TECHNICAL REPORT

ISO/IEC TR 21897

First edition
2022-11

Information technology — Data centres — Impact of the ISO 52000 series on energy performance of buildings

Technologies de l'information — Centres de données — Impact de la série ISO 52000 sur la performance énergétique des bâtiments

Reference number
ISO/IEC TR 21897:2022(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **iv**

Introduction ..... **v**

1 Scope **1**

2 Normative references **1**

3 Terms, definitions and abbreviated terms **1**
- 3.1 Terms and definitions 1
- 3.2 Abbreviated terms 4
- 3.3 Symbols (variables) 4
- 3.4 Symbols (indices) 5

4 Background, motivation and exclusions **6**
- 4.1 Background and motivation 6
- 4.2 Exclusions 7

5 Data centre assessment boundary **7**
- 5.1 Data centre boundary in the ISO/IEC 30134 series 7
- 5.2 Assessment boundary of the system in the ISO 52000 series 8

6 General principles of the overarching EPB framework and procedures **9**
- 6.1 Output of the method 9
- 6.2 General description of the procedures 10
- 6.3 General description of the routing 10
- 6.4 Types of assessment 11
  - 6.4.1 General 11
  - 6.4.2 Calculated energy performance 11
  - 6.4.3 Measured overall energy performance and comparison with calculations 12

7 Assessment of primary or weighted energy performance **13**
- 7.1 Weighted overall energy balance 13
- 7.2 Primary energy factors 13
- 7.3 Weighting factors for exported energy 15

8 General approach for data centre energy flows **15**
- 8.1 Data centre energy flows considered in the ISO/IEC 30134 series 15
- 8.2 General energy flows considered in the ISO 52000 series 15
  - 8.2.1 General 15
  - 8.2.2 Electricity and other carriers with exportation 16
  - 8.2.3 Energy carriers without exportation 20
  - 8.2.4 Exported heat on-site produced and not included in thermal use of the system 20
- 8.3 Data centre energy flows in an EPB approach 21

9 Impacts of the EPB approach on data centre KPIs **22**
- 9.1 Impacts on conversion factors (case of metered energy consumption) 22
- 9.2 Impact on power usage effectiveness (PUE — ISO/IEC 30134-2) 25
- 9.3 Impact on the renewable energy factor (REF — ISO/IEC 30134-3) 25
- 9.4 Impact on the energy reuse factor (ERF — ISO/IEC 30134-6) 26
- 9.5 Impact on the excess electrical energy factor (XEEF — ISO/IEC TR 23050) 26
- 9.6 Impact on IT equipment energy efficiency for servers ($ITEE_{SV}$ — ISO/IEC 30134-4) 26

Annex A (informative) **Examples of primary energy assessment of a data centre as used for PUE assessment** **27**

Annex B (informative) **Examples of primary energy assessment of data centre as used for REF assessment** **35**

Annex C (informative) **Examples of primary energy assessment of data centre as used for ERF assessment** **42**

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see https://patents.iec.ch).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html. In the IEC, see www.iec.ch/understanding-standards.

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

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

It is recognized that no “free” energy exists, even if certain processes or technical solutions are implemented in data centres, whose names can potentially suggest that energy is free (e.g. renewable energy, "free" cooling with air or water, geo-cooling, etc.).

In particular:

— even if the cost of certain renewable energy sources is low compared to non-renewable sources, there are still costs associated with the use or implementation of renewable energies such as transport and/or storage;

— some energy-efficient solutions implemented in data centres can also have other capital and operational energy costs;

— the remaining energy going out of a subsystem of a data centre, if not evaluated inside or outside the data centre boundary, is lost; every effort in order to minimize these losses results in improved energy efficiency of the data centre.

Regulatory frameworks exist (for example, in the European Union) which request primary energy assessment and that the energy consumption of computer rooms included in commercial or residential buildings can be assessed within primary energy as part of the overall energy consumption for these types of buildings.

The common objective of the key performance indicators (KPI) specified in the ISO/IEC 30134 series is the efficient or effective use or utilization of energy and other resources.

The ISO 52000 series defines methods and tools to assess the energy performance of buildings (EPB), routing and energy balance, together with greenhouse gas emissions.

These methods and tools are to be used (when mandatory) for mixed use buildings that include a data centre or server room in their premises. They can also be used in the case of stand-alone data centres.

Information technology — Data centres — Impact of the ISO 52000 series on energy performance of buildings

1 Scope

This document proposes elements for the expression of energy production, storage, reuse and consumption in reference to primary energy in data centres, taking into account both the elements needed for energy assessment and the concepts developed in the framework of the ISO 52000 series for energy performance of buildings (EPB).

This document:

— provides the main definitions and concepts from the ISO 52000 series needed to make a primary energy assessment for data centres;

— provides approaches for discriminating true sources of energy used by a given data centre;

— compares, where relevant, the terms used in both the ISO/IEC 30134 series and ISO 52000 series and provides explanations on the use of factors for converting final or delivered energy to primary energy which take a different approach in each series (and how to move from one to the other);

— illustrates the impact of using the EPB approach on data-centre-energy-related key performance indicators (KPIs), both in general and by the provision of examples;

— provides known sources of weighting or conversion factors to be used when there are no recognized or agreed local factors applicable to the studied data centre energy performance assessment.

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 (all parts), *Information technology — Data centres key performance indicators*

ISO/IEC 22237 (all parts), *Information technology — Data centre facilities and infrastructures*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in the ISO/IEC 30134 series and the ISO/IEC 22237 series and the following 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
assessment boundary
boundary where the delivered and exported energy are measured or calculated

[SOURCE: ISO 52000-1:2017, 3.4.2]

3.1.2
bin
statistical temperature class (sometimes a class interval) for the outdoor air temperature, with the class limits expressed in a temperature unitNote 1 to entry: The bin usually includes non-consecutive interval of times with the same temperature condition.

[SOURCE: ISO 52000-1:2017, 3.6.2]

3.1.3
delivered energy
energy, expressed per energy carrier, supplied to the data centre through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy

Note 1 to entry: Delivered energy can be calculated for defined energy uses or it can be measured.

[SOURCE: ISO 52000-1:2017, 3.4.6, modified — Reference to "technical building systems" replaced by "data centre".]

3.1.4
distant
<to the data centre premises>not on-site nor nearby

[SOURCE: ISO 52000-1:2017, 3.4.7, modified — Domain changed from "<to the building site>" to "<to the data centre premises>".]

3.1.5
electricity grid
public electricity network

[SOURCE: ISO 52000-1:2017, 3.4.8]

3.1.6
energy carrier
substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes

[SOURCE: ISO 52000-1:2017, 3.4.9]

3.1.7
energy source
source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process

EXAMPLE Oil or gas fields, coal mines, sun, wind, the ground (geothermal energy), the ocean (wave energy, ocean thermal energy), forests etc.

[SOURCE: ISO 52000-1:2017, 3.4.15]

3.1.8
exported energy
energy, expressed per energy carrier, supplied by the technical data centre systems through the assessment boundary

Note 1 to entry: It can be specified by generation types [e.g. combined heat and power (CHP) and photovoltaic (PV)] in order to apply different conversion factors.

Note 2 to entry: Exported energy can be calculated or it can be measured.

[SOURCE: ISO 52000-1:2017, 3.4.20, modified — Reference to "building systems" replaced by "data centre systems"; in Note 1 to entry, reference to "weighting factors" replaced by "conversion factors".]

3.1.9
final energy
energy as delivered to an energy-using system

Note 1 to entry: This concept is sometimes referred to as "delivered energy".

[SOURCE: ISO/IEC 13273-1:2015, 3.1.11, modified — Note 2 to entry deleted.]

3.1.10
nearby
<energy source> usable only at local or district level, connected to the same branch of the distribution network (for electricity: distribution network meaning medium voltage or lower) or having a dedicated connection, requiring specific equipment for the assessed data centre to be connected to it (e.g. district heating or cooling)

Note 1 to entry: This definition is based on that given for the same term in ISO 52000-1:2017, 3.4.24.

Note 2 to entry: The concept of "nearby" is expressed here in relation to the data centre premises. See Annex A and Annex B for further explanation.

3.1.11
non-renewable energy
energy taken from a source which is depleted by extraction (e.g. fossil fuels)

Note 1 to entry: Resource that exists in a finite amount that cannot be replenished on a human time scale.

[SOURCE: ISO 52000-1:2017, 3.4.26]

3.1.12
on-site
building, premises and the parcel of land on which the data centre is located

Note 1 to entry: On-site is defining a strong link between the energy source (localization and interaction) and the data centre

[SOURCE: ISO 52000-1:2017, 3.4.27, modified — References to "the building" replaced by "the data centre" in both the definition and Note 1 to entry; "Building" added to the beginning of the definition.]

3.1.13
perimeter
<boundary classification> origin of delivered energy

Note 1 to entry: This document distinguishes between "on-site", "nearby" and "distant" energy sources.

[SOURCE: ISO 52000-1:2017, 3.4.28]

3.1.14
primary energy
energy that has not been subjected to any conversion or transformation process

Note 1 to entry: Primary energy includes non-renewable energy and renewable energy. If both are taken into account it can be called total primary energy.

[SOURCE: ISO 52000-1:2017, 3.4.29]

3.1.15
technical data centre system
technical equipment for heating, cooling, ventilation, humidification, dehumidification, domestic hot water, lighting, building automation and control and electricity production (other than for IT services)

Note 1 to entry: A technical data centre system can refer to one or to several data centre services.

Note 2 to entry: A technical data centre system is composed of different sub-systems. A technical data centre sub-system is a part of a technical data centre that performs a special function (e.g. air handling, cold generation and distribution, water-based cooling, etc.).

Note 3 to entry: Electricity production can include electrical power supply generation equipment (including fuel storage), cogeneration, wind power and photovoltaic systems, transformers.

3.1.16
uninterruptible power system
UPS
combination of convertors, switches and energy storage devices (such as batteries), constituting a power system for maintaining continuity of load power in case of input power failure

Note 1 to entry: Continuity of load power occurs when voltage and frequency are within rated steady-state and transient tolerance bands, and with distortion and interruptions within the limits specified for the output port. Input power failure occurs when voltage and frequency are outside rated steady-state and transient tolerance bands, or with distortion or interruptions outside the limits specified for the UPS.

[SOURCE: IEC 62040-1:2017, 3.1.01]

3.2 Abbreviated terms

For the purposes of this document, the abbreviated terms given in the ISO/IEC 30134 series, the ISO/IEC 22237 series and the following apply.

CHP	combined heat and power
COP	coefficient of performance
EPB	energy performance of buildings
ERF	energy reuse factor
ITEEsv	IT equipment energy efficiency for servers
PV	photovoltaic
CHP	cogeneration, combined heat and power
PDU	power distribution unit
PUE	power usage effectiveness
REF	renewable energy factor
RER	renewable energy ratio
SLA	service level agreement
UPS	uninterruptible power system
XEEF	excess electrical energy factor

3.3 Symbols (variables)

For the purposes of this document, the following symbols apply. These symbols are used throughout the document in combination with the indices defined in 3.4.

E	energy consumption or loss

f	weighting factor (e.g. primary energy factor)
Q	quantity of heat
R	ratio
t	time
X	conversion factor (ratio of weighting factors)

EXAMPLE 1 $E_{pe;DC;tot}$ = total data centre primary energy

EXAMPLE 2 $E_{pe;IT;tot}$ = total information technology equipment primary energy

EXAMPLE 3 $E_{del;DC;nren}$ = non-renewable energy delivered to the data centre

EXAMPLE 4 $E_{nb;DC;ren}$ = renewable energy produced nearby the data centre

3.4 Symbols (indices)

For the purposes of this document, the following indices apply:

A	other appliances
AB	assessment boundary
an	annually
avl	available
C	temperature and humidity control systems
chp	combined heat and power
cooling	delivered (energy) used by the entire cooling system
cr(1), cr(2)..,cr(n)	energy carriers
DC	data centre
del	delivered (energy)
dhc	district heating/cooling
dst	distant
el	electricity
EnEPus;el	total energy for non-EPB uses and DC and total energy for non-EPB non-DC uses
EPus	energy performance use
excess	excess (energy)
exp	exported (energy)
gas	gas
gen	produced by the generator
grid	from public electricity grid

in	total delivered (electrical energy) provided to the data centre
IT	information technology equipment
meas	measured
nb	nearby
nDC	non-data-centre
nEPus	non-energy-performance use
nexp	without energy export
nren	non-renewable (energy)
pe	primary (energy)
pr	produced on-site
PSD	power supply and distribution
Q	quantity of heat
rdel	redelivered (energy)
ren	renewable (energy)
reuse	energy reuse
S	service
tmp	temporarily exported (to be reused later) either to the grid or to an energy storage
tot	total
we	weighted (energy)
Z	zone

4 Background, motivation and exclusions

4.1 Background and motivation

The common objective of the key performance indicators (KPIs) of the ISO/IEC 30134 series is the efficient or effective use or utilization of resources including:

— minimization of energy and other resource consumption;

— effectiveness of the IT load (processing, storage and transport) within the data centre, maximizing the IT output with the minimum energy consumption;

— reuse of unconsumed resources (e.g. energy reuse in the form of waste heat);

— utilization of renewable energy, both generated on- and off-site.

The KPIs consider the different data centre services (IT, cooling, lighting, power supply, etc.) in relation to the main form of final energy used in data centres, electricity. Final (or delivered) energy can come from different sources of primary energy, and to do such assessments it is necessary to consider if the energy is the result of investment of effort done by the data centre owner/manager or by energy providers.

In general, the ISO/IEC 30134 series provides essential tools for the resource management of data centres both in terms of operation of facilities and of decision-making. These documents can also be used to support pre-regulatory or regulatory proceedings, or to benchmark facilities projects or realizations.

In many countries approaches of incentives for energy efficiency such as energy saving certificates or certificates of renewable energy production have been implemented. Whether at the level of data centres management or at incentive or regulatory processes, the existing measures can require the energy performance to be expressed in a primary energy reference system.

The ISO 52000 series aims at achieving international harmonization of the methodology for the assessment of the energy performance of buildings (EPB). The documents from the ISO 52000 series can be used for energy assessment of buildings containing a data centre.

4.2 Exclusions

This document does not address design, material or organizational aspects of data centre power supply and energy management, but focuses instead on methods, tools and references to process delivered and exported energy data from various carriers to assess primary energy balances in data centres.

Although the following topics are important and can affect the data centre energy efficiency, they will not be covered in this document.

— Monitoring or metering of energy consumption (developed in the ISO/IEC 30134 series), due to the fact that primary energy is calculated from final energy and losses measurement or assessment.

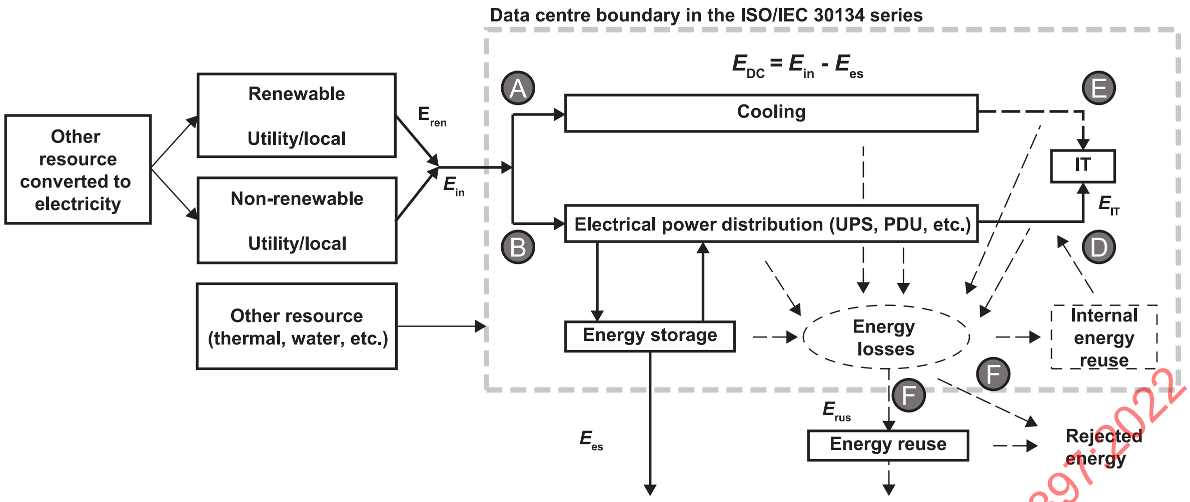
— Power quality relation to energy production, transport and transformation; assessing the primary energy balance of a data centre can lead to challenging energy carriers and it is the role of data centre managers to ensure that the choice of an energy carrier resulting from high primary energy efficiency also meets the power quality criteria such as those for electronic equipment, but these issues are not treated in this document.

NOTE ISO/IEC 30134-1:2016, Clause A.2 insists on the relationship between absolute energy consumption (contribution to KPIs) and availability of service [level of service level agreement (SLA)]. It proposes solutions based on uninterruptable power systems (UPS), stressing that tolerance to faults and ensuring availability to meet SLAs are important factors in the energy consumption of data centre equipment and infrastructures. In terms of energy assessment, the higher the power quality, the greater the potential losses in the data centre power supply to be considered, whether considering final energy (e.g. for KPIs) or primary energy (e.g. in an EPB approach).

5 Data centre assessment boundary

5.1 Data centre boundary in the ISO/IEC 30134 series

The ISO/IEC 30134 series considers the boundary of a data centre being crossed by the relevant energy flows in order to determine energy-related KPIs. Energy flows can be metered at this boundary. Flows and boundaries are illustrated in Figure 1.



Key

⟶	electrical energy
- - - -▸	thermal energy
– – –▸	re-useable energy
⟶	other energy

Figure 1 — Schema representing the concept of a data centre boundary and energy flows

For the purpose of this document E_{DC}, E_{excess} and E_{reuse} are detailed in Clause 8.

5.2 Assessment boundary of the system in the ISO 52000 series

In the EPB approach from the ISO 52000 series, the assessment boundary is related to the assessed object (e.g. data centre, data centre spaces, systems or sub-systems).

Inside the assessment boundary the system losses are explicitly taken into account in the energy balance; outside the assessment boundary they are taken into account in the conversion factor applied to the energy carrier.

Energy can be imported or exported through the assessment boundary. The assessment boundary defines the overall energy balance.

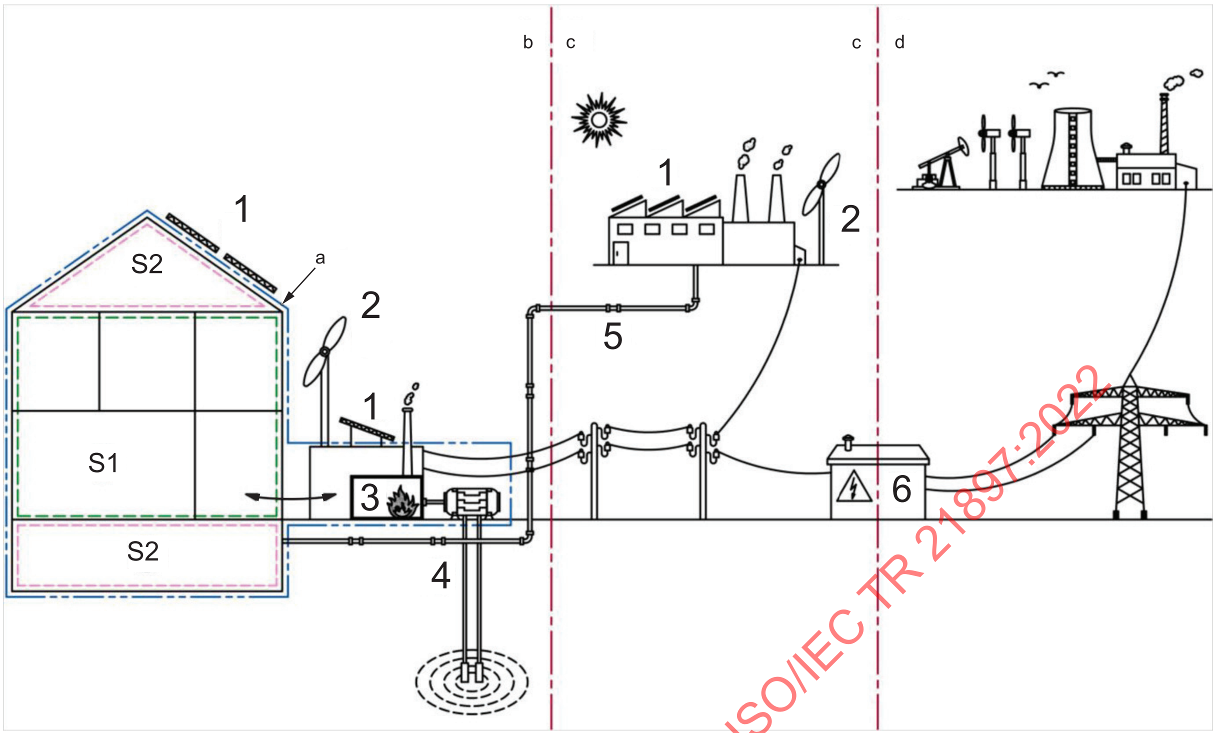
Some of these energy flows can be quantified based on the meters (e.g. gas, electricity, district heating). For active solar, wind or water energy systems the incident solar radiation on solar panels or the kinetic energy of wind or water is not part of the energy balance of the building. Only the energy delivered by the generation devices, the auxiliary energy needed to supply the energy from the source (e.g. solar collector) to the building, and the thermal losses are taken into account in the energy balance.

As shown schematically in Figure 2, the delivered energies are classified as:

— on-site,

— nearby,

— distant.



Key

a assessment boundary (use energy balance)
b on-site
c nearby
d distant

S1 thermally conditioned space
S2 space outside thermal envelope

1 photovoltaic (PV)
2 wind
3 boiler room
4 heat pump
5 district heating / cooling
6 substation (low voltage and possible storage)

Figure 2 — Schema representing the concept of perimeters and assessment boundary

Primary energy factors, or weighting factors, are defined for each energy flow delivered or exported through the assessment boundary taking into account the origin for delivered and destination for exported.

In case of energy produced on-site or nearby and for distant energy, the weighting factors are calculated according to the related EPB standards and regional/local regulations when they exist. Default values of weighting factors are proposed in Clause 9.

Inclusion or exclusion of energy contribution according to the perimeter (origin) depends on the calculation objective: e.g. for defining the renewable energy factor (REF) of ISO/IEC 30134-3 or to determine the energy flows to be taken into account in the exported energy.

6 General principles of the overarching EPB framework and procedures

6.1 Output of the method

The main output of ISO 52000-1 is the overall energy performance of a building or part of a building (e.g. building unit). Secondary outputs include breakdown in partial energy performance such as:

— per energy service (heating, lighting, etc.);

— per building unit;

— per time interval (hour, month, etc.);

— breakdown in energy flows at different perimeters and delivered versus exported energy.

6.2 General description of the procedures

ISO 52000-1 provides the modular and over-arching framework for the assessment of the energy performance of buildings.

ISO 52000-1 is the common basis for the calculated and measured energy performance and also for energy performance inspection, at whole building, building units or building element level.

The ISO 52000 series facilitates the inspection of technical building systems which can be used in the building assessment process through a tuned approach for inspection and assessment of EPB.

Depending on the application, additional documents related to the energy performance of buildings that cover other parts of the modular structure can be needed (i.e. local EPB documents).

The method to assess the energy performance of buildings has to take into account many parameters, including:

— object types: whole building, building unit, building part, or building element (building fabric or technical building system);

— building (and/or space) category (e.g. residential, office, etc.);

— application types: calculated or measured overall energy performance or inspection;

— each of these applications can in turn have different goals: check compliance with national or regional energy performance requirements, energy performance certificate;

— assessment types: design, as-built, etc.;

— energy services: heating, cooling, ventilation, (de-)humidification, domestic hot water, lighting; including building automation and control, PV and wind as energy sources, etc.

These parameters can be directly or indirectly related to national or regional regulations. It is necessary to have gathered the values of these parameters in preparation of the energy performance assessment.

6.3 General description of the routing

After this preparation, the energy assessment can be performed by completing the following steps:

a) determination of the assessment boundary and perimeters;

b) calculation or measurement of the energy flows at the assessment boundary;

c) weighting of the energy flows according to primary energy factors or other metrics (e.g. CO_2 emission); this is performed with controlling factors to allow the inclusion or exclusion from the energy performance of the effect of exported energy and of any compensation between energy carriers;

d) aggregation to the energy performance and the renewable energy contribution:

  — for calculated overall energy performance,

  — for calculated energy performance at building or system element level,

  — for measured overall energy performance.

NOTE To provide flexibility to different countries in the application of documents governing EPB, clearly identified options are allowed.

6.4 Types of assessment

6.4.1 General

The EPB assessment includes the building services and applies to assumed (standard) operating conditions. If the measured EPB assessment is not corrected to cover the same building services and assumed conditions, these two types of EPB assessment cannot be compared.

The typical applications of the different EPB assessment types is summarized in Table 1.

Table 1 — EPB assessment types

Type	Subtype	Input data			Type of application
		Use	Climate	Building	
Calculated (asset)	Design	Standard	Standard	Design	Building permit, certificate under conditions
	As-built	Standard	Standard	Actual	Energy performance certificate, regulation
	Actual	Actual	Actual	Actual	Validation
	Tailored	Depending on purpose			Optimization, validation, retrofit planning, energy audit
Measured (operational)	Actual	Actual	Actual	Actual	Monitoring
	Climate-corrected	Actual	Corrected to standard	Actual	Monitoring, energy audit
	Use-corrected	Corrected to standard	Actual	Actual	Monitoring
	Standard	Corrected to standard	Corrected to standard	Actual	Energy performance certificate, regulation

6.4.2 Calculated energy performance

6.4.2.1 Output data

The output data of this type of assessment are listed in Table 2.

Table 2 — Calculated energy performance output data

Description	Symbol	Unit
Total yearly output data		
Weighted energy performance[a]	E_{we}	kWh/an kg CO_2/an €/an
Renewable energy ratio[b] (RER)	R_{ren}	—
Electricity available for use outside the building	$E_{exp;el;avl;an}$	kWh/an
Yearly output data per service or per building zone		

[a] Although the scope of this document focuses on energy balances, the same concepts apply to carbon equivalent emission assessments (they are not developed in this document).

[b,c] The renewable energy ratio (RER; R_{ren}) is the ratio of renewable primary energy of the building (per service) to the total primary energy of the building (for that service).

Table 2 *(continued)*

Description	Symbol	Unit
Weighted energy performance per service or per zone or per service and zone	$E_{we;S}$ $E_{we;S;z(i)}$	kWh/an kg CO_2/an €/an
Renewable energy ratio (RER) per service[c]	$R_{ren,S}$	—
Delivered energy per service or per zone or per service and zone	$E_{del;S}$ $E_{del;S;z(i)}$	kWh/an

[a] Although the scope of this document focuses on energy balances, the same concepts apply to carbon equivalent emission assessments (they are not developed in this document).

[b,c] The renewable energy ratio (RER; R_{ren}) is the ratio of renewable primary energy of the building (per service) to the total primary energy of the building (for that service).

6.4.2.2 Calculation interval

The possible calculation intervals are:

— hourly,

— monthly,

— seasonal,

— yearly,

— bin.

The calculation interval needs to be consistent throughout the whole calculation. Provisions to combine different calculation intervals are given in the relevant modules of local EPB standards.

6.4.3 Measured overall energy performance and comparison with calculations

6.4.3.1 General

This method is only applicable to existing buildings in the use phase.

The measured energy performance is calculated in the same way as the calculated energy performance using the measured delivered and exported energy amounts $E_{del;cr(i);meas}$ and $E_{exp;cr(j);meas}$ instead of the corresponding calculated amounts.

6.4.3.2 Output of the method

The output of the measured energy performance is in principle the same as the output from the calculated energy performance given in Table 2, with the following restrictions:

— the history of the energy delivery and export is seldom known (seasonal or yearly amounts only are usually known), therefore the ratio between exported and redelivered energy has to be assumed as null;

— the renewable energy ratio cannot be determined if the contribution of renewable sources cannot be measured;

— the availability of measured energy data for specific services and/or building zones depends on the number and quality of installed metering devices.

6.4.3.3 Measurement intervals and measurement period

The calculation period (time span over which the energy performance is evaluated) is the same as for the calculated energy performance.

The measurement interval is the time span between readings of meters or use of known amounts of energy. If there are several energy carriers and/or energy uses, measurement intervals can be asynchronous.

The measurement period is the interval of time covered by measurement intervals. In order to average out the effect of climate and/or user behaviour, the required measurement period can be a multiple of the calculation period.

Validation criteria specify the required number of measurement intervals and the minimum required duration of the measurement period.

7 Assessment of primary or weighted energy performance

7.1 Weighted overall energy balance

The weighted overall energy, E_{we}, is calculated with using Formula (1):

$$E_{we} = E_{we;del;an} - E_{we;exp;an} \quad (1)$$

where

$E_{we;del;an}$ is the annual weighted delivered energy;

$E_{we;exp;an}$ is the annual weighted exported energy, including temporarily exported energy, calculated according to Formula (4).

In order to allow time-dependent weighting factors, the weighting can be performed in each calculation interval (see 6.4.2.2).

$E_{we;del;an}$ is given by Formula (2):

$$E_{we;del;an} = E_{we;del;nexp;an} + E_{we;del;el;an} \quad (2)$$

where

$E_{we;del;nexp;an}$ is the annual weighted delivered energy for all carriers without energy export, according to Formula (5);

$E_{we;del;el;an}$ is the annual weighted delivered electricity, according to Formula (3).

7.2 Primary energy factors

The basic idea of primary energy balance is that each energy flow crossing the assessment boundary is characterized by the following set of properties:

— $E_{del;exp}$, which is the actual energy amount of energy crossing the assessment boundary;

— $E_{pe;nren}$, which is the associated non-renewable primary energy;

— $E_{pe;ren}$, which is the associated renewable primary energy;

— $E_{pe;tot}$, which is the total associated primary energy and is given by $E_{pe;nren} + E_{pe;ren}$.

The associated amount of primary energy is the energy that has been extracted from the sources (before any transformation) to provide the actual energy amount where it is evaluated.

This includes:

— as a minimum, the actual energy;

— as a common option, the transport overheads (typical example is 1,1 for fossil fuels);

— as a further possible option, the energy overhead for infrastructure construction (default value was 1,35 for fossil fuels in EN 15603).

The primary energy factors are the ratio of a given type of primary energy (renewable, non-renewable, total) to the actual energy amount.

Different values for the primary energy factors are possible for energy exported, redelivered or exported to functions at the data centre site that are not included in the energy performance.

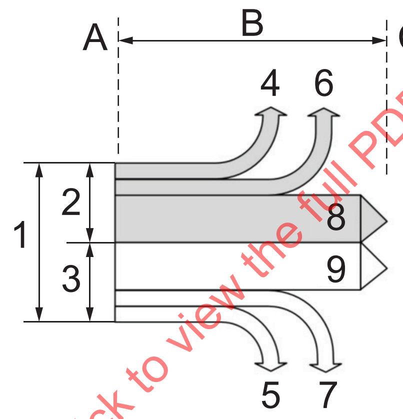
The primary energy factor from delivered and exported energy can be different. It can also differ depending on the energy carrier.

For each delivered or exported energy flow or energy carrier there are three primary energy factors (see Figure 3):

— total primary energy factor ($f_{pe;tot}$),

— non-renewable primary energy factor ($f_{pe;nren}$),

— renewable primary energy factor ($f_{pe;ren}$).



$$f_{pe;tot} = \frac{1}{8+9} \quad f_{pe;nren} = \frac{2}{8+9} \quad f_{pe;ren} = \frac{3}{8+9}$$

Key

A energy source in nature
B upstream chain of energy supply
C inside the assessment boundary

1 total primary energy
2 non-renewable primary energy
3 renewable primary energy
4 non-renewable infrastructure related energy
5 renewable infrastructure related energy
6 non-renewable energy to extract, refine, convert and transport
7 renewable energy to extract, refine, convert and transport
8 delivered non-renewable energy
9 delivered renewable energy

Figure 3 — Primary energy factors

7.3 Weighting factors for exported energy

There are two complementary types of weighting factor for exported energy. They are based on the evaluation of:

— the resources used to produce the exported energy carrier, that are used for "Step A" evaluation (see ISO 52000-1:2017, 9.6.6.2);

— the resources avoided by the external grid due to the export of the energy carrier, that are used for "Step B" evaluation (see ISO 52000-1:2017, 9.6.6.3).

8 General approach for data centre energy flows

8.1 Data centre energy flows considered in the ISO/IEC 30134 series

The data centre energy flows of the ISO/IEC 30134 series are shown in Figure 1.

Unless explicitly mentioned, all assessments in the ISO/IEC 30134 series are made with delivered, non-weighted (or final) energy flows since electricity from the grid is the most common energy carrier used for data centre services. In order to take into account energy carriers other than electricity, conversion factors are given in the annexes of ISO/IEC 30134-6:2021 to integrate those carriers in the KPI assessments, in relation to final energy flows. The relation between conversion factors used in the ISO/IEC 30134 series and the weighting factors (or primary energy factors) used in ISO 52000 series is developed in 9.1.

The main energy flows (by default on an annual basis) considered in ISO/IEC 30134 series are:

— E_{DC} which is the total data centre energy consumption;

— E_{IT} which is IT equipment energy consumption;

— $E_{cooling,DC}$ which is the delivered energy used by the entire cooling system attributable to data centre services;

— E_{PSD} which is the losses of energy in the power supply and distribution system;

— E_{in} which is the total delivered electrical energy provided to the data centre, calculated as follows:

$$E_{in} = E_{ren} + E_{nren}$$

where

E_{ren} is the total delivered electrical energy produced by renewable energy sources either from the grid or produced locally; and

E_{nren} is the total delivered electrical energy produced by non-renewable energy sources either from the grid or produced locally.

8.2 General energy flows considered in the ISO 52000 series

8.2.1 General

The overarching approach for calculating the energy performance of a system (building) is provided in Formula (1).

The following subclauses outline the details needed for this calculation as follows:

— for electricity and any other energy carriers with exportation: 8.2.2;

— for other carriers that are not exported: 8.2.3.

The case of exported heat produced on-site and not included in thermal use of the system is developed in 8.2.4.

8.2.2 Electricity and other carriers with exportation

Energy uses relevant to energy performance of buildings, $E_{EPus;el}$, are provided by the grid (both delivered directly, $E_{del;el;EPus}$, and redelivered, part of $E_{rdel;el;EPus}$), by energy storage (considered as redelivered, remaining part of $E_{rdel;el;EPus}$) or produced on-site, $E_{pr;el;EPus}$. Related energy flows are calculated using Formula (3):

$$E_{EPus;el} = E_{del;el;EPus} + E_{rdel;el;EPus} + E_{pr;el;EPus} \tag{3}$$

Energy uses not relevant to energy performance of buildings, $E_{nEPus;el}$, are provided by the grid (both delivered directly, $E_{del;el;nEPus}$, and redelivered, part of $E_{rdel;el;nEPus}$), by energy storage (considered as redelivered, remaining part of $E_{rdel;el;nEPus}$) or produced on-site, $E_{pr;el;nEPus}$. Related energy flows are calculated using Formula (4):

$$E_{nEPus;el} = E_{del;el;nEPus} + E_{rdel;el;nEPus} + E_{pr;el;nEPus} \tag{4}$$

Energy produced on-site, $E_{pr;el}$, is used for energy performance of buildings matters, $E_{pr;el;EPus}$, for other uses inside the system not relevant to energy performance of buildings, $E_{pr;el;nEPus}$, and exported (definitively to be transported and used by other grid subscribers, $E_{exp;el;grid}$, or temporarily as local storage or injected to the grid to be used after a small period of time, $E_{exp;el;tmp}$). Related energy flows are calculated using Formula (5):

$$E_{pr;el} = E_{pr;el;EPus} + E_{pr;el;nEPus} + E_{exp;el;grid} + E_{exp;el;tmp} \tag{5}$$

Energy redelivered, $E_{del;el;rdel}$, either from the grid or from local storage, is used for energy performance of buildings matters, $E_{del;el;rdel}$, and for other uses inside the system not relevant to energy performance of buildings, $E_{rdel;el;nEPus}$. Related energy flows are calculated using Formula (6):

$$E_{del;el;rdel} = E_{rdel;el;EPus} + E_{rdel;el;nEPus} \tag{6}$$

$$E_{del;el;rdel} = E_{exp;el;tmp}$$

Energy delivered from the grid, $E_{del;el;grid}$, is used for energy performance of buildings matters, $E_{del;el;EPus}$, and for other uses inside the system not relevant to energy performance of buildings, $E_{del;el;nEPus}$. Related energy flows are calculated using Formula (7):

$$E_{del;el;grid} = E_{del;el;EPus} + E_{del;el;nEPus} \tag{7}$$

These energy flows for carriers with exportation are illustrated in Figure 4.

Energy uses for data centres are not considered as contributing to the energy performance of buildings with which they are included for an assessment. The above formulae are to be used in a simple case where the assessed system consists only of the data centre facility and buildings.

In the case of a system in which a data centre facility is accommodated in buildings using energy for other purposes, energy uses considered as non-relevant to energy performance of buildings, $E_{nEPus;el}$, have to be assessed separately for the data-centre, as $E_{DC;el}$, and the remaining installations $E_{nDC;el}$ (see Figure 5), as in Formula (8):

$$E_{nEPus;el} = E_{DC;el} + E_{nDC;el} \tag{8}$$

where

$$E_{DC;el} = E_{del;el:DC} + E_{rdel;el;DC} + E_{pr;el;DC} \text{ and } E_{nDC;el} = E_{del;el:nDC} + E_{rdel;el;nDC} + E_{pr;el;nDC}$$

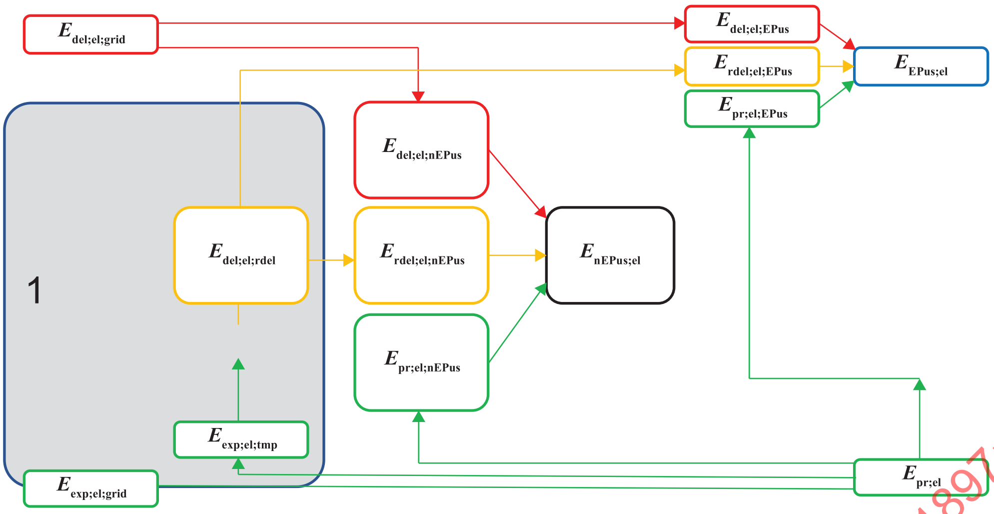
with

$$E_{del;el:nEPus} = E_{del;el;DC} + E_{del;el;nDC}$$

$$E_{rdel;el;nEPus} = E_{rdel;el;DC} + E_{rdel,el;nDC}$$

$$E_{pr;el;nEPus} = E_{pr;el;DC} + E_{pr;el;nDC}$$

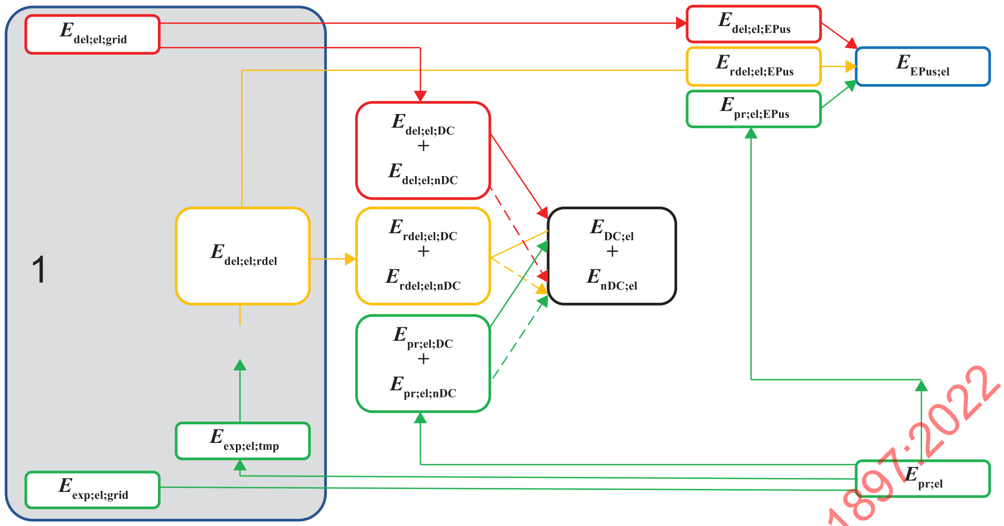
Calculation or measurement rules for both $E_{nDC;el}$ and $E_{EPus;el}$ are not developed in this document and can be achieved under the principles of the ISO 52000 series.



Key

blue square	EPB uses of electricity	$E_{EPus;el}$	total energy for EPB uses
black square	non-EPB uses of electricity	$E_{nEPus;el}$	total energy for non-EPB uses
red square	delivered electricity from the grid	$E_{del;el;grid}$	total energy delivered by the grid
red arrow	flow of delivered electricity	$E_{del;el;EPus}$	delivered energy for EPB uses
		$E_{del;el;nEPus}$	delivered energy for non-EPB uses
green square	on-site produced electricity	$E_{pr;el}$	total energy produced on-site
green arrow	flow of on-site produced electricity	$E_{pr;el;EPus}$	energy produced on-site for EPB uses
		$E_{pr;el;nEPus}$	energy produced on-site for non-EPB uses
		$E_{exp;el;grid}$	energy produced on-site exported to the grid
		$E_{exp;el;tmp}$	energy produced on-site temporarily exported (to be reused later) either to the grid or to an energy storage
yellow square	redelivered electricity	$E_{del;el;rdel}$	total redelivered energy
yellow arrow	flow of redelivered electricity	$E_{rdel;el;EPus}$	redelivered energy for EPB uses
		$E_{rdel;el;nEPus}$	redelivered energy for non-EPB uses

Figure 4 — General reference energy balance and energy flows for carriers with exportation



Key

blue box	EPB uses of electricity
black box	non-EPB uses of electricity
red box	delivered electricity from the grid
red arrow	flow of delivered electricity
red dashed arrow	flow of delivered electricity
green box	on-site produced electricity
green arrow	flow of on-site produced electricity
green dashed arrow	flow of on-site produced electricity
yellow box	redelivered electricity
yellow arrow	flow of redelivered electricity
yellow dashed arrow	flow of redelivered electricity

$E_{EPus;el}$	total energy for EPB uses
$E_{DC;el}$	total energy for non-EPB DC uses
$E_{nDC;el}$	total energy for non-EPB non-DC uses
$E_{del;el;grid}$	total energy delivered by the grid
$E_{del;el;EPus}$	delivered energy for EPB uses
$E_{del;el;DC}$	delivered energy for non-EPB DC uses
$E_{del;el;nDC}$	delivered energy for EPB non-DC uses
$E_{pr;el}$	total energy produced on-site
$E_{pr;el;EPus}$	on-site produced energy for EPB uses
$E_{pr;el;DC}$	on-site produced energy for non-EPB DC uses
$E_{pr;el;nDC}$	on-site produced energy for non-EPB non-DC uses
$E_{exp;el;grid}$	on-site produced energy exported to the grid
$E_{exp;el;tmp}$	on-site produced energy temporarily exported (to be reused later) either to the grid or to an energy storage
$E_{del;el;rdel}$	total redelivered energy
$E_{rdel;el;EPus}$	redelivered energy for EPB uses
$E_{rdel;el;DC}$	redelivered energy for non-EPB DC uses
$E_{rdel;el;nDC}$	redelivered energy for non-EPB non-DC uses

Figure 5 — General energy flows applied to data centres for carriers with exportation

The contribution to the annual weighted energy performance of delivered electricity, $E_{we;del;el;an}$, is given by Formula (9):

$$E_{we;del;el;an} = \sum_{t} E_{del;el;t} \times f_{we;del;el;t} \quad (9)$$

where

$E_{del;el;t}$ is the delivered electricity in each calculation interval, t;

$f_{we;del;el;t}$ is the time-dependent weighting factor of delivered electricity.

The contribution of exported electricity to the annual weighted energy performance, $E_{we;exp;el;an}$, is given by Formula (10):

$$E_{we;exp;el;an} = E_{we;exp;el;an;A} + k_{exp} \times \sum_i E_{we;exp;el;cr(i);an;AB} \tag{10}$$

where

$E_{we;exp;el;an;A}$ is the weighted exported electricity calculated using factors that reflect the resources used to generate the exported electricity;

$E_{we,exp,el,cr(i);an;AB}$ is the difference between the weighted exported energy calculated using factors that reflect the avoided resources off-site the studied system and the weighted exported energy using factors that reflect the resources used to generate the exported energy;

k_{exp} is a factor that is used to control which part of the exported energy is included in the energy performance of the system.

8.2.3 Energy carriers without exportation

The annual weighted delivered energy, $E_{we;del;nexp;an}$, for all energy carriers, cr(j), without energy export is calculated using Formula (11).

$$E_{we;del;nexp;an} = \sum_t \left(\sum_j E_{del;cr(j);t} \times f_{we;del;cr(j);t} \right) \tag{11}$$

where

$E_{del;cr(j);t}$ is the amount of the delivered energy carrier, cr(j), during time-step, t

$f_{we;del;cr(j);t}$ is the time-dependent weighting factor for the delivered energy carrier, cr(j).

8.2.4 Exported heat on-site produced and not included in thermal use of the system

In this subclause the production of heat by a generator is considered either by a dedicated generator like a combined heat and power (CHP) system producing both electricity and thermal energy from an energy carrier (e.g. gas) or by any system recovering heat losses from the data centre (e.g. from racks in a server room) to heat offices/spaces inside the data centre or in the building (case of a mixed-use building with a data centre) and/or to feed in a district heating system (the heat being used outside the data centre system).

The effect of non-EPB thermal use or of thermal energy export is excluded from the energy performance assessment (see Figure 6) with the following procedure.

For each energy carrier or input to the generator (or the set of generators) $E_{del;cr(i)}$ in kWh, generating heat:

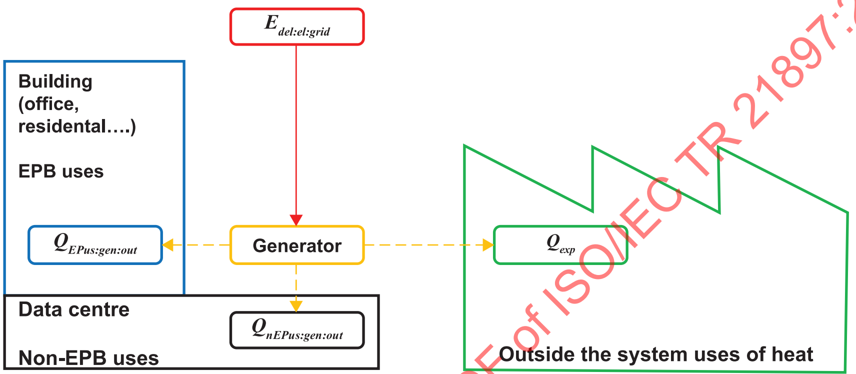
— the generator(s) input, $E_{del;cr}$, is calculated, taking into account all loads, $Q_{EPus;gen}$, $Q_{nEPus;gen}$ and Q_{exp},

where

$Q_{\mathrm{EPus;gen}}$	is the heat generated for the considered on-site EPB services;
$Q_{\mathrm{nEPus;gen}}$	is the heat generated for other on-site uses than the considered EPB services;
Q_{exp}	is the heat exported.

— the share of each energy carrier, $E_{\mathrm{del,cr}(i);\mathrm{EP}}$, is calculated in kWh and is to be taken into account in the energy performance assessment with Formula (12):

$$E_{\mathrm{del;cr}(i);\mathrm{EP}} = E_{\mathrm{del;cr}(i)} \times \frac{Q_{\mathrm{EPus;gen}} + Q_{\mathrm{nEPus;gen}}}{Q_{\mathrm{EPus;gen}} + Q_{\mathrm{nEPus;gen}} + Q_{\mathrm{exp}}} \quad (12)$$



Key

- red box: energy delivered to the on-site heat generator from a carrier, $E_{\mathrm{del;cr}}$
- red arrow: flow of delivered energy to the on-site heat generator
- yellow box: on-site heat generator
- yellow dashed arrow: flow of thermal energy (heat)
- blue box: on-site heat produced by the generator for EPB uses, $Q_{\mathrm{EPus;gen}}$
- black box: on-site heat produced by the generator for non-EPB uses, $Q_{\mathrm{nEPus;gen}}$
- green box: on-site heat produced by the generator and exported for distant uses, Q_{exp}

Figure 6 — Reference diagram for thermal energy export

8.3 Data centre energy flows in an EPB approach

To illustrate the respective and equivalent energy flows of both approaches from the ISO/IEC 30134 series and the ISO 52000 series , the case of a data centre (non-EPB uses of energy), with some building facility (EPB uses) attached to the data centre, will be considered hereafter, corresponding to Figure 1 and Figure 4 in the case of electricity delivered by the grid and produced locally with renewable and non-renewable sources.

With reference to Figure 1 and Figure 4, Formula (13) shows:

$$E_{\mathrm{DC}} = E_{\mathrm{nEPus;el}} = E_{\mathrm{del;el;nEPus}} + E_{\mathrm{rdel;el;nEPus}} + E_{\mathrm{pr;el;nEPus}} \quad (13)$$

where the non-EPB uses of electrical energy of the data centre are:

$E_{del;el;nEPus}$ is the total electrical energy delivered from the grid including electricity produced on distant sites by renewable and non-renewable sources;

$E_{rdel;el;nEPus}$ is the electrical energy, produced locally or nearby either by renewable (e.g. PV, wind) or by non-renewable (e.g. generators powered by diesel fuels for additional supply), and temporarily stored (e.g. in batteries of a UPS) on a short period of time and redelivered;

$E_{pr;el;nEPus}$ is the total electrical energy produced locally or nearby either by renewable (e.g. PV, wind) or by non-renewable (e.g. generators powered by diesel fuels for additional supply).

With reference to Figure 1 and Figure 4, Formula (14) shows:

$$E_{excess} = E_{pr;el;EPus} + E_{rdel;el;EPus} + E_{exp;el;grid} \quad (14)$$

where

$E_{pr;el;EPus}$ is the total on-site or nearby produced electrical energy for EPB uses (i.e. in the attached building);

$E_{rdel;el;EPus}$ is the electrical energy, produced locally or nearby either by renewable (e.g. PV, wind) or by non-renewable (e.g. generators powered by diesel fuels for additional supply), temporarily stored (e.g. in batteries of a UPS) on a short period of time and redelivered for EPB uses (i.e. in the attached building);

$E_{exp;el;grid}$ is the total electrical energy produced locally or nearby either by renewable (e.g. PV, wind) or by non-renewable (e.g. generators powered by diesel fuels for additional supply), exported to the grid.

With reference to Figure 1 and Figure 4, two options are possible for E_{reuse}:

1) in the case of a stand-alone data centre (without any EPB uses of energy associated with the data centre):

$$E_{reuse} = Q_{exp}$$

2) in the case of a data centre in a mixed-use building (with EPB uses of energy):

$$E_{reuse} = Q_{EPus;gen;out} + Q_{exp}$$

More detailed cases are presented in Annexes A, B and C.

9 Impacts of the EPB approach on data centre KPIs

9.1 Impacts on conversion factors (case of metered energy consumption)

The EPB approach affects KPIs that consider energy consumption and estimate the relative share of these consumptions provided by different sources of energy.

In general, the energy-related KPIs for data centres are calculated with reference to electricity, the most common form of final energy. In the case of mixed uses of energy, the ISO/IEC 30134 series provides default conversion factors to express those uses of energy from various carriers in reference to electrical energy. As the EPB approach is based on primary energy, default conversion factors to a common reference (weighting factors) are provided in ISO 52000-1 for different energy carriers.

The following formulae are used to compare the default values for final electrical energy and primary energy in both series of standards. To compare primary energy needed from two different carriers of energy, cr(i) and cr(j), in reference to final energy respectively for each carrier, the following relations are used:

$$E_{pe;cr(i)} = f_{pe;cr(i)} \times E_{del;cr(i)} \text{ and } E_{pe;cr(j)} = f_{pe;cr(j)} \times E_{del;cr(j)}$$

where

$$E_{pe;cr(i)} = E_{pe;cr(j)}$$

$$f_{pe;cr(i)} \times E_{del;cr(i)} = f_{pe;cr(j)} \times E_{del;cr(j)}$$

The expression of final energy from carrier i in relation to carrier j is given by Formula (15):

$$E_{del;cr(i)} = \frac{f_{pe;cr(j)}}{f_{pe;cr(i)}} \times E_{del;cr(j)} \quad (15)$$

Weighting factors, $f_{pe;cr(i)}$, are those used in the ISO 52000 series, while conversion factors are those used in the relevant parts of the ISO/IEC 30134 series. These conversion factors are ratios of weighting factors, as shown in Formula (16):

$$_{i}^{j}X = \frac{f_{pe;cr(j)}}{f_{pe;cr(i)}} \quad (16)$$

Formula (15) can be expressed now as follows [Formula (17)]:

$$E_{del;cr(i)} = {}_{i}^{j}X \cdot E_{del;cr(j)} \quad (17)$$

and the relationship between weighting factors from carriers i and j can be expressed as shown in Formula (18):

$$f_{pe;cr(j)} = {}_{i}^{j}X \cdot f_{pe;cr(i)} \quad (18)$$

For the ISO/IEC 30134 series it has been decided to refer only to electricity (el) as final energy (i).

As a practical example for district cooling, the weighting factor proposed as default in ISO 52000-1:2017, Annex B is $f_{pe;dhc;tot}$ = 1,3 with the default weighting factor for electricity, $f_{pe;el;tot}$ = 2,5. The resulting conversion factor for district cooling is calculated with Formula (19) as:

$$_{el}^{dhc}X = \frac{f_{pe;dhc;tot}}{f_{pe;el;tot}} = \frac{1,3}{2,5} = 0,52 \quad (19)$$

The value obtained is different from the default one proposed in ISO/IEC 30134-2:2016 of 0,4. But taking a weighting factor for electricity $f_{pe;el;tot}$ = 3,34 as commonly used in North America (2,5 being common for Europe), the conversion factor becomes 0,39.

Keeping the example of district cooling (or district chilled water), the conversion factor proposed as default in ISO/IEC 30134-2:2016, Annex B, $_{el}^{dhc}X$ = 0,4. This value has been agreed upon by specialists gathered in an international task force to harmonize global metrics for data centre energy efficiency with a weighting factor for electricity $f_{\text{pe;el;tot}}$ = 3,34. The weighting factor for district cooling is calculated with Formula (20) as:

$$f_{\text{pe;dhc;tot}} = {}^{\text{dhc}}_{\text{el}}X \cdot f_{\text{pe;el;tot}} = 0{,}4 \times 3{,}34 = 1{,}34 \quad (20)$$

The value obtained is very close to the default value of this weighting factor for this carrier in ISO 52000-1:2017, Annex B, of 1,3. But taking the default weighting factor for electricity $f_{\text{pe;el;tot}}$ = 2,5, the resulting weighting factor for district cooling would be as shown in Formula (21):

$$f_{\text{pe;dhc;tot}} = 0{,}4 \times 2{,}5 = 1 \quad (21)$$

Table 3 compares the default values of weighting factors proposed in ISO 52000-1 to the equivalent ones calculated from conversion factors used in the ISO/IEC 30134 series.

Table 3 — Default weighting factors proposed by EPB standards and their equivalent from data centre KPI standards

			From EN ISO 52000-1:2017			ISO/IEC 30134 series equivalent, $f_{\text{pe;tot}}$	
			$f_{\text{pe;nren}}$	$f_{\text{pe;ren}}$	$f_{\text{pe;tot}}$	$f_{\text{pe;el;tot}}$ = 2,5	$f_{\text{pe;el;tot}}$ = 3,34
	Delivered from distant source						
1	Fossil fuels	Solid	1,1	0	1,1	0,88	1,17
2		Liquid	1,1	0	1,1	0,88	1,17
3		Gaseous	1,1	0	1,1	0,88	1,17
4	Bio fuels	Solid	0,2	1	1,2		
5		Liquid	0,5	1	1,5		
6		Gaseous	0,4	1	1,4		
7	Electricity		2,3	0,2	2,5	2,5	3,34
	Delivered from nearby source						
8	District heating	1,3	0	1,3	1	1,34	
9	District cooling	1,3	0	1,3	1	1,34	
	Delivered from on-site						
10	Solar	PV	0	1	1		
11		Thermal	0	1	1		
12	Wind		0	1	1		
13	Environment	Geo-, aero-, hydrothermal	0	1	1		
	Exported electricity						
14	Never redelivered		2,3	0,2	2,5	2,5	3,34
15	Temporary exported and redelivered later		2,3	0,2	2,5	2,5	3,34
16	To non-EPB uses		2,3	0,2	2,5	2,5	3,34

Table 4 compares the default values of conversion factors used in the ISO/IEC 30134 series to the equivalent ones calculated from weighting factors proposed in ISO 52000-1.

Table 4 — Default conversion factors proposed in data centre KPI standards and their equivalent from EPB standards

Energy carrier	${}^{\text{cr}}_{\text{el}}X$		
	ISO/IEC 30134 series	ISO 52000-1 equivalent	
		$f_{\text{pe;el;tot}}$ = 2,5	$f_{\text{pe;el;tot}}$ = 3,34
District chilled water	0,4	0,52	0,39
District hot water	0,4	0,52	0,39
District steam	0,4	0,52	0,39
Fuel (for absorption type chiller)	0,35	0,4	0,35

9.2 Impact on power usage effectiveness (PUE — ISO/IEC 30134-2)

Power usage effectiveness (PUE) is a ratio of energies.

The impact of expressing these energies in reference to primary or final energies can not have any impact if the only form of energy used in the data centre is electricity (including that used for environmental controls) and if there is no energy exported from the data centre.

Where mixed energy sources are used in the data centre, and conversion factors of other energies to electricity are chosen (see 8.1), the impact can be limited to the inclusion/exclusion of "free" energies (e.g. direct free cooling with external air, water cooling from streams or lakes, geo-cooling). Excluding those free energies from the PUE calculation results in lower PUE values than assessing their thermal energy content, except if they are exported (reused) outside the data centre.

Examples of primary energy assessments are given in Annex A. These examples are based on those proposed in ISO/IEC 30134-2:2016, Annex B.

In the case of derivative PUE assessments, such as interim PUE (iPUE) or partial PUE (pPUE), data collected for their calculation can also be retrieved for primary energy assessments.

As ISO 52000-1 considers hourly, monthly, seasonal and annual periods for energy performance assessment, iPUE on the same reference period (hourly, monthly, or seasonal) in general would not be impacted.

pPUE can address the case of mixed uses buildings, which is the general framework of the ISO 52000 series.

9.3 Impact on the renewable energy factor (REF — ISO/IEC 30134-3)

The main impact of considering primary energy assessment with renewable energies used in a data centre is in the characterization of the origin of renewable energies.

ISO/IEC 30134-3 considers the final renewable energies as the same whether they are produced on-site or purchased from the utility with a certificate, but does not take into account the renewable character if the energy is coming from an installation in the neighbourhood of the data centre (e.g. if there is no official certificate involved).

ISO 52000-1 considers the on-site or nearby production of renewable energies to be equivalent in terms of primary energy due to low or no losses of energy to transport it to the data centre. In the case of renewable energy bought to a utility or via certificates, primary energy assessment of this form of renewable energy takes into account losses of energy for transport in the grid.

Due to different hypothesis in their respective definitions, even though they are both ratios of renewable energy by total energy (final energies for REF and primary energies for RER), REF and RER can provide different values for a given configuration of a stand-alone data centre.

Examples of primary energy assessments are given in Annex B. These examples are based on those proposed in ISO/IEC 30134-3:2016, Annex B.

9.4 Impact on the energy reuse factor (ERF — ISO/IEC 30134-6)

The energy reuse factor (ERF) is based on the assessment of data centre energy losses recovered as thermal energy used outside the data centre. This type of assessment is considered in ISO 52000-1 with the possible use of recovered energy in other buildings or building parts to improve the energy performance of the system in which the data centre is included (outside the assessment boundary of the data centre considering the ISO/IEC 30134 series, but inside the assessment boundary of the building system considering the ISO 52000 series).

When the energy is recovered outside the data centre and the building system, and is not contributing directly to the energy performance of the system under study, this impacts the energy performance by partly reducing the energy delivered to the data centre or EPB system as explained in 8.2.4.

Examples of primary energy assessments are given in Annex C. These examples are based on those proposed in ISO/IEC 30134-6:2021, Annex A. Energy reuse is also assessed for examples in Annexes A and B.

9.5 Impact on the excess electrical energy factor (XEEF — ISO/IEC TR 23050)

Excess energy is in theory similar to energy reuse: it is the electrical energy produced or stored in the data centre but used outside its boundary. But in practice, it contributes either to electrical energy uses for EPB in the case of data centres in mixed-use buildings, or to exported energy in the case of stand-alone data centres with energy production or storage (other than UPS for IT equipment) on-site. Only the latter is illustrated in Annexes A and B, in particular in Annex B with cases of local renewable energy produced on-site and exported to the grid.

9.6 Impact on IT equipment energy efficiency for servers ($ITEE_{SV}$ — ISO/IEC 30134-4)

This KPI compares services to final energy consumption of servers offering these services, so it seems unnecessary to envisage a version of IT equipment energy efficiency for servers (ITEEsv) with reference to primary energy consumption of servers only. Trying to assess ITEEsv in relation to primary energy would complicate this KPI assessment with little or no added value. The primary energy assessment of IT equipment, as presented in Annex A, is sufficient, and any improvement made to $ITEE_{SV}$ can be reflected in $E_{pe;IT}$ evolution.

Annex A
(informative)

Examples of primary energy assessment of a data centre as used for PUE assessment

A.1 General

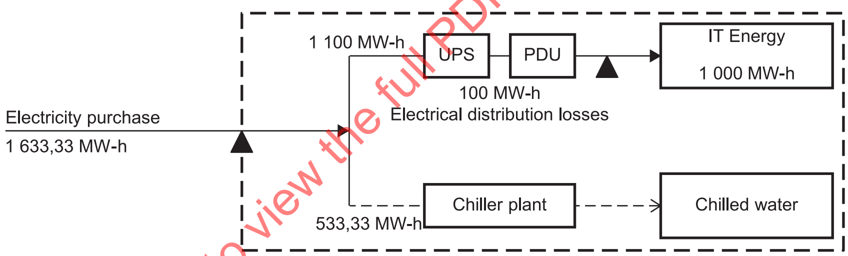
In this annex, the main elements and hypothesis for energy consumption assessments are those from the examples in ISO/IEC 30134-2:2016, Annex B.

NOTE The figures in this annex are modified versions of those from ISO/IEC 30134-2.

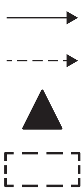
A.2 Use cases for various energy carriers

A.2.1 Case of a data centre purchasing all electricity

This first example is the classic case where all the energy consumed in the data centre comes from the grid (purchased from a utility) including energy for cooling IT equipment.



Key



electricity

other energy

measurement point

system boundary

Figure A.1 — Data centre purchasing all electricity

Using the data from Figure A.1,

$$E_{IT} = E_{del;el;IT} = 1\ 000\ \text{MWh}$$

$$E_{DC} = E_{del;el;DC} = E_{del;el;nEPus} = 1\ 633\ \text{MWh}$$

$E_{pe;DC} = f_{pe;el} \times E_{del;el;DC} = 2{,}5 \times 1\,633 = 4\,083{,}33$ MWh

with $f_{pe;el}$ taken from Table 3 (default value for electricity proposed in ISO 52000-1).

$E_{pe;IT} = f_{pe;el} \times E_{del;el;IT} = 2{,}5 \times 1\,000 = 2\,500$ MWh

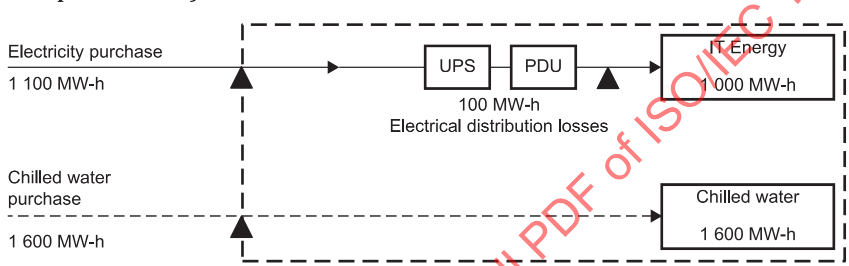
As $E_{rdel;el;EPus} = 0$, $E_{pr;el;EPus} = 0$, $E_{exp;el;grid} = 0$ and as there is no energy recovered, then:

$E_{excess} = 0$

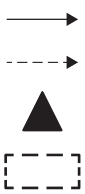
$E_{reuse} = 0$

A.2.2 Case of a data centre purchasing electricity and chilled water

In this example, only the electrical energy ultimately needed for IT equipment comes from the grid (purchased from a utility); the energy for cooling (chilled water) IT equipment comes from a district cooling network (also purchased).



Key



electricity

other energy

measurement point

system boundary

Figure A.2 — Data centre purchasing electricity and chilled water

Using the data from Figure A.2,

$E_{IT} = E_{del;el;IT} = 1\,000$ MWh

$E_{DC} = E_{del;el;DC} + E_{del;dhc;DC} = E_{del;el;nEPus} + E_{del;dhc;nEPus} = 1\,100 + 1\,600 = 2\,700$ MWh

$E_{pe;DC} = f_{pe;el} \times E_{del;el;DC} + f_{pe;dhc} \times E_{del;dgc;DC} = 2{,}5 \times 1\,100 + 1{,}3 \times 1\,600 = 4\,830$ MWh

and with $f_{pe;el}$ and $f_{pe;dhc}$ taken from Table 3 (default value for electricity district heating and cooling proposed in ISO 52000-1):

$E_{pe;IT} = f_{pe;el} \times E_{del;el;IT} = 2{,}5 \times 1\,000 = 2\,500$ MWh

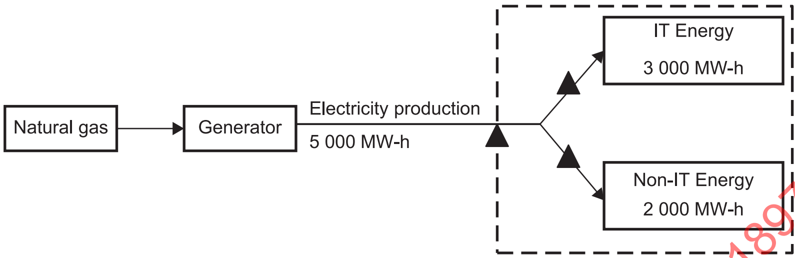
As $E_{rdel;el;EPus} = 0$, $E_{pr;el;EPus} = 0$, $E_{exp;el;grid} = 0$ and as there is no energy recovered, then:

$E_{excess} = 0$

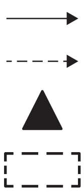
$E_{reuse} = 0$

A.2.3 Case of a data centre purchasing natural gas

This use case is similar to the first one in terms of energy use in the data centre (only electrical energy), but the electricity is produced by, for example, a nearby gas turbine fuelled by a natural gas network (purchased from a gas utility or supplier).



Key



electricity
other energy
measurement point
system boundary

Figure A.3 — Data centre purchasing natural gas

Using the data from Figure A.3,

$E_{IT} = E_{del;el;IT} = 3\ 000$ MWh

$E_{DC} = E_{del;gas;DC} = E_{del;gas;nEPus} = 5\ 000$ MWh

$E_{pe;DC} = f_{pe;gas} \times E_{del;gas;DC} = 1{,}1 \times 5\ 000 = 5\ 500$ MWh

with $f_{pe;gas}$ taken from ISO 52000-1:2017, Table 6 (default value for gaseous fossil fuels proposed in ISO 52000-1):

$E_{pe;IT} = f_{pe;gas} \times E_{del;gas;IT} = 1{,}1 \times 3\ 000 = 3\ 300$ MWh

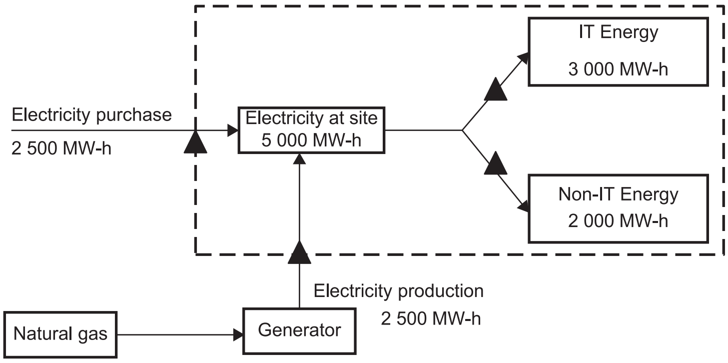
As $E_{rdel;el;EPus} = 0$, $E_{pr;el;EPus} = 0$, $E_{exp;el;grid} = 0$ and as there is no energy recovered, then:

$E_{excess} = 0$

$E_{reuse} = 0$

A.2.4 Case of a data centre purchasing electricity and natural gas

In this example too, all the energy consumed by the data centre is electricity. Half of it comes from the electricity grid and the other half is produced (as in the previous case) by a nearby natural gas generator.



Key

- → electricity
- - - -→ other energy
- ▲ measurement point
- [dashed box] system boundary

Figure A.4 — Data centre purchasing electricity and natural gas

Using the data from Figure A.4,

$$E_{IT} = E_{del;el;IT} + E_{del;gas;IT} = 3\ 000\ \text{MWh}$$

$$E_{DC} = E_{del;el;DC} + E_{del;gas;DC} = E_{del;el;nEPus} + E_{del;gas;nEPus} = 2\ 500 + 2\ 500 = 5\ 000\ \text{MWh}$$

with $f_{pe;el}$ and $f_{pe;gas}$ taken from Table 3 (default value for electricity and gaseous fossil fuels proposed in ISO 52000-1):

$$E_{pe;DC} = f_{pe;el} \times E_{del;el;DC} + f_{pe;gas} \times E_{del;gas;DC} = 2{,}5 \times 2\ 500 + 1{,}1 \times 2\ 500 = 9\ 000\ \text{MWh}$$

In the case of a proportional electrical energy use on average during the period of the assessment of both carriers (electricity and natural gas), it is considered in this example that:

$$E_{del;el;IT} = E_{del;gas;IT} = E_{IT} / 2 = 1\ 500\ \text{MWh}$$

then

$$E_{pe;IT} = f_{pe;el} \times E_{del;el;IT} + f_{pe;gas} \times E_{del;gas;IT} = 2{,}5 \times 1\ 500 + 1{,}1 \times 1\ 500 = 5\ 400\ \text{MWh}.$$

As $E_{rdel;el;EPus} = 0$, $E_{pr;el;EPus} = 0$, $E_{exp;el;grid} = 0$ and as there is no energy recovered, then:

$$E_{excess} = 0$$

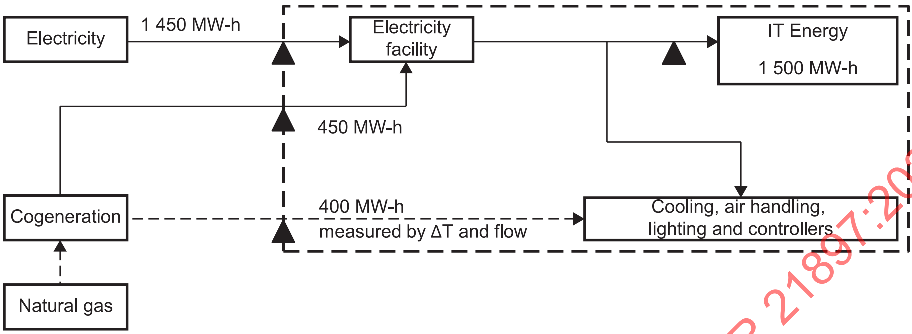
$$E_{reuse} = 0$$

A.3 Cogeneration use case

In this use case, a cogeneration (or CHP) system fuelled by natural gas provides electrical energy to the data centre, in conjunction with electricity provided by the grid and thermal energy for cooling the IT equipment.

For this use case, ISO/IEC 30134-2 considers two assessment methods for the PUE calculation:

— Method 1: the determination of thermal energy for cooling data centre equipment, produced by the CHP system, based on the measurement of chilled water flow and difference of temperatures (see Figure A.5). In this case, the CHP system is considered nearby (but not inside the boundary, as there is only a meter for the electrical energy produced by the CHP system) the data centre for PUE assessment.

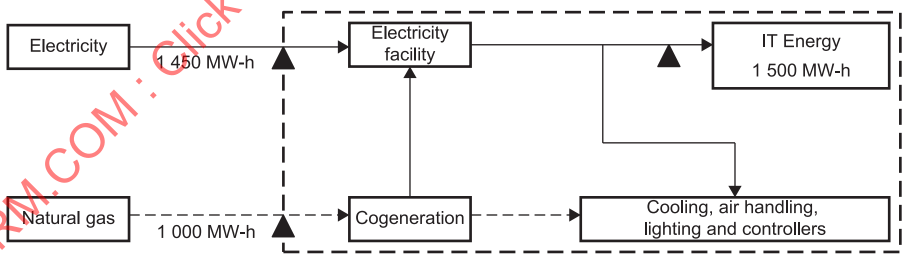


Key

- → electricity
- - - -→ other energy
- ▲ measurement point
- [- -] system boundary

Figure A.5 — Method 1: Measurement of chilled water flow

— Method 2: the calculation of the part of the metered energy at the input of the CHP system, required to produce chilled water for cooling data centre equipment (Figure A.6). In this case, the CHP system is considered inside the boundary of the data centre as all the energy (from natural gas) necessary to produce both electrical and thermal energy is metered.



Key

- → electricity
- - - -→ other energy
- ▲ measurement point
- [- -] system boundary

Figure A.6 — Method 2: Calculation of energy required to produce chilled water

For both methods the primary energy balance is expressed as:

$$E_{pe;DC} = E_{pe;el;DC} + E_{pe;chp;DC} = E_{pe;el;DC} + E_{pe;gas;DC} + Q_{pe;gas;DC}$$

where

$E_{pe;el;DC}$ is the total primary energy for electricity from the grid;

$E_{pe;chp;DC}$ is the total primary energy consumed by the combined heat and power (CHP) system to produce electrical energy $E_{pe;gas;DC}$ and thermal energy $Q_{pe;gas;DC}$.

and

$$E_{pe;DC} = f_{pe;el} \times E_{del;el;DC} + f_{pe;gas;el} - E_{del;gas;el;DC} + f_{pe;gas;Q} \times Q_{del;gas;DC}$$

Method 1

In Method 1, all delivered energies are measured by meters, fluid flows and temperatures. It is recommended in ISO/IEC 30134-2 to consider the district heating and cooling conversion factor for chilled water production of the cogeneration. Then from Table 3 (with ISO 52000-1 default values):

$f_{pe;el} = 2{,}5$, $f_{pe;gas;el} = 1{,}1$, $f_{pe;gas;Q} = 1{,}3$ and

$$E_{pe;DC} = 2{,}5 \times 1\,450 + 1{,}1 \times 450 + 1{,}3 \times 400 = 4\,640 \text{ MWh}$$

Method 2

In Method 2, only delivered electrical energy from the grid and global energy delivered by natural gas for the cogeneration are known.

Assuming the following ratios of conversion from input delivered energy of 45 % for electricity, 40 % for thermal energy and 15 % of losses,

$$E_{del;gas;el;DC} = 0{,}45 \times E_{del;chp;DC} = 0{,}45 \times 1\,000 = 450 \text{ MWh}$$

$$Q_{del;gas;DC} = 0{,}40 \times E_{del;chp;DC} = 0{,}40 \times 1\,000 = 400 \text{ MWh}$$

which are identical to those measured in Method 1.

Therefore, the primary energy balance of the data centre by Method 2 is also 4 640 MWh.

Due to the fact that electricity is provided by two carriers, the grid and the cogeneration system, with different weighting factors, the primary energy of IT equipment is:

$$E_{pe;IT} = (\alpha \times f_{pe;el} + \beta \times f_{pe;gas;el}) \times E_{del;el;IT}$$

with α and β determined by the allocation of energy sources during the period of assessment, and in a simplified approach with:

$$E_{del;el;DC} = E_{del;grid;el;DC} + E_{del;gas;el;DC} = 1\,450 + 450 = 1\,900 \text{ MWh}$$

$$E_{del;grid;el;DC} = \alpha \times E_{del;el;DC}$$

$$E_{del;gas;el;DC} = E_{del;chp;el;DC} = \beta \times E_{del;el;DC},$$

then:

$$\alpha = \frac{E_{del;grid;el;DC}}{E_{del;el;DC}} = 1\,450/1\,900 = 0{,}763$$

$$\beta = \frac{E_{del;chp;el;DC}}{E_{del;el;DC}} = 450/1\,900 = 0{,}237$$

$$E_{pe;IT} = (0{,}763 \times 2{,}5 + 0{,}237 \times 1{,}1) \times 1\,500 \cong 3\,252 \text{ MWh}$$

NOTE Allocation factors for electricity of each carrier can be determined on a more detailed basis considering, if available, all the energy consumptions or productions related to their periods of consumption or production for the entire assessment period chosen, as explained in ISO 52000-1 and ISO/TR 52000-2.

NOTE 2 See ISO 52000-1:2017, Table C.7 for definitions of α and β.

As $E_{rdel;el;EPus} = 0$, $E_{pr;el;EPus} = 0$, $E_{exp;el;grid} = 0$ and as there is no energy recovered, then:

$$E_{excess} = 0$$

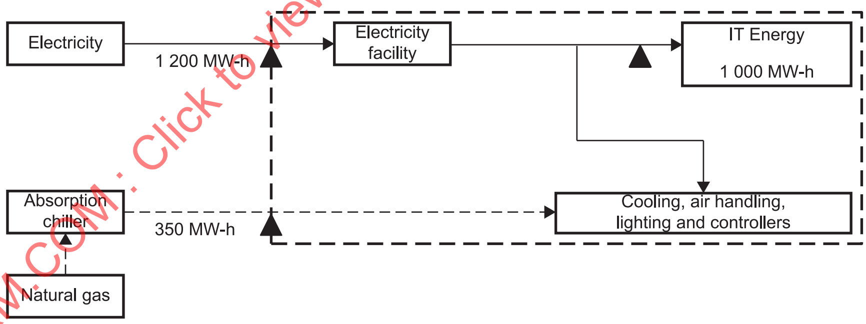
$$E_{reuse} = 0$$

A.4 Absorption type chiller use case

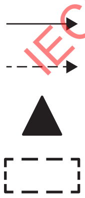
In this use case an absorption chiller, fuelled by natural gas, is dedicated to providing thermal energy for cooling the IT equipment, in conjunction with electricity provided by the grid.

For this use case, ISO/IEC 30134-2 considers two assessment methods for the PUE calculation:

— Method 1: the determination of thermal energy for cooling data centre equipment, produced by an absorption chiller, based on the measurement of chilled water flow and difference of temperatures (see Figure A.7). In this case, the absorption chiller is considered nearby (but not inside the boundary, as there is no measurement of natural gas consumed by the absorption chiller) data centre for PUE assessment,



Key



electricity

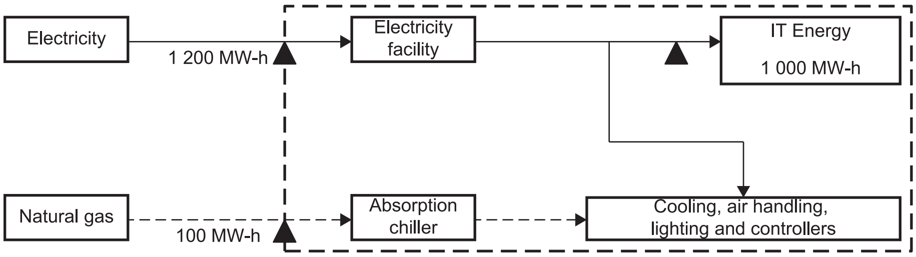
other energy

measurement point

system boundary

Figure A.7 — Method 1: Measurement of chilled water flow

— Method 2: the calculation of the part of the metered energy at the input of the absorption chiller, required to produce chilled water for cooling data centre equipment (see Figure A.8). In this case the absorption chiller is considered inside the boundary of the data centre as the energy (from natural gas) necessary to produce thermal energy is metered.



Key

→	electricity
- - -→	other energy
▲	measurement point
[- -]	system boundary

Figure A.8 — Method 2: Measurement of input gas

For this use case, in order to assess primary energy consumptions, it is necessary either to know the total natural gas energy delivered or to have the coefficient of performance (COP) of the absorption chiller (or conversion factor as stated in ISO/IEC 30134-2:2016, Annex B). Considering that both setups for Method 1 and Method 2 apply to the same data centre, 100 MWh of natural gas produce 350 MWh of thermal energy (chilled water), i.e. the absorption chiller COP is 3,5.

The primary energy balance is expressed as:

$$E_{pe:DC} = E_{pe;el;DC} + E_{pe;gas;DC}$$

where

$E_{pe;el;DC}$ is the total primary energy for electricity from the grid;

$E_{pe;gas;DC}$ is the total primary energy consumed by the absorption chiller;

and

$$E_{pe:DC} = f_{pe;el} - E_{del;el;DC} + f_{pe;gas} - E_{del;gas;DC}$$

From Table 3 (with ISO 52000-1 default values):

$$f_{pe;el} = 2{,}5 \text{ and } f_{pe;gas} = 1{,}1$$

$$E_{pe:DC} = 2{,}5 \times 1\,200 + 1{,}1 \times 100 = 3\,110 \text{ MWh}$$

$$E_{IT} = E_{del;el;IT} = 1\,000 \text{ MWh}$$

$$E_{pe:IT} = f_{pe;el} \times E_{del;el;IT} = 2{,}5 \times 1\,000 = 2\,500 \text{ MWh}$$

As $E_{rdel;el;EPus} = 0$, $E_{pr;el;EPus} = 0$, $E_{exp;el;grid} = 0$ and as there is no energy recovered, then:

$$E_{excess} = 0$$

$$E_{reuse} = 0$$

Annex B
(informative)

Examples of primary energy assessment of data centre as used for REF assessment

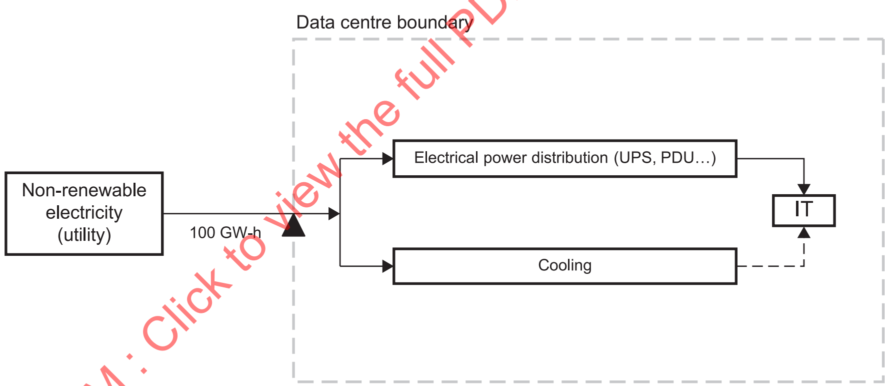
B.1 General

In this annex, the main elements and hypothesis for energy consumption assessments are those from the examples in ISO/IEC 30134-3:2016, Annex B.

B.2 Use cases

B.2.1 Case of a data centre purchasing electricity from the grid without renewable energy certificates

This first example is the classic case where all the energy consumed in the data centre comes from the grid (purchased from a utility) without renewable energy certificates nor local renewable energy production.



Key

electrical energy
thermal energy
measurement point

Figure B.1 — Grid energy purchased without renewable energy certificates