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Indian Standard

सूचान प्रौद्योगिकी — डेटा केंद्र प्रमुख प्रदर्शन संकेतक

भाग 6 ऊर्जा पुन: उपयोग कारक (ईआरएफ)

Information Technology — Data Centres Key Performance Indicators

Part 6 Energy Reuse Factor (ERF)

ICS 35.020

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NATIONAL FOREWORD

This Indian Standard (Part 6) which is identical to ISO/IEC 30134-6 : 2021 'Information technology —Data centres key performance indicators — Part 6: Energy reuse factor (ERF)' issued by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) jointly was adopted by the Bureau of Indian Standards on the recommendation of the Cloud Computing, IT & Data Centres Sectional Committee and approval of the Electronics and Information Technology Division Council.

Other parts in this series are:

Part 1 Overview and general requirements

Part 2 Power usage effectiveness (PUE)

Part 3 Renewable energy factor (REF)

Part 4 IT Equipment energy efficiency for servers (ITEEsv)

Part 5 IT Equipment utilization for servers (ITEUsv)

Part 8 Carbon usage effectiveness (CUE)

Part 9 Water usage effectiveness (WUE)

The text of ISO/IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminologies and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as ' Indian standard ' ; and

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practiceis to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their places, are listed below along with their degree of equivalence for the editions indicated. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

International Standards	*Corresponding Indian Standards*	*Degree of Equivalence*
ISO/IEC 30134-1 : 2016 Information technology — Data centres — Key performance indicators — Part 1: Overview and general requirements	IS/ISO/IEC 30134-1 : 2016 Information technology data centers key performance indicators: Part 1 Overview and general requirements	Identical
ISO 8601-1 : 2019Date and time — Representations for information interchange — Part 1: Basic rules	IS/ISO 8601-1 : 2019 Date and time representations for information interchange: Part 1: Basic rules	Identical

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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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 and, with less than half of the world's population having access to an internet connection (in 2014), that growth in data can only accelerate. In addition, with many governments having "digital agendas" to provide both citizens and businesses with ever-faster broadband access, the very increase in network speed and capacity will, by itself, generate ever more usage (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 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.

The energy reuse factor (ERF) provides the data centre practitioner with greater visibility into energy efficiency in data centres that make beneficial use of any reused energy from the data centre.

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 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. The document presents specific rules on ERF's use, along with its theoretical and mathematical development. The document concludes with several examples of site concepts that can employ the ERF metric.

Indian Standard

INFORMATION TECHNOLOGY — DATA CENTRES KEY PERFORMANCE INDICATORS

PART 6 ENERGY REUSE FACTOR (ERF)

1 Scope

This document specifies the energy reuse factor (ERF) as a KPI to quantify the reuse of the energy consumed in a data centre. ERF is defined as the ratio of energy being reused divided by the sum of all energy consumed in a data centre. The ERF does reflect the efficiency of the reuse process; the reuse process is not part of a data centre.

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 30134-1:2016, *Information technology — Data centres — Key performance indicators — Part 1: Overview and general requirements*

ISO 8601-1:2019, *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 terms and definitions given in ISO/IEC 30134-1 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
reused energy
reuse of energy
utilization of energy used in the data centre for an alternate purpose outside the data centre boundary

Note 1 to entry: Energy ejected to the environment does not constitute reused energy.

3.1.2
handoff point
point at the boundary of the data centre where energy is measured and is handed off to another party

Note 1 to entry: An example is an energy company which utilizes the energy outside the data centre boundary.

3.2 Abbreviated terms

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

AC	alternating current
COP	coefficient of performance
CRAC	computer room air conditioner units
CRAH	computer room air handler units
DX	direct expansion
ERE	energy reuse efficiency
ERF	energy reuse factor
PUE	power usage sffectiveness
IT	information system
UPS	uninterruptible power system
PDU	power distribution unit
r.m.s	root mean square

3.3 Symbols

For the purposes of this document the following symbols apply.

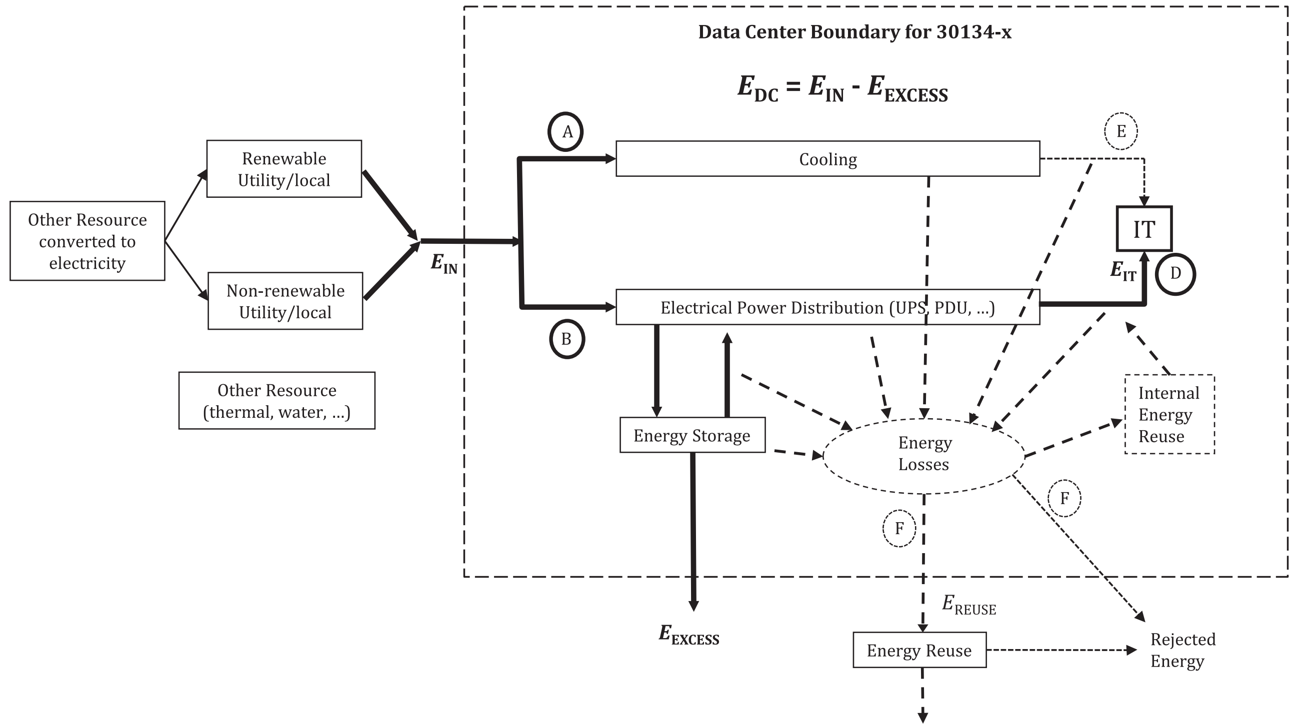
E_{COOLING}	energy used by the entire cooling system attributable to the data centre including support spaces (annual)
E_{DC}	total data centre energy consumption (annual)
E_{EXCESS}	data centre excess energy (annual)
E_{IT}	IT equipment energy consumption (annual)
E_{LIGHTING}	energy used to light the data centre and support spaces (annual)
E_{POWER}	energy lost in the power distribution system through line-loss and other infrastructure (e.g. UPS or PDU) inefficiencies (annual)
E_{Reuse}	energy from the data centre (annual) that is used outside of the data centre and which substitutes partly or totally energy needed outside the data centre boundary (annual)

4 Applicable area of the data centre

For the determination of ERF, the data centre under consideration shall be viewed as a system bounded by interfaces through which energy flows (see Figure 1). The calculation of ERF accounts for energy crossing this boundary. The bounded areas are the same as those used in calculations for PUE (as specified in ISO/IEC 30134-2) and other KPIs from the ISO/IEC 30134 series.

As shown in Figure 1, the data centre boundary is "drawn" around the data centre at the point of handoff from the utility provider. This is a critical distinction when alternate energy types and mixed-use buildings are analysed. It is equally important to ensure all energy types are included in ERF. All energy carriers (such as fuel oil, natural gas, etc.) and energy generated elsewhere (such as electricity, chilled water, etc.) that feed the data centre shall be included in the calculation.

Assuming there is no energy storage, conservation of energy requires that the energy into the data centre must equals the energy out. In the simple schematic of Figure 1, that means A + B = F. This is oversimplified, as there are losses and heat generated at the cooling (A minus E), UPS, and Power Distribution Unit (PDU) (B minus D) points as well, but this waste heat also has to leave the boundary. Once a boundary is defined for a data centre, it can be used to properly understand the ERF concept.



Key

electrical energy

thermal energy

other energy

re-usable energy

Figure 1 — Simplistic data centre components and boundary

It is critical to include all energy carriers at the point of utility handoff. It is also critical to include all of the data centre's energy consumption in the calculations, which includes but is not limited to generators, inside and outside lighting, fire detection and suppression, associated office/cubicle space strictly intended for data centre personnel, receiving areas, storage areas, etc. For clarity, the diagrams only show the large components to demonstrate the ERF concept.

ERF only considers energy being reused outside the boundary of a data centre. Energy reused inside the data centre boundary shall not be counted towards ERF as it already is accounted for in a lower PUE and including it in ERF is double counting. Examples of this are shown in Annex A.

NOTE Conversion of internal "reuse" (double/multi-use) into electrical energy for use in PUE calculation leads to double counting and shall not be included in PUE.

In Figure 1, any portion of (F) that is reused outside the data centre boundary (such as in a mixed-use building or a different building and not rejected to the atmosphere) is considered reused energy for determining ERF.

To determine ERF, the practitioner will need to identify and account for all energy streams crossing the data centre boundary coming in and any energy streams that will have beneficial use going out of the data centre boundary.

The energy coming in would typically be electricity but can also be natural gas, diesel fuel, chilled water, or conditioned air from another space.

The energy leaving the data centre boundary will most often take the form of heated water or heated airflow; these are what this document considers to be potentially reused energy. However, any form of energy that is reused outside of the data centre boundary shall be accounted for.

Processes that take advantage of the reused energy for other uses are outside the data centre boundary and the benefits of that reused energy and the efficiency of the reuse process are not considered in the ERF.

While reuse technologies are important to a data centre's overall energy use, they are too complex to try to define or measure by ERF.

NOTE The simplest example would be some form of chiller being driven by data centre waste heat. The reused energy to be considered for ERF is the waste heat going into the chiller and not the cooling energy delivered by the chiller to another space outside the data centre space.

A simple test of a specific technology employed in a data centre to determine if the energy reuse should be considered in ERF is if the PUE of the data centre would be different with or without that technology. If the technology causes a lower PUE, then it should not be considered as part of ERF. For example, if warm air from the data centre is used to heat the UPS battery room in the winter, this will result in a lower PUE; therefore, that double-/multi-use of energy shall not be included when calculating ERF. The heat from the data centre, when transferred to the battery room, stays within the data centre boundary and is therefore accounted for in lowering the PUE by reducing electricity demand for heating the battery room. It has no effect on ERF. If it had been used to heat an adjacent, non-data centre space (e.g. an adjacent cafeteria), then the heat crossed the data centre boundary and counts in ERF but not PUE. Examples of ERF usage are described in Annex A.

5 Determination of ERF

ERF provides a way to determine the factor of energy reuse. Heat is the most common example, where some of the heat produced by the data centre is utilized for beneficial purposes outside the data centre boundary and is not regarded as waste heat.

ERF ranges from 0 to 1,0. An ERF of 0,0 means no energy is reused, while a value of 1,0 means that, theoretically, all the energy brought into the data centre is reused. Any equipment outside of the data centre boundary for increasing the temperature delivered, like heat pumps, shall not be included in the calculation.

ERF is defined as:

$$\mathrm{ERF} = \frac{E_{\mathrm{Reuse}}}{E_{\mathrm{DC}}}$$

Where the only energy source is from an electrical utility, E_{DC} is determined by the energy measured at the utility meter. ERF may be applied in mixed-use buildings when measurement of the difference between the energy used for the data centre and that for other functions is possible.

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

a) power delivery — including UPS systems, switchgear, generators, PDUs, batteries, and distribution losses external to the IT equipment;

b) cooling system — including chillers, cooling towers, pumps, CRAHs, CRACs, and DX units;

c) others — including data centre lighting, elevator, security system, and fire suppression system;

d) all the infrastructure needed to transfer or to enhance the reused heat flow to the handoff point at the data centre boundary.

E_{IT} is the energy consumed by IT equipment (annual) that is used to capture, manage, process, store, or transmit data within the compute space, which includes but is not limited to:

1) IT equipment (e.g. compute, storage, and network equipment);

2) supplemental equipment (e.g. Keyboard-Video-Monitor switches, monitors, and workstations/ laptops used to monitor, manage and/or control the data centre).

6 Measurement of E_{Reuse} and E_{DC}

The measurement of the E_{DC} shall be carried out at the boundary of the data centre at the handoff point, where the data centre operator measures the power acquired from the energy supplier. If the energy is produced inside the physical boundaries of the data centre, the point of measurement shall be at the logical boundary.

The measurement of the E_{Reuse} shall be carried out at the logical boundary of the data centre at the handoff point, where the energy provided is handed off to be used by the other party. In most cases, the energy transferred is in the form of thermal energy, measured by increase in temperature and flow with reference to incoming provision (see Annex A for reference). The measurements shall be converted to the equivalent units used for E_{DC}, i.e. kWh. The measurement and conversion shall be measured at the hand off point of the data centre boundary.

Measurement of E_{DC} shall be undertaken using either:

a) watt meters with the capability to report energy use, or

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

In case of E_{Reuse}, where the measurement is often made from the fluid or gaseous flow, where the energy is transferred as heat, the measurement shall be undertaken with meters capable of measuring the energy added to the flow from the data centre boundary.

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

ERF without any subscripts shall be determined as an annualized value.

7 Application of ERF

ERF can be used by data centre managers to monitor and report reused energy in relation to energy consumption in the data centre.

This KPI can be used independently, but to get a more holistic picture of the resource efficiency of the data centre, other KPIs from the ISO/IEC 30134 series should be considered.

8 Reporting of ERF

8.1 Requirements

8.1.1 Standard construct for communicating ERF data

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

a) the data centre (including the boundaries of the structure) under inspection,

b) the ERF value,

c) the termination date of the period of measurement using the format of ISO 8601-1 (e.g. yyyy-mm-dd),

d) the kind of energy reused (thermal, electrical, chemical, mechanical).

As seasonal changes can affect the amount of the energy reused, the reported value shall be annualized.

8.1.2 Data for public reporting of ERF

8.1.2.1 Required information

The following data shall be provided when publicly reporting ERF data:

a) contact information,

NOTE 1 Only the organization’s name or contact should be displayed in public inquiries.

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

NOTE 2 Only state or local region information are required to be displayed in public inquiries.

c) measurement results: ERF with appropriate nomenclature,

d) the kind of energy reused (thermal, electrical, chemical, mechanical).

8.1.2.2 Supporting evidence (where required by authorities having jurisdiction)

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

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

b) measurement results: ERF with appropriate nomenclature,

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

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

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

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

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

h) general description of the use of the energy outside the data centre boundary and name of the receiving entity.

8.2 Recommendations

8.2.1 Trend tracking data

The following information can be useful in tracking the ERF trends within a data centre:

a) data centre size (facility in m^2),

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

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

d) data centre contact information,

e) data centre environmental conditions,

f) data centre's mission,

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

h) data centre commissioned date,

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

j) average and peak server CPU utilization,

k) percentage of servers using virtualization,

l) average age of IT equipment by type,

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

n) data centre availability objectives (see ISO/IEC 30134-1:2016, Annex A),

o) cooling and air-handling details,

p) the kind of energy reused (thermal, electrical, chemical, mechanical).

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

8.3 ERF derivatives, interim ERF

The definition of ERF clearly indicates that it is an annual figure. In cases where a need to report the ERF on other periods of time exists (e.g. energy billing reasons), ERF can also be reported on other time periods with a prefix "i" (interim) and the time period in the subscript, e.g. $iERF_{dd.mm.yyyy - dd.mm.yyyy}$. It should be noted, however, that the non-annual period of ERF reporting can be strongly affected by the variables such as outdoor temperatures and can not be comparable with other periodical values of ERF. The time periods shall also be consistent with the reporting of iPUE or other interim KPIs.

Annex A
(informative)

Examples of use

A.1 Examples of ERF usage

A.1.1 General

The following examples are provided to assist in the rapid adoption of ERF through widespread understanding. The recurrent theme in all of these examples is that if the beneficial energy reuse occurs outside the data centre and its support infrastructure (the boundary), then ERF is the correct metric to use. Otherwise, if reuse occurs within the boundary, PUE is the correct metric.

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

A.1.2 Correct use of ERF

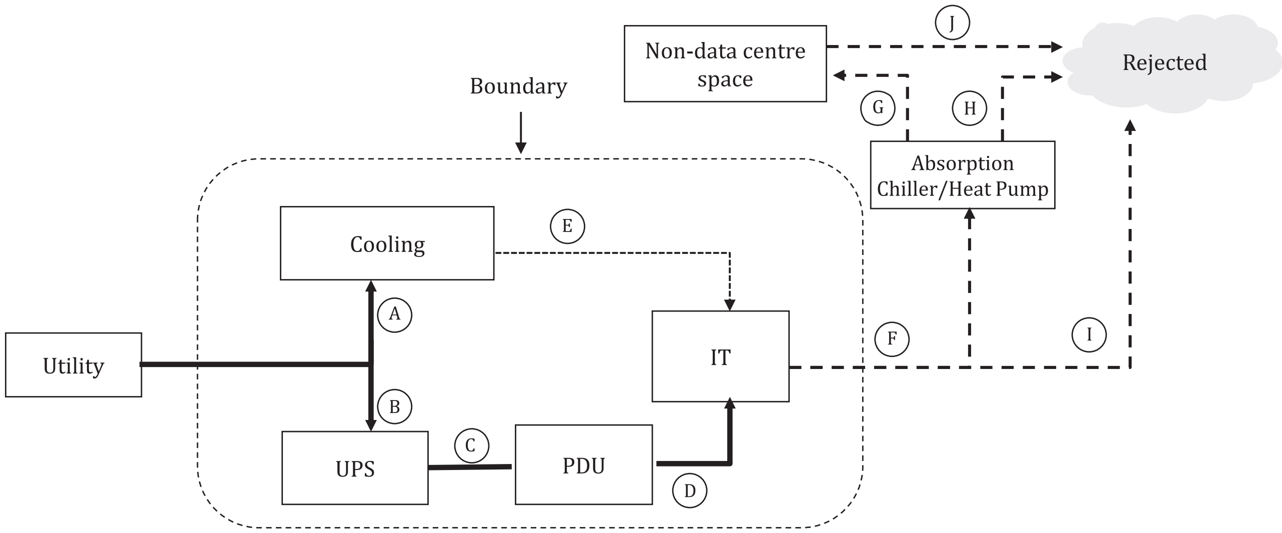
A.1.2.1 Warm air/water reuse outside the data centre boundary

An example of straightforward energy reuse is heat from the data centre being used to heat adjacent, non-data centre spaces outside the boundary. The energy in the heated water or heated air that leaves the data centre is the reused energy, and its measurement constitutes E_{Reuse} for the calculation of ERF.

A.1.2.2 Heat to run an absorption chiller or using heat pump to increase temperature

Figure A.1 shows a schematic for a high-level reuse scenario. The boundary is delineated by the dashed line. In this example, waste heat is used to drive the absorption chiller (F). The cooling energy from that chiller is used to cool an ancillary non-data centre space (G). Another example is to use a heat pump to increase the temperature of the waste heat, in order to utilize the energy outside the data centre. For the calculation of ERF, the definition of ERF requires the measurement of the energy crossing the boundary to be considered as the E_{Reuse}. Again, the value of energy crossing the boundary is the energy at (F).

In this case ERF is F/(A + B) and PUE is (A + B)/D.



Key

(solid bold arrow)	electrical energy
(fine dashed arrow)	thermal energy
(thin solid arrow)	other energy
(bold dashed arrow)	re-usable energy

Figure A.1 — Reuse of data centre waste heat

A.1.2.3 Heat to generate electricity used elsewhere

There are technologies in development for reverse heat engines that can create electricity from heat. Schematically, this would be equivalent to that equipment being in the same location as the absorption chiller. In either case, the reuse energy is measured where it crosses the data centre boundary. Only the value of (F) should be considered in calculating ERF.

A.1.3 Incorrect use of ERF

A.1.3.1 Heat to run an absorption chiller or generate electricity for use in the data centre

In the case of energy reused to drive a process inside the boundary, the reuse increases the efficiency of the space, but this benefit is captured in PUE. In this case, that capital investment is made to improve efficiency of the data centre and as such, PUE is be reduced. Figure A.2 depicts this arrangement, with the boundary encompassing the absorption chiller. In this case, (I) and (H) both leave the data centre but neither are reused. In the case of Figure A.2, ERF = 0,0. PUE is equal to (A+B)/D. Note that one would fully expect the PUE of the data centre in Figure A.2 to be lower than the PUE in Figure 1. The benefit of the absorption chiller is taken into account in the PUE of Figure A.2. The PUE should be less because the added beneficial cooling from (G) would reduce the amount of cooling energy needed at (E) and, therefore, at (A). After the reuse process, the reused energy that leaves the non-data centre spaces will also be rejected (J).

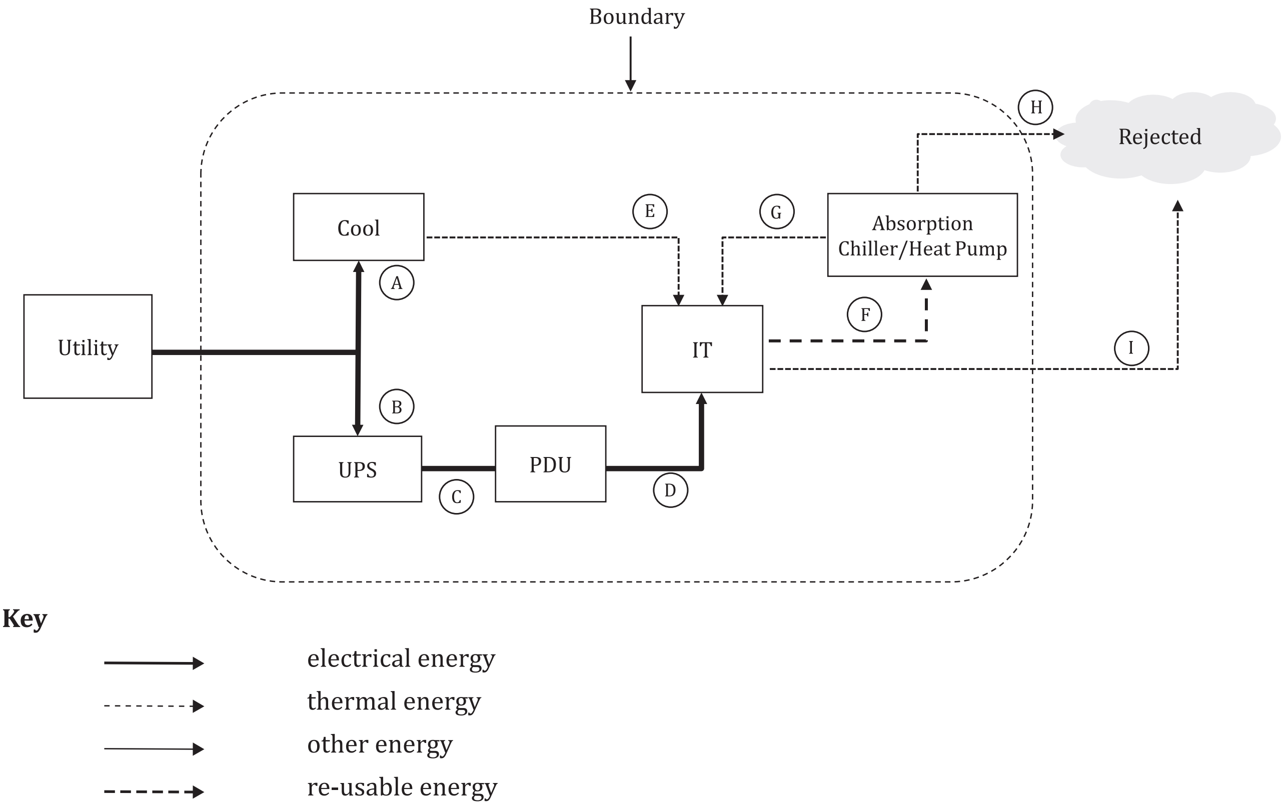


Figure A.2 — Schematic showing reuse of heat within the data centre

A.1.3.2 Heating a data centre support space or pre-heating of data centre generators

As discussed earlier in this document, reuse of data centre heat to heat the data centre's battery space or electrical room does not make that facility a candidate for ERF. That reuse, which simply reduces the amount of energy needed to be procured for the data centre operation, also reduces PUE but is not part of any ERF calculation. Similarly, the case where waste heat is used to preheat generators for data centre electricity production is not an application for ERF. Rather, it is an investment to improve data centre energy efficiency gain and it simply reduces PUE.

A.1.4 Split-system complications

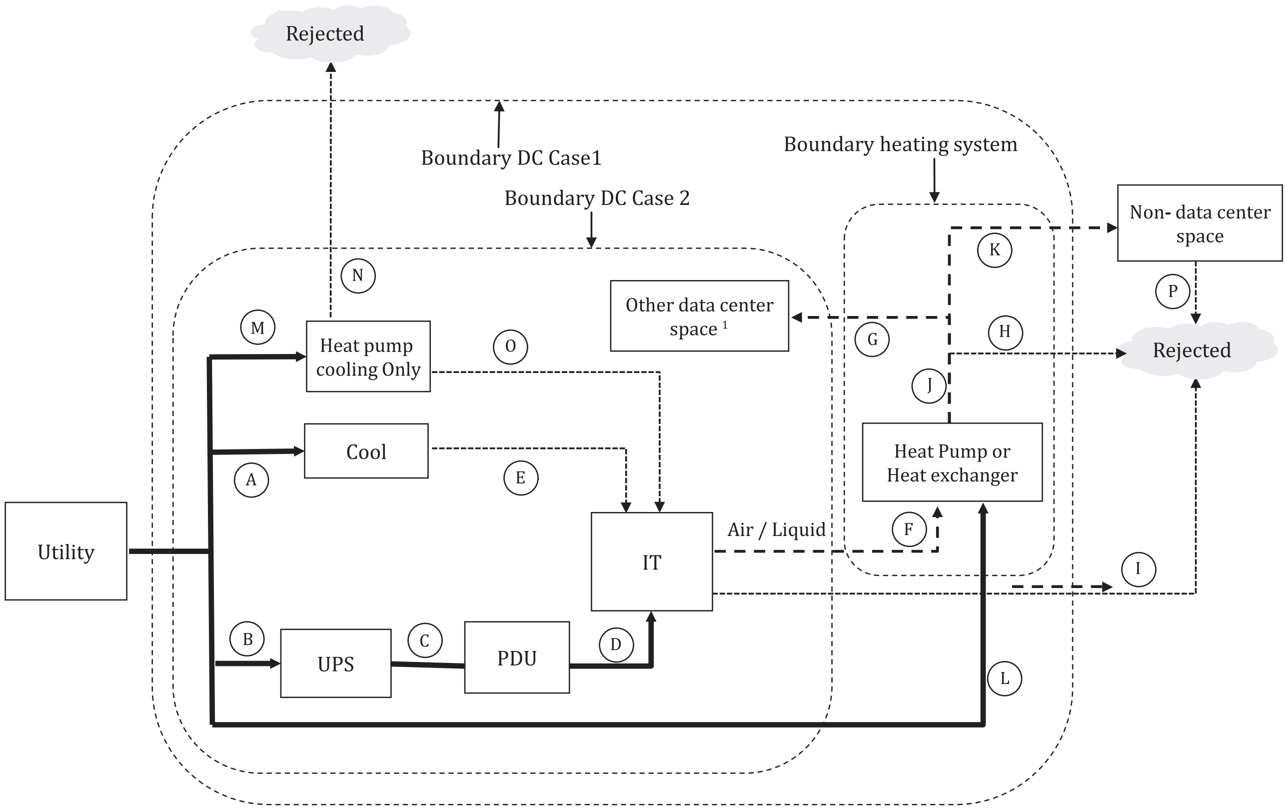
With reference to Figure A.2, if the cooling energy (G) turns out to be used both in the data centre (within the boundary) and in a non-related space (outside the boundary), the amount of energy (F) that is reused shall be appropriated for each space. A first-order approximation can be as simple as a ratio of chilled water flow. If 75 % of the cooling from the absorption chiller is used outside the data centre, then 75 % of the energy reused (0,75 × F) should be included in calculating ERF. Such complex designs are beyond the scope of this document, but the guidelines presented can be applied to all scenarios.

A.1.5 Heat pumps and liquid cooling

A.1.5.1 General

For small data centres (e.g. Edge Cloud data centres with low latency) or in countries with low electricity prices, it can be reasonable to use heat pumps for cooling or to reuse waste heat for heating purposes. In other cases, liquid cooling can be an option to increase IT-density (e.g. HPC, GPU-Cloud or renovation of existing data centres). These technologies enable the reuse of waste heat and coincidently savings on cooling expenses.

Figure A.3 shows different arrangement possibilities for these technologies and KPI calculation rules, which meet the system boundary model of ERF and PUE as in previously explained examples.



Key

electrical energy	
thermal energy	
other energy	
re-usable energy	
1*	other environmental conditioning, e.g. preheating diesel generators, preheater/reheater HVAC, heating offices/labs

Figure A.3 — Reuse of waste heat with heat pumps or liquid cooling

Heat pumps are machines, which bring, with the help of mechanical work, thermal energy from a lower temperature level, together with the engine power, to a higher temperature level. The efficiency factor of a heat pump is the COP, calculated as benefit divided by expenses, usually referring to their hot side, as opposed to cooling machines, where performance refers to the cooling

A.1.5.2 Heat pumps for cooling purpose only

Generally, a heat pump is similar to a cooling machine. However, in most cases the emitted heat is used as well. If a heat pump is only used for cooling (100 %), the hot side is discharged. for example, via an external air cooler using outside air. This option can operate all year-round, because of the high liquid temperatures in comparison to the outside temperatures. Only if there is no heat recovery can it be counted as a cooling system as shown on the left side in Boundary DC case 2 in Figure A.3.

PUE is (A+B+M)/D and ERF is 0. COP (Cooling) is O/M whereas the manufacturer can declare COP (Heating) with N/M, where N=M+O.

A.1.5.3 Heat pumps for heating purpose and mixed arrangements

The design becomes more complex when parts of the hot side are reused outside of the data centre for heating purposes. The heat pump is then considered as a heating system and shall be included in the calculation of various non-data centre KPIs to compare and optimize heating systems that comply with local regulations. This is shown on the right side in Figure A.3 in Boundary DC cases 1 and 2. However, even if the heat pump is positioned in the data centre as in Boundary DC case 1, and even if it is supplied with power from the DC site, only (F) can be taken, or percentages of (F) if (G) or (H) are present, which is the energy from the IT that supplies the heat pump or a heat exchanger. Energy that is rejected (H) or consumed in the data centre (G) is not part of the ERF. It is incorrect to consider (K) as reusable energy, as it contains the power (L), which is needed to supply the heating system. Therefore, it is the same with (L), which is linked to the energy for the heating system and not with the data centre energy or KPIs. Just as with the electricity, heat needs to be transported on the secondary circuit (J) inside the heating systems.

This means that PUE is (A+B+M)/D. The efficiency of the heat pump COP (Heating) is J/L. For ERF, F×(K/J×100 %)/(A+B+M-L) is calculated or, to be more precise, the electricity (J-L) × (K/J×100 %)/(A+B+M-L) is considered, where J is F+L and G+H+K.

In the case of liquid cooling, it can be possible to avoid the use of heat pumps or high-temperature heat pumps. A heat exchanger can meet the requirements and additional electricity (L) to reduce cooling costs is not needed. The waste heat counts as 0 for the primary energy factor if it is used for a heating system as industrial exhaust air.

Other arrangements, technologies and energy flows are possible but as defined here, the reusable energy used in the data centre reduces the PUE and will only be considered here. For ERF, all that needs to be done is to look at the energy components that cross the boundaries of the data centre. As a heating system has its own system boundaries and energy requirements to generate the heat output, only the waste heat that supplies the heating system is used for the ERF calculation. After the reuse process, the reused energy that leaves the non-data centre spaces will also be rejected (P).

Annex B
(informative)

Energy conversion factors

B.1 Energy measurement at the data centre boundary

Where the values of non-electrical energy have to be converted to electrical energy, the declaration of the supplier for conversion factors and heating values shall be utilized. If no declaration of the 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[11] and the ASHRAE/TGG book on energy measurement[10].

Table B.1 — Energy measurement methods at the data centre boundary

Energy type	Typical units	Comments
Electricity	Kilowatt hour (kWh)	An annualized energy consumption is the basis.
Diesel fuel	Litres (l)	How many litres of fuel per year? 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? There are roughly 10,5 kWh in 1 m^3 of natural gas.
Hydrogen	Kilograms (kg)	How much Hydrogen per year? There are roughly 33,3 kWh in 1 kg of Hydrogen.
Bioethanol	Litres (l)	How many litres of fuel per year? There are roughly 6,0 kWh in a litre of bioethanol.
Heated/cooled water	Cubic metre (m^3)	How much heated or cooled water was used per year? 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? 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 22 °C room, then use 8 °C as the temperature difference, which would mean $2,6 \times 10^{-3}$ kWh for every m^3 of air used.

The above values are calculated from published thermal physical properties of the individual fluids. The above table is provided as a guide for informational purposes only. A detailed engineering analysis should be completed to get the specific values for each individual application.

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