INTERNATIONAL STANDARD

# ISO/IEC 30134-8

First edition
2022-03

# Information technology — Data centres key performance indicators —

## Part 8: Carbon usage effectiveness (CUE)

*Technologies de l'information — Indicateurs de performance clés des centres de données —*

*Partie 8: Performance carbone (CUE)*



Reference number
ISO/IEC 30134-8:2022(E)

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# Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 39, *Sustainability, IT and data centres*.

A list of all parts in the ISO/IEC 30134 series can be found on the ISO and IEC websites.

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# Introduction

The global economy is today 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 while 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 facilities.

The historical data generation growth rate exceeds the capacity growth rate of information and communications technology hardware. 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 (Jevons Paradox). Data generation and the consequential increase in data processing and storage are directly linked to increasing power consumption.

With this background, data centre growth, and power consumption in particular, is an inevitable consequence; this 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 water) and the reduction of $CO_2$ emissions essential.

Within the ISO/IEC 30134 series, the term “resource usage effectiveness” is 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.

Carbon usage effectiveness (CUE) is intended to enable data centre practitioners to quickly calculate the sustainability of their data centres, compare the results and determine if any energy efficiency and/or sustainability improvements need to be made. The impact of operational carbon usage is emerging as being extremely important in the design, location and operation of current and future data centres.

In order to determine the overall resource efficiency of a data centre, a holistic suite of metrics is required. This document is one of a series of International 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 efficiency. This document does not specify limits or targets for the KPI and does not describe or imply, unless specifically stated, any form of aggregation of this KPI into a combination with other KPIs for data centre resource efficiency. This document presents specific rules on CUE’s use, along with its theoretical and mathematical development. This document concludes with several examples of site concepts that could employ the CUE metric.

# Information technology — Data centres key performance indicators —

## Part 8: Carbon usage effectiveness (CUE)

## 1 Scope

This document specifies carbon usage effectiveness (CUE) as a key performance indicator (KPI) for quantifying the $CO_2$ emissions of a data centre during the use phase of the data centre life cycle.

CUE is a simple method for reporting the $CO_2$ intensity of the data centre operating. By reporting $CO_2$ emissions, it is possible to present the data centre's contribution to climate change (enhanced greenhouse effect).

This document:

a) defines the CUE of a data centre;

b) introduces CUE 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; and

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

## 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.

ISO/IEC 30134-1, *Information technology — Data centres — Key performance indicators — Part 1: Overview and general requirements*

ISO 8601-1, *Date and time — Representations for information interchange — Part 1: Basic rules*

## 3 Terms, definitions, abbreviated terms and symbols

### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

**3.1.1**
**carbon usage effectiveness**
**CUE**
ratio of the data centre annual $CO_2$ emissions and IT equipment energy demand

**3.1.2**
**total data centre energy consumption**
total annual energy consumption for all energy types serving the data centre at its boundary

Note 1 to entry: The total data centre energy is measured in kWh; the energy is measured with energy metering devices at the boundary of the data centre or at points of generation within the boundary.

Note 2 to entry: This includes energy derived from sources such as natural gas, hydrogen, bioethanol and district utilities (e.g. chilled water, condenser water).

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

[SOURCE: ISO/IEC 30134-2:2016, 3.1.7, modified.]

**3.1.3**
**IT equipment energy consumption**
energy consumed by equipment that is used to manage, process, store or route data within the compute space

Note 1 to entry: The IT equipment energy consumption is measured in kWh; examples for IT equipment are servers, storage equipment, and telecommunications equipment.

[SOURCE: ISO/IEC 30134-2:2016, 3.1.1, modified.]

**3.1.4**
**global warming potential**
radiative impact of a given greenhouse gas relative to that of carbon dioxide

**3.1.5**
**greenhouse gases**
**GHG**
gaseous constituent of the atmosphere that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere and clouds

Note 1 to entry: Within the context of this document, seven GHGs are considered: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride ($SF_6$) and nitrogen trifluoride ($NF_3$).

Note 2 to entry: A list of greenhouse gases with their recognized global warming potentials is provided in ISO 14067.

**3.1.6**
**carbon dioxide equivalent**
global warming potential of a greenhouse gas expressed in terms of the global warming potential of one unit of carbon dioxide

**3.1.7**
**emission factor for carbon dioxide**
specific carbon dioxide emission stemming from the data centre's energy use and facility operations

Note 1 to entry: The term "facility operations" covers $CO_2$ emissions caused, for example, by refrigerants or diesel generators.

## 3.2 Abbreviated terms

For the purposes of this document, the abbreviated terms in ISO/IEC 30134-1 and the following apply.



 

$CO_2$ carbon dioxide

$CO_2e$ carbon dioxide equivalent

CUE carbon usage effectiveness

DC data centre

DC $CO_2$ Data-centre-related carbon dioxide emissions

dCUE design carbon usage effectiveness

EFC emission factor for carbon dioxide

ex external

GHG greenhouse gases

GWP global warming potential

iCUE interim carbon usage effectiveness

iPUE interim power usage effectiveness

int internal

pCUE partial carbon usage effectiveness

PUE power usage effectiveness

## 3.3 Symbols

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

$C_{DC}$ $CO_2$ emissions of the data centre in kg

$C_{DC,ee}$ $CO_2$ emissions of the data centre for testing emergency power supply engines

$C_{DC,ex,el}$ data centre $CO_2$ emissions for electricity from the grid

$C_{DC,int,el}$ data centre $CO_2$ emissions for on-site generation (e.g. testing diesel engines)

$C_{DC,rf}$ data centre $CO_2$ emissions for refrigerant (leakage)

$C_S$ $CO_2$ emissions of a subsystem in kg

$c_{rf}$ filling capacity of refrigerant

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

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

$E_{ex,el}$ acquired electrical energy from outside the data centre boundaries

$E_{ex,el,ad}$ acquired electrical energy and all additional energy supply from outside the data centre boundaries

$E_{int,el}$ electrical energy produced inside the data centre boundaries

$E_{int,el,ad}$ electrical energy and all additional energy supply produced inside the data centre boundaries

$f_e$ EFC in kg $CO_2e$/kWh

$f_{e,ex}$ EFC of external energy demand in kg $CO_2e$/kWh

$f_{e,ex,el}$ EFC of external electrical energy demand

$f_{e,int}$ EFC of internal energy demand in kg $CO_2e$/kWh

$f_{e,int,el}$ EFC of internal electrical energy demand

$f_{e,int,rf}$ EFC of refrigerant

$P_{DC}$ annual average data centre power in kW

$r_{L,a}$ annual leakage rate

$r_{L,m}$ monthly leakage rate

$t_D$ runtime for diesel engines

$t_G$ runtime for gas engines

$\eta_{U,C}$ carbon usage effectiveness

$\eta_{U,C,p}$ partial carbon usage effectiveness

$\eta_{U,P}$ power usage effectiveness

$\eta_{U,P,i}$ interim power usage effectiveness

## 4 Applicable area of the data centre

CUE as specified in this document:

— is associated with the data centre infrastructure and IT equipment within its boundaries only;

— describes the CUE relative to facilities with given environmental conditions, IT load characteristics, availability requirements, maintenance and security requirements;

— measures the relationship between the total data centre $CO_2$ emissions and the IT equipment energy consumed.

CUE does not:

— account for the efficiency of other resources such as human resources, space or water;

— provide a data centre productivity metric;

— provide a standalone, comprehensive efficiency metric.

## 5 Determination of CUE

CUE provides a way to determine the carbon emissions associated with data centres. CUE has an ideal value of 0,0, indicating that no carbon use is associated with the data centre's operations. CUE has no theoretical upper boundary.

CUE is defined using Formula (1):

$$\eta_{U,C} = \frac{C_{DC}}{E_{IT}} \qquad (1)$$



 

NOTE 1 The values for $C_{DC}$ differ regarding to the CUE category (see 6.2.2).

NOTE 2 The accuracy of measuring IT energy for CUE is not necessarily the same as the accuracy of measuring IT energy for PUE (e.g. CUE category 1 can be reported with an accuracy of measuring IT energy referring to PUE category 2).

CUE may be applied in mixed-use buildings when measurement of the $CO_2$ emisions caused by the data centre and that for other functions is possible.

# 6 Measurement of CUE

## 6.1 General

All KPIs of the ISO/IEC 30134 series are defined within the same boundaries.

## 6.2 Calculation and measurement method of $CO_2$

### 6.2.1 Calculation, measurement period and frequency

The minimum calculation and measurement period requires twelve months of cumulative DC $CO_2$ values. Annualized data used to calculate CUE shall be documented. The annual DC $CO_2$ values collected or calculated shall cover the same time period. It is not necessary to define the frequency of measurement and calculation or assessments for the annual CUE determination, as the annual DC $CO_2$ value is a continuous integration of DC $CO_2$ emitted in that timeframe. The required EFC values shall be determined in accordance with Annex C.

NOTE 1 The measurement or assessment frequency can be necessary for subsystem improvements (refer to partial PUE), but is not required for CUE disclosures.

NOTE 2 Direct measurements for $CO_2$ can sometimes be taken (e.g. for diesel engines). However, calculations are also sometimes made by measurements of energy, refrigerant losses, etc. and their EFC.

### 6.2.2 Categories of CUE

#### 6.2.2.1 Introduction

CUE categories 1 to 3 are defined, as shown in Table 1, to provide a defined route that refines the extent of the carbon emission sources considered.

**Table 1 — CUE categories**

| Source | Category 1 ($CUE_1$)<br>basic | Category 2 ($CUE_2$)<br>intermediate | Category 3 ($CUE_3$)<br>advanced |
|---|---|---|---|
| Considered emission source | External and internal DC electricity. | External and internal DC electricity, all additional DC energy supply and all additional DC emission sources. | Reserved for future use. |
| Considered GHG | $CO_2$ | $CO_2$ equivalents. | Reserved for future use. |

Annex A provides examples for the calculation of the CUE categories.

#### 6.2.2.2 CUE category 1: $CO_2$ emissions from electricity only

For category 1, the $CO_2$ emissions of all internal and external power supplies are considered, taking into account electricity only. In the event that different energy sources are used, Annex B provides examples for energy conversion factors. For instance, internal power supply can come from diesel engines whereas external power supply can come from acquired electricity from the grid.

The CUE of category 1 only covers $CO_2$ as one of the GHGs.

For category 1, CUE can be calculated using Formula (2):

$$\eta_{U,C,1} = \frac{C_{DC}}{E_{IT}} = \frac{\left(E_{ex,el} \times f_{e,ex,el}\right) + \left(E_{int,el} \times f_{e,int,el}\right)}{E_{IT}} \tag{2}$$

### 6.2.2.3 CUE category 2: $CO_2$ emissions from all energy

The CUE of category 2 covers both $CO_2$ and $CO_2e$ for all external and internal power supplies, for all additional energy supplies and for all additional $CO_2e$-related emission sources.

For example, $CO_2e$ are considered for external electricity from the grid, additional data centre energy from internal combined heat and power stations based on natural gas, refrigerant losses or static transfer switches isolation gases.

For category 2 CUE can be calculated by Formula (3).

$$\eta_{U,C,2} = \frac{C_{DC}}{E_{IT}} = \frac{\left(E_{ex,el,ad} \times f_{e,ex}\right) + \left(E_{int,el,ad} \times f_{e,int}\right)}{E_{IT}} \tag{3}$$

### 6.2.2.4 CUE category 3: reserved for future use

Category 3 is reserved for future use.

# 7 Application of CUE

CUE can be used by data centre managers to monitor and report $CO_2$ emissions in relation to IT energy consumption in the data centre. This KPI can be used independently but to achieve a more holistic picture of the resource efficiency of the data centre, other KPIs of the ISO/IEC 30134 series should be considered. Using CUE particularity PUE should be considered. Where CUE is reported, the corresponding PUE value should also be reported.

# 8 Reporting of CUE

## 8.1 Requirements

### 8.1.1 Standard construct for communicating CUE data

For a reported CUE to be meaningful, the reporting organization shall provide the following information:

a) the DC under inspection,

b) the CUE value,

c) the CUE category,

d) the termination date of the period of measurement using the format of ISO 8601-1 (i.e. yyyy-mm-dd).

The CUE category shall be provided as a subscript to the name of the metric, e.g. $CUE_2$ for a category 2 value.

### 8.1.2 Data for public reporting of CUE

#### 8.1.2.1 Required information

The following data shall be provided, when publicly reporting CUE 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 are required to be displayed in public inquiries);

c) measurement results: CUE with appropriate nomenclature;

d) factors, values and year for calculating $CO_2$ emissions.

#### 8.1.2.2 Required supporting evidence

Information on the DC which shall be available upon request as a minimum includes:

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

b) measurement results: CUE with appropriate nomenclature;

c) $E_{IT}$ and DC $CO_2$;

d) measurement(s) start dates and assessment completion dates;

e) the accuracy level;

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

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

h) corresponding PUE value and category;

i) factors reference according to Annex C.

NOTE 1 The PUE category provides information on the accuracy of measuring IT energy consumption.

NOTE 2 The IEC 62052 series and IEC 62053 series provide a reference for measurement of electrical energy.



## 8.2 Recommendations

### 8.2.1 Trend tracking data

The following information can be useful in tracking the CUE trends within a DC:

a) DC size (facility $m^2$);

b) total DC design load for the facility (e.g. 10 MW);

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

d) DC contact information;

e) DC environmental conditions;

f) DC location and region;

g) DC's mission;

 

h) DC archetype percentages (e.g. 20 % web hosting, 80 % email);

i) DC commissioned date;

j) numbers of servers, routers, and storage devices;

k) average and peak server CPU utilization;

l) percentage of servers using virtualization;

m) average age of IT equipment by type;

n) average age of facility equipment by type (cooling and power distribution equipment);

o) DC availability objectives (see ISO/IEC 30134-1:2015, Annex A);

p) cooling and air-handling details.

NOTE Other KPIs within the ISO/IEC 30134 series can assist in the recording of the above information.

## 8.3 Examples of reporting CUE values

Using the construct of 8.1.1, this subclause provides two examples of specific CUE designations and their interpretation:

EXAMPLE 1

Sample CUE designations:

DC X: $CUE_1$ (2018-12-31) = 0,90 kg $CO_2$ per kWh

Interpretation:

In the year 2018 the CUE value of DC X was 0,90. It was a category 1 CUE.

EXAMPLE 2

Sample CUE designations:

DC Y: $CUE_2$ (2018-06-30) = 1,1 kg $CO_2$e per kWh

Interpretation:

In the period 2017-07-01 – 2018-06-30 the CUE value of data centre Y was 1,1. It was a category 2 CUE.

## 8.4 CUE derivatives

### 8.4.1 Purpose of CUE derivatives

Often, CUE values are needed:

a) to indicate CUE for periods less than 12 months; and/or

b) to provide the CUE for separated, non-standalone data centres (i.e. mixed building); and/or

c) to predict a desired CUE value during the design stage of the data centre.

For this purpose, CUE derivatives are introduced in 8.4.3 to 8.4.5, which address these specific needs. Each derivative shall be accompanied with specific information that describes the specific situation.



 

### 8.4.2 Using CUE derivatives

CUE reporting shall be consistent with PUE reporting. The boundary conditions of the PUE report shall be the same for CUE reporting. For reporting CUE, if there is a derivative PUE, a derivative CUE with the same boundary conditions shall be provided.

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

designed, interim pCUE (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.

### 8.4.3 Interim CUE

The definition of CUE clearly indicates that it is an annual figure. In cases where a need to report the CUE for other periods of time exists, CUE may be also reported for other time periods with a prefix "i" and the time period in the subscript e.g. $\text{iCUE}_{\text{yyyy-mm-dd – yyyy-mm-dd}}$.

It should be noted, however, that the non-annual period of CUE reporting can be affected by variables such as outdoor temperatures and is not comparable with other periodical values of CUE. The time periods shall be consistent with the reporting of iPUE or other interim KPIs.

iCUE shall describe a CUE measured for a period of less than a year.

In addition to 8.1.1, the reporting of iCUE shall include the start date of the period of measurement using the format of ISO 8601-1.

### 8.4.4 Partial CUE

Partial CUE is used to describe the CUE of a data centre that is a subset of an entity under evaluation (building or system) sharing resources with other areas not considered in the CUE assessment. Partial CUE values shall be reported with a prefix "p" as pCUE. For separate metered facilities, pCUE shall be determined and reported in all cases where a pPUE value has been determined and reported. The appropriate designation and reporting of pCUE shall be consistent with pPUE application.

The purpose of partial CUEs is the analysis of saving potential through detection of inefficient zones and infrastructure subsystems. This is the aim of the energy management process. In addition, pCUE can be used to verify effectiveness of improvement measures.

While $\text{CUE}_1$ is defined using $E_{\text{DC}}$, $\text{pCUE}_1$ is determined on the electricity use of sub-systems of the data centre's infrastructure.

While $\text{CUE}_2$ is defined using $E_{\text{DC}}$ and all additional DC $CO_2$e emission sources, $\text{pCUE}_2$ is determind on the energy use and the specific additional $CO_2$ emissions of subsystems of the DC infrastructure.

The boundaries of these subsystems are within the data centre. Therefore, pCUE applies to all kinds of data centres.

In addition to 8.1.1, the reporting of pCUE should include a list of shared resources.

Partial CUE can be calculated using Formula (4):

$$\eta_{\text{U,C,p}} = \frac{C_{\text{S}}}{E_{\text{IT}}} \qquad (4)$$

To be useful in an energy management process and carbon footprint calculation, the zones for the subsystems shall be defined in every individual data centre. Electrical distribution (including uninterruptible power supply), air handling and cooling are typical subsystems that apply to most data centres nowadays.

### 8.4.5 Design CUE

Design CUE is used to describe a predicted CUE for a data centre prior to its operation. Design CUE shall be determined as part of the planning process and should be independent of the real or expected load. Design CUE values shall be reported with a prefix “d” as dCUE. They represent a target that the designer is giving based on optimal operation of the DC. They are derived from the infrastructure element specifications and take into account the external influences such as climatic conditions at the planned DC site, etc.

In addition to 8.1.1 the reporting of dCUE should include a schedule of dCUE and dPUE based on target IT loads.



 

# Annex A
(informative)

# Examples of use

## A.1 Correct use of CUE

Annex A provides examples for the correct use and calculation of the CUE to assist in the rapid adoption of CUE through widespread understanding. These examples are all based on the same DC specifications.

The DC availability is class 3, according to ISO/IEC 22237-1. The annual IT electricity consumption, $E_{IT}$, is 700 000 kWh. The annual data centre electricity consumption, $E_{DC}$, is 900 000 kWh. The $PUE_1$ (2016-12-31) of the DC is 1,3.

There is electricity of diesel generator only in the case of missing electricity from the grid and testing. The generator is tested 4 times a year for 8 hours per test run. The nominal power of the engine is 500 kVA. There are no other plants that provide data centre electricity on-site.

The data centre runs 4 uninterupable power supplies (UPS) with 250 kVA each. The UPS provide electricity for IT euquipment and for 50 % of the computer room airconditioners. A chiller including freecooling is used. The chiller is filled with 500 kg of refrigerant (R134a) and has an annual leak rate of 10 % of the refrigerant. The power of the data centre comes from the German power grid.

NOTE The PUE in this annex is specified in ISO/IEC 30134-2.



## A.2 CUE category 1

The data centre is supplied with electricity from the power grid all year round (12 months). Therefore there are indirect $CO_2$ emissions for the electricity from the grid. The annual $CO_2$ emissions for purchased electricity are calculated as follows (using hypothetical example values):

$$C_{DC} = C_{DC,ex,el} + C_{DC,int,el}$$

For this example:

$$C_{DC,ex,el} = \eta_{U,P} \times E_{IT} \times f_{e,ex,el} = 1{,}3 \times 700\ 000\ \text{kWh} \times 0{,}47\ \text{kg}\ CO_2\text{e/kWh} = \text{approx. } 420\ 000\ \text{kg}\ CO_2$$

where $f_{e,ex,el}$ is 0,47 kg $CO_2$/kWh for the German power grid; and:

$$C_{DC,int,el} = t_D \times P_{DC} \times f_{e,int,el} = 32\ \text{h} \times 100\ \text{kW} \times 0{,}3\ \text{kg}\ CO_2/\text{kWh} = 960\ \text{kg}\ CO_2$$

So, for this example the DC CUE for category 1 is calculated as follows:

$$CUE_1 = (420\ 000\ \text{kg}\ CO_2 + 960\ \text{kg}\ CO_2) / 700\ 000\ \text{kWh} = \text{approx. } 0{,}60\ \text{kg}\ CO_2 / \text{kWh}$$

## A.3 CUE category 2

The data centre is supplied with electricity from the power grid all year round (12 months). Therefore, there are indirect $CO_2$ emissions for the electricity from the grid.

The emergency power supply engine is tested four times per year for 8 h per day. It is a gas-driven engine. DC $CO_2$ emissions for on-site generation (testing emergency power supply engines) are calculated as follows (using hypothetical example values):

$$C_{DC,int,el} = t_D \times P_{DC} \times f_{e,int,el} = 32\text{ h} \times 100\text{ kW} \times 0{,}2\text{ kg } CO_2e/\text{kWh} = 640\text{ kg } CO_2e$$

For category 2 the emissions from R134a as refrigerant are also considered. In this case the leakage rate is 10 % of the filling capacity (500 kg).

DC $CO_2$ emissions for refrigerant leackage are calculated as follows:

$$C_{DC,rf} = c_{rf} \times r_{L,a} \times f_{e,int,rf} = 500\text{ kg} \times 0{,}10 \times 1\,300\ CO_2e = 65\,000\text{ kg } CO_2e$$

So, for this example the DC CUE for category 2 is calculated as follows:

$$CUE_2 = (420\,000\text{ kg } CO_2e + 640\text{ kg } CO_2e + 65\,000\text{ kg } CO_2e) / 700\,000\text{ kWh} = \text{approx. } 0{,}70\text{ kg } CO_2e/\text{kWh}$$

## A.4 CUE category 3

Catergory 3 is reserved for future use.

## A.5 interim CUE category 2

The data centre is supplied with electricity from the power grid all year round (12 month). Therefore there are indirect $CO_2$ emissions for the electricity from the grid. The $CO_2$ emissions for purchased electricity are calculated as follows (using hypothetical example values):

$$C_{DC,ex,el} = \eta_{U,P,i(01.07.2016-31.07.2016)} \times E_{IT(01.07.2016-31.07.2016)} \times f_{e,ex,el} = 1{,}7 \times 60\,000\text{ kWh} \times 0{,}47\text{ kg } CO_2/\text{kWh} = \text{approx. } 48\,000\text{ kg } CO_2$$

where iPUE, $\eta_{U,P,i(01.07.2016-31.07.2016)}$, is 1,7 because free cooling is not available in summer.

The emergency power supply engines are tested four times per year for 8 hours per day. In this case, the emergency power supply is provided by gas engines. There was one emergency power supply between 01.07.2016 – 31.07.2016.

DC $CO_2$ emissions for on-site generation (testing emergency power supply engines) are calculated as follows:

$$C_{DC,int,el} = t_G \times P_{DC} \times f_{e,int,el} = 8\text{ h} \times 137\text{ kW} \times 0{,}2\text{ kg } CO_2e/\text{kWh} = 219\text{ kg } CO_2e$$

where

$$P_{DC} = \eta_{U,P,i} \times E_{IT} = 1{,}7 \times 60\,000\text{ kWh} / 744\text{ h} = \text{approx. } 137\text{ kW}$$

DC $CO_2$ emissions for refrigerant leakage are calculated as follows:

$$C_{DC,rf} = c_{rf} \times r_{L,m} \times f_{e,int,rf} = (500\text{ kg} \times 0{,}10 \times 1\,300\ CO_2e) / 12 = 5\,400\text{ kg } CO_2e$$

So, for this example the iCUE for category 2 is calculated as follows:

$$\eta_{U,C,i,2(01.07.2016-31.07.2016)} = (C_{DC,ex,el} + C_{DC'ee} + C_{DC,rf}) / E_{IT}$$

$$CUE_2 = (48\,000 + 219 + 5400)\text{ kg } CO_2e / 60\,000\text{ kWh} = 0{,}89\text{ kg } CO_2e / \text{kWh}$$



 

# Annex B
(informative)

# Energy conversion factors

For the conversion of the values of non-electrical energy to electrical energy, the conversion factors and heating values declared by the supplier are utilized. If no declaration of supplier for conversion factors and heating values is available, conversion factors from Table B.1 should be used. There are several energy types and methods for measuring them (see Table B.1). A range of conversion factors and measurement techniques can be found at the U.S. Energy Information Administration (EIA) website and the ASHRAE/TGG book on energy measurement.



**Table B.1 — Energy conversion examples**

| **Energy type** | **Typical units** | Conversion examples |
|---|---|---|
| Electricity | Kilowatt hour (kWh) | An annualized energy consumption is the basis |
| Diesel Fuel | Litres (l) | How many litres of fuel per year?<br>There are roughly 9,9 kWh in a litre of diesel fuel. |
| Natural Gas | Cubic metre ($m^3$) | How many cubic metres of gas per year?<br>There are roughly 10,5 kWh in 1 $m^3$ of natural gas. |
| Hydrogen | Kilogram (kg) | How many kilograms of hydrogen per year?<br>There are roughly 33,3 kWh in 1 kilogram of hydrogen (in liquid state below minus 253 °C). |
| Bioethanol | Kilogram (kg) | How many kilograms of bioethanol per year?<br>There are roughly 6,0 kWh in 1 kilogram of bioethanol. |
| Heated/cooled water | Cubic metre ($m^3$) | How much heated or cooled water was used per year?<br>There are roughly 1,16 kWh in 1 $m^3$ of water that changes its temperature by 1 °C[a]. |
| Airflow | Cubic metre ($m^3$) | How much heated or cooled air was used per year?<br>There are roughly $3,25 \times 10^{-4}$ kWh in 1 $m^3$ of air that changes its temperature by 1 °C[b]. |

[a] As a first estimate, use a difference in temperature between the water supply and return temperatures. For example, if the water is leaving at 40 °C and returning at 25 °C, there is a 15 °C temperature difference, which would mean 17,4 kWh for every $m^3$ water used.

[b] As a first estimate, use a difference in temperature between the warm air and the air it is replacing. For example, if 30 °C air is being fed to a 20 °C room, then use 10 °C as the temperature difference, which would mean $3,25 \times 10^{-3}$ kWh for every $m^3$ of air used.

The values of Table B.1 are calculated from published thermal physical properties of the individual fluids. Table B.1 is provided as a guide for informational purposes only.

 