of maximum power demand of all infrastructure sub-systems. While peak load of UPS systems can be monitored and related to IT load, maximum load of the cooling infrastructure depends on IT load and outside air temperature. Machine characteristics provided by vendors can deviate from power demand in a real data centre. Therefore, a metric is required to determine power demand of a cooling infrastructure under individual, real operating conditions. This metric can be provided by CPR.

According to D.2.3.2, a plot of CPR against outside air temperature and humidity – if applicable – leads to a better understanding of the real power demand of a cooling infrastructure. Typical values of CPR for compressor based cooling systems are in the range of 2 to 3. At moderate outside air temperature optimized systems can achieve values well above 3, as do all free cooling systems.

At higher outside air temperatures the values of CPR can fall below 2 and for low part loads even below 1, i.e. the cooling infrastructure requires more electrical energy then the amount of heat it removes. Although this should not occur at higher loads and does not put the total capacity of a data centre at risk, CPR should be monitored at different IT loads to verify the development of CPR to higher values at higher IT loads.

D.3 Determination of Cooling Efficiency Factor (CEF)

D.3.1 Calculation of CEF

CEF is the inverse of CER:

$$CEF = \frac{1}{CER} = \frac{E_{\text{cooling}}}{Q_{removed}} \quad \text{(D.2)}$$

In contrast to CER, CEF enables to express efficiency of a cooling system in percentage of removed heat. E.g. a system with a CEF of 0,25 requires 25 % of the removed heat as electrical energy input for the process of heat removal.

D.3.2 Partial CEF (pCEF)

The concept of CEF allows to define sub-systems of a cooling system, e.g. CRAC (or CRAH), chiller and dry cooler as a chain of cooling infrastructure that is built to move the heat from server room to outside air.

The definition of partial CEF is related to the electrical energy use of the sub-system:

$$pCEF = \frac{E_{\text{cooling subsystem}}}{Q_{\text{removed}}} \quad \text{(D.3)}$$

Formula (D.3) allows to analyse the efficiency of all sub-systems transporting the total heat along the chain of a cooling infrastructure. Similar to CEF, which is the percentage of electrical energy use of the overall cooling system required to remove the heat, pCEF is the percentage of electrical energy use of every sub-system.

D.3.3 Example

Figure D.1 shows an example of a very efficient cooling system comprising CRAH, chiller and dry cooler. The dotted line shows the external temperature with its scale in °C on the right hand side.

The overall cooling system shows a CEF between 10 % to 14 % (deep purple line). The lighter coloured lines show the pCEF of CRAH at about 4 %, chiller at about 2 % and dry cooler at about 5 % to 7 %. Using pCEF to analyse this cooling chain shows potential for optimization for the dry cooler. It has the highest electrical energy use even at low external temperature.

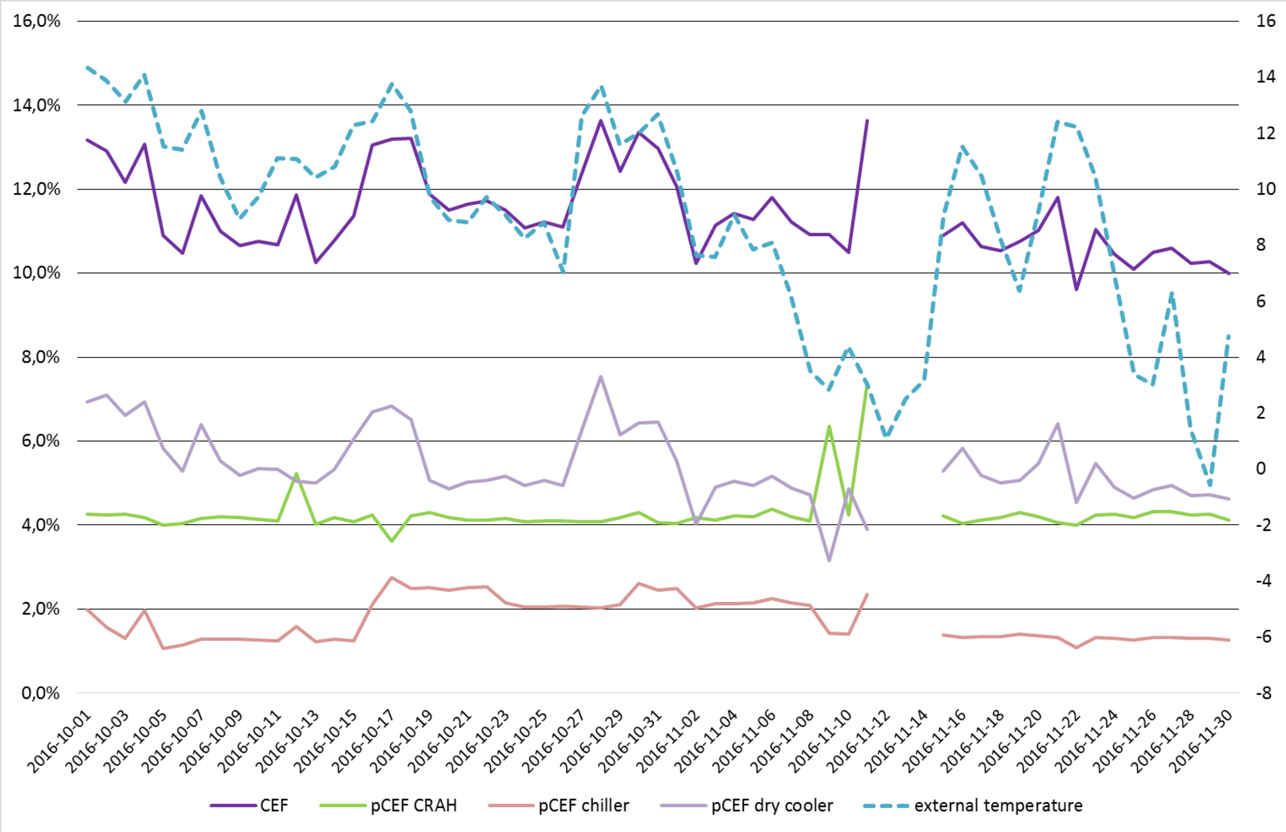

Figure D.1 — Example of measured CEF and it's derivatives

The knowledge of CEF and pCEF supports data centre operators in optimizing their cooling infrastructure and achieve desired design values.

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