UN environment programme

Sustainable Procurement Guidelines for Data Centres and Servers

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About United for Efficiency

U4E (united4efficiency.org/) is a global initiative led by UNEP, which accelerates the transition to energy-efficient and climate friendly lighting, appliances and equipment.

Our integrated approach targets:

- Standards and regulations;
- Awareness raising and capacity building;
- Market monitoring, verification and enforcement;
- Funding and financial delivery mechanisms; and
- Environmentally sound management and health.

U4E provides tailored technical support through in-house experts and specialized partners to get the most out of countries' energy resources. Enhancing efficiency unlocks savings on consumer electricity bills, helps businesses thrive through greater productivity, improves resiliency of power utilities to meet growing demands for electricity, and assists governments in realizing sustainable development ambitions.

The initiative is active in developing and emerging economies worldwide. U4E provides technical assistance by pursuing solutions for lighting, refrigeration and holistic cold-chain, space conditioning, electric motor systems, distribution power transformers, and system-scale improvements across these and other technologies. The product areas utilize well over half of the world's electricity.

U4E has a proven set of tools, assessments and guides developed with a diverse array of experts across many leading organizations which reflect international best practices. The contents are practically applied in market transformation projects at the regional, national and local scales.

This growing suite of resources equips policymakers to understand the significant opportunities and steps needed to start transforming their markets to eco-efficient appliances and equipment.

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Abbreviations

AC	Alternating Current
AI	Artificial Intelligence
APA	Auxiliary Processing Accelerator
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CDU	Coolant Distribution Unit
CEF	Cooling Efficiency Factor
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CER	Cooling Effectiveness Ratio
CPU	Central Processing Unit
CRAC	Computer Room Air Conditioning
CRAH	Computer Room Air Handler
DC	Direct Current
DDR channel	Double Data Rate channel
DIMM	Dual Inline Memory Module
DVFS	Dynamic Voltage and Frequency Scaling
DX	Direct Expansion air handler
ERF	Energy Reuse Factor
ETSI	European Telecommunications Standards Institute
GB	Gigabyte
GDP	Gross Domestic Product
GHG	Green House Gases
GPU	Graphics Processing Unit
HDD	Hard Disk Drive
HFC	Hydrofluorocarbon
HPC	High Performance Computing
I/O device	Input/Output device; between a server and other devices
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission

ISO	International Organization for Standardization
IT	Information technology
ITEEsv	IT Equipment Energy Efficiency for servers
ITEUsv	IT Equipment Utilization for servers
ITU	International Telecommunication Union
IXP	Internet Exchange Point
KPI	Key Performance Indicators
MSP	Managed Service Provider
MTDC	Multi-Tenant Data Centres
NDC	Nationally Determined Contributions
OECD	Organization for Economic Cooperation and Development
OS	Operating system
PCI	Peripheral Component Interconnect
PDU	Power Distribution Unit
PSU	Power Supply Unit
PUE	Power Usage Effectiveness
RAM	Random Access Memory
RDHx	Rear Door Heat exchanger
REF	Renewable Energy Factor (Electricity)
SATA	Serial Advanced Technology Attachment
SERT	Server Efficiency Rating Tool
SHS	Storage Heavy Servers
SPEC	Standard Performance Evaluation Corporation
SPP	Sustainable Public Procurement
SSD	Solid State Drive
U4E	United for Efficiency
UNEP	United Nations Environment Programme
UPS	Uninterruptible Power Supply
WUE	Water Usage Effectiveness

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01 Introduction

The public sector wields significant purchasing power, accounting for 12 per cent of GDP in OECD countries and up to 30 per cent in developing nations. This demonstrates the considerable potential for public procurement to be leveraged as a means to drive a nation's economy to a greener and more sustainable one. Public procurement refers to the purchase made by governments, state and semi-state-owned enterprises for goods, services and works. As public procurement accounts for a substantial portion of the taxpayers' money, governments are expected to carry it out efficiently and with high standards of conduct to ensure quality service delivery and to safeguard the public interest[1].

Public procurement can be an important tool in reducing the environmental impact of data centres, known for their high energy consumption in the broader information technology sector. Governments can exert significant influence over markets by redirecting spending from conventional digital infrastructure and services to cleaner technologies and practices by enabling bidders to propose innovative solutions that meet associated criteria. This strategic shift not only signals an important message to the market, but also boosts demand for such solutions, creating critical mass necessary to catalyse broader adoption through increased accessibility and affordability. Thus, Governments can promote the development of energy efficient data centres by not only shaping the enabling environment through policies and programmes addressing equipment purchased by the private sector but also leading by example with procurements for public digital infrastructure.

The inclusion of environmental considerations in public sector purchasing decisions is commonly referred to as "green public procurement" or "GPP." While this term is often used interchangeably with "sustainable public procurement" or "SPP," SPP is generally a broader concept encompassing both environmental and socio-economic considerations. Although the recommendations in the Guidelines could be applied to a broader range of procurement activities beyond the public sector, due to the nature of data centers and the strong involvement of public authorities, the term Sustainable Public Procurement (*SPP*) will be used throughout the document. This approach to public procurement is widely regarded as an international best practice, reflected in Target 12.7[2] of the Sustainable Development Goals (SDGs),[3] which aims to "promote public procurement practices that are sustainable, in accordance with national policies and priorities." Both national and local governments around the world are increasingly leveraging public procurement as a strategic policy instrument to address national sustainable development objectives and global challenges.[4]

1 https://www.oecd.org/gov/public-procurement/
2 www.unep.org/explore-topics/resource-efficiency/what-we-do/sustainable-public-procurement/sdg-127-target-and
3 https://sdgs.un.org/goals
4 2022 UNEP Sustainable Public Procurement Global Review: www.oneplanetnetwork.org/knowledge-centre/resources/sustainable-public-procurement-2022-global-review-parts-i-and-ii

Public procurement not only drives economic and environmental sustainability but also has the potential to help ensure men and women benefit equally from sustainable development initiatives. By integrating gender criteria in procurement policies—such as requiring bidders to demonstrate gender-inclusive policies or ensuring equal opportunities in employment—governments can advance gender equality while promoting innovation and sustainability in the digital infrastructure sector. For more information on gender considerations, UN Women has developed a "Gender-responsive procurement model policy framework" to provide a standardised set of definitions and procedures.

Data centres are extremely energy-intensive facilities characterized by a sizable carbon footprint. A server, which usually runs non-stop, typically uses several hundred watts of power when in active mode and tens of watt in passive mode. A data centre typically counts few thousands to few millions of servers. Since many developing countries lack a stable or adequate electricity supply, data centre operators are captive to backup and alternative power supplies often in the form of diesel generators, increasing the cost of operation and CO2 emissions while worsening air quality and noise. Globally, data centres used an estimated 460 TWh in 2022 - around 2 per cent[5]. In 2022, Meta's data centre electricity consumption reached 11,167,416 MWh—equivalent to the total national electricity usage of Costa Rica. By 2030, electricity consumption from data centres is expected to reach up to 3,000 TWh – a 4 to 10-fold increase in their energy use today. Cloud and hyperscale data centres accounted for many workloads (~90 per cent) and energy use (~65 per cent), up from ~20 per cent in 2010. In addition, the vast amounts of energy that go into data centre servers and ancillary equipment eventually end up as waste heat that must be managed by cooling systems, consuming refrigerants and often large amounts of water.

The number of data centres in developing countries is expected to continue to rapidly increase due to economic growth driven by increasing demand for data, decrease of connection cost (primarily in edge computing - meaning data processed in smart devices closer to the user) and a growing demand for data processing and storage sovereignty (o reduce the cost of usage and to increase speed, it is aimed for data content from overseas to be stored locally, and increase the control on data.). As countries worldwide adopt data localization requirements and regulations, businesses need options to store consumers' data within their national borders. Several Key Performance Indicators (KPIs) have been standardized around energy use, the share of renewable energy used, water consumption, and overall server efficiency, among others, such as the International Organization for Standardization and the International Electrotechnical Commission's ISO/IEC 30134. However, there is still a widespread lack of knowledge and information that helps governments and businesses assess energy consumption and environmental impacts to make more informed decisions.

To achieve digitalization objectives while preserving scarce high-quality water resources, national electricity networks, and reducing their carbon footprint, countries are encouraged to regulate the sector with more energy-efficient servers and climate-friendly data centres.

5 Electricity 2024, Analysis and forecast to 2026. IEA – IEA, January 2024

There is a notable lag in the development of practical support measures to facilitate implementation of SPP. According to the United Nation Environment Programme's (UNEP) latest data on SDG Indicator 12.7.1 on "Degree of sustainable *public procurement policies and action plan implementation*", 71 per cent countries6 with an SPP legal framework have established environmental criteria or guidelines for the public procurement of products within the category of "office electronics". Despite notable advancements in sustainability criteria for office electronics, only six countries, constituting 17 per cent of the total, have established specific criteria for data centres and related equipment. The majority of these countries are located in Europe, followed by the Asia Pacific region.

In response to these challenges, UNEP's United for Efficiency (U4E) initiative has developed this set of technical specifications as a reference for establishing requirements for the procurement of data centres. In addition to public procurement, these Guidelines can be used as a starting point for other types of data centre procurement (such as through the private sector) and the basis of government regulations. These Guidelines were developed in a consultative process meant to reflect current global best practices, with the understanding that their contents should be adapted to local circumstances rather than applied verbatim based on generalized recommendations.

6 71 per cent, or 35 out of the 49 countries. For further detail, please see the report on the main findings and conclusion of the 2022 data collection exercise on SDG Indicator 12.7.1. This biennial reporting exercise measures the "number of countries implementing sustainable policies and action plans" across six parameters.

02 Methodology and Scope of the Guidelines

These guidelines apply to data centres, computer servers and data storage products. Computer server and data storage products that comply with these guidelines are widely available on the global market at prices with typically competitive rates of return. Data centres that have all the features and key performance indicators (KPI) that comply with these guidelines are considered to follow international best practices. The data centre is considered both as a dedicated building and as a system, with all its components as well as individual computer servers used outside of the building. The efficiency of data centres heavily depends on the pieces of equipment used, but also on their correct integration into a single system, where aspects on cooling, power distribution, airflow management, and IT infrastructure shall work together to optimize performance, minimize energy consumption, and reduce operational costs.

The recommendations are based on the following considerations:

- Energy requirements should focus on products that exceed the average market efficiency as there is a considerable gap between average legacy technology and opportunities for significant improvements.

- Efficiency requirements should be based on the relevant energy label for the products if available. The simplest way to set the sustainable procurement efficiency requirement is to use the energy label by targeting the energy efficiency classes with the most efficient products. Some countries use endorsement labels, which can only be used by the most efficient products in the market, such as ENERGY STAR® in USA (for computer servers and data storage products) and Blue Angel in Germany (for data centres) as shown in Figure 1. Endorsement labels are also an easy way to identify the efficient products in the market. Nevertheless, it is recommended that the requirements of the endorsement label are checked to ensure they are not obsolete and still target the most efficient products in the market (around the top 20 per cent in energy efficiency). If they do not, the labelling system[7] needs updating before it can be used in the sustainable procurement process.

- Products must be available at a reasonable price for public agencies such as by calculating total cost of ownership or setting a benchmark range for premium on sustainable products (e.g. 5-20 per cent over conventional products).

7 Further information available at U4E´s Guideline “Energy Labelling Guidance for lighting and appliances”, available at: https://united4efficiency.org/resources/energy-labelling-guidance-for-lighting-and-appliances/

Figure 1: Endorsement label examples

This publication provides recommendations aligned with international best practices. However, assessing local conditions and consulting stakeholders remain essential to ensure they are appropriately tailored. Additionally, as markets and technologies evolve, periodic adaptations may be necessary to stay up to date. The recommendations address the following technical requirements:

- ***Performance criteria*** including power usage effectiveness, water usage effectiveness, cooling effectiveness ratio, the related IT equipment energy efficiency for servers, server efficiency, power supply efficiency, and idle state efficiency; and

- ***Operating conditions*** including location, renewable energy factor, resilience, modularity, cooling design, temperature and humidity range, power management, and utilization rate.

Such recommendations aim to facilitate preparation of tender documents to:

- Select and/or approve where to host data;

- Authorize the establishment of new data centres;

- Specify requirements when buying servers;

- Establish minimum energy performance standards requirements and/or label schemes for servers and data storage products.; and

- address performance requirements for the Service Level Agreement between the cloud provider and public authority.

Computer servers and data storage products criteria are already subject to routine test reporting to address regulatory requirements in major international markets such as the European Union[8] and Japan[9]. If any of the relevant criteria are not specified in local supplier technical documentation, buyers can also request details from the manufacturer directly without additional testing cost implication. The performance values recommended in these guidelines are based on commonly available products in the international market. For example, it is estimated that the average performance rates compliance ranges between 24-34 per cent of current international market (2022 servers benchmark – idle power). Even some low-end configurations can meet the new levels, which allows lower cost options for smaller volume purchasers.[10]

The testing procedures are referenced in Annex 1. Annex 2 provides key award criteria to help distinguish between alternatives during tender bids and as a reference to establish labelling schemes. Annex 3 features the methodology for calculating the Server Efficiency Rating Tool (SERT) Efficiency Score. Annex 4 details the characteristics for resilient servers according to ENERGY STAR® criteria.

8 Commission regulation (EU) 2019/424
9 New energy conservation standards for electronic computers, 2019
10 ENERGY STAR® Version 4.0 Computer Servers Draft 1 Specification Webinar, 2022

03 Summary of Performance Criteria

Data centres

Performance Criteria	Procurement Requirements
Location	Location with reliable access to • internet network through fibre optic • stable electricity • clean water (through network or natural source) • locally produced renewable energy • mitigation of climate risks (drainage, barriers…)
Resilience	The level of resilience should be procured or built based on business requirements and impact assessment results. In public procurement, a Tier III or Class 3 certified data centre is generally sufficient to ensure data access.

<table>
<tr><th>Performance Criteria</th><th>Procurement Requirements</th></tr>
<tr><td>Power usage effectiveness (PUE)</td><td>
<table>
<tr><th>Year</th><th>2025</th><th>2027</th><th>2029</th><th>2031</th></tr>
<tr><td>Existing colocation data centre to host data</td><td>PUE ≤ 1.5
HH: PUE ≤ 1.7</td><td>PUE ≤ 1.4
HH: PUE ≤ 1.6</td><td>PUE ≤ 1.3
HH: PUE ≤ 1.5</td><td>PUE ≤ 1.2
HH: PUE ≤ 1.4</td></tr>
<tr><td>New data centre building</td><td>By design:
PUE ≤ 1.4
HH: PUE ≤ 1.6

During ramp up period of operation (at 3 years):
PUE ≤ 1.5
HH: PUE ≤ 1.7</td><td>By design:
PUE ≤ 1.3
HH: PUE ≤ 1.5

During ramp up period of operation (at 3 years):
PUE ≤ 1.4
HH: PUE ≤ 1.6</td><td>By design:
PUE ≤ 1.2
HH: PUE ≤ 1.4

During ramp up period of operation (at 3 years):
PUE ≤ 1.3
HH: PUE ≤ 1.5</td><td>By design:
PUE ≤ 1.1
HH: PUE ≤ 1.3

During ramp up period of operation (at 3 years):
PUE ≤ 1.2
HH: PUE ≤ 1.4</td></tr>
</table>
Note: Hot and Humid (HH) climate correspond to ASHRAE climate zone 0A (Extremely Hot-Humid), 1A (Very Hot-Humid), 2A (Hot-Humid) and 3A (Warm-Humid). Definitions are available at ANSI/ASHRAE Standard 169-2013. Climate group can be determined for the data centre location with the ASHRAE weather data viewer 2021.
The PUE category 3 value is preferable if available, otherwise PUE category 2.
</td></tr>
<tr><td>Modularity</td><td>The IT room structure should be modular, as should the cooling plant to adapt to cooling needs. Unused equipment should be capable of being shut down. Pumps, fans, and compressors should be high-performance, monitored, and equipped with variable frequency or speed control.</td></tr>
<tr><td>IT room cooling design</td><td> In the case of air-cooling systems, hot and cold aisles compartmentation should be put in place. The physical layout of the building should not obstruct or restrict the use of free cooling (either air or water), or other equipment with an economisation / free cooling mode. </td></tr>
</table>

<table>
<tr><th>Performance Criteria</th><th>Procurement Requirements</th></tr>
<tr><td>Motors efficiency (fans, pumps and compressors)</td><td>It is recommended to use IE4, IE5 or NEMA Super Premium electric motors and IE2 Variable Speed Drives.</td></tr>
<tr><td>Uninterruptible power supply (UPS) efficiency</td><td>Conformity with IEC 62040 series for UPS systems.
Voltage and frequency independent (VFI) UPS with minimum efficacy of:
<table>
<tr><th>Power range (kW)</th><th>Minimum Performance</th></tr>
<tr><td>≥ 0.05 kW to ≤ 0.3 kW</td><td>85.5 %</td></tr>
<tr><td>> 0.3 kW to ≤ 3.5 kW</td><td>88.0 %</td></tr>
<tr><td>> 3.5 kW to ≤ 10 kW</td><td>91.0 %</td></tr>
<tr><td>> 10 kW to ≤ 200 kW</td><td>93.0 %</td></tr>
<tr><td>> 200 kW</td><td>95 %</td></tr>
</table>
The UPS should also be able to keep a temperate of between 0°C to 40°C. Conformity with IEC 62040 series for UPS systems is required.</td></tr>
<tr><td>Distribution transformer</td><td>The minimum peak efficiency index (%) is given in Table 2 for liquid-immersed and dry-type large power transformers</td></tr>
<tr><td>Water usage effectiveness (WUE)</td><td>
<table>
<tr><th>Year</th><th>2025</th><th>2027</th><th>2029</th><th>2031</th></tr>
<tr><td>Water Usage Effectiveness</td><td>≤ 1.5 L/ kWh</td><td>≤ 1 L/ kWh</td><td>≤ 0.5 L/ kWh</td><td>≤ 0.2 L/ kWh</td></tr>
</table>
Note: These maximum water consumption values are not always compatible with adiabatic cooling used to lower the PUE.</td></tr>
</table>

Performance Criteria	Procurement Requirements				
	Year	**2025**	**2027**	**2029**	**2031**
Cooling efficiency ratio (CER)	**Existing colocation data centre to host data**	CER ≥ 2.5	CER ≥ 2.9	CER ≥ 3.8	CER ≥ 5.7
	New data centre building	CER by design ≥ 2.9 CER after 3 years of operation ≥ 2.5	CER by design ≥ 3.8 CER after 3 years of operation ≥ 2.9	BCER by design ≥ 5.7 CER after 3 years of operation ≥ 3.8	CER by design ≥ 10 CER after 3 years of operation ≥ 5.7
Renewable energy factor (REF)	**Renewable Energy Factor**	≥ 50%	≥ 60%	≥ 70%	≥ 80%
Cooling refrigerants	Refrigerants used in the data centre for cooling the equipment should be lower than 10 GWP. For air conditioning equipment, GWP should be lower than 680.				
Lighting efficiency	**Efficacy**	≥ 150 lm/W	≥ 170 lm/W	≥ 190 lm/W	≥ 210 lm/W

Performance Criteria	Procurement Requirements				
Annual utilisation rate of IT equipment (ITEUsv)	**Year**	**2025**	**2027**	**2029**	**2031**
	Existing colocation data centre to host data	ITEUsv ≥ 50%	ITEUsv ≥ 60%	ITEUsv ≥ 70%	ITEUsv ≥ 80%
	New data centre building	ITEUsv ≥ 50% after 3 years of operation	ITEUsv ≥ 60% after 3 years of operation	ITEUsv ≥ 70% after 3 years of operation	ITEUsv ≥ 80% after 3 years of operation
Reused energy factor	**Year**	**2025**	**2027**	**2029**	**2031**
	Energy reused factor	≥ 30%	≥ 40%	≥ 50%	≥ 60%

Computer servers and data storage products

<table>
<tr><th>Performance criteria</th><th>Standard Procurement Requirements</th></tr>
<tr><td>Operating temperature and humidity range</td><td>Class A3 IT equipment or higher should be purchased.</td></tr>
<tr><td>Server efficiency</td><td>
<table>
<tr><th>Product Type</th><th>Minimum server efficiency*</th></tr>
<tr><td colspan="2">One socket (one processor)</td></tr>
<tr><td>Rack</td><td>26.4</td></tr>
<tr><td>Tower</td><td>24.4</td></tr>
<tr><td>Resilient</td><td>6.6</td></tr>
<tr><td colspan="2">Two sockets (two processors)</td></tr>
<tr><td>Rack</td><td>30.4</td></tr>
<tr><td>Tower</td><td>26.5</td></tr>
<tr><td>Blade or Multi-Node</td><td>29.1</td></tr>
<tr><td>Resilient</td><td>6.0</td></tr>
<tr><td colspan="2">More than two sockets (more than 2 processors)</td></tr>
<tr><td>Rack</td><td>31.9</td></tr>
<tr><td>Blade or Multi-Node</td><td>26.8</td></tr>
</table>
</td></tr>
<tr><td>The IT equipment energy efficiency for servers (ITEEsv)</td><td>When a server is replaced, the ITEEsv of the new equipment should be greater than that of the old equipment. Also, the ITEEsv of the new server must be higher than the average ITEEsv of a group of servers analysed with the same benchmark method or at least of the replaced server. When a server is added to increase capacity, the expected value of ITEEsv of the group should be higher than before, showing an improvement of overall energy effectiveness.</td></tr>
</table>

<table>
<tr><th>Performance criteria</th><th>Standard Procurement Requirements</th></tr>
<tr><td>Data storage efficiency</td><td>
<table>
<tr><th>Workload type</th><th>Specific workload test</th><th>Minimum performance</th></tr>
<tr><td>Transaction</td><td>Hot band</td><td>28.0 IOPs/watt</td></tr>
<tr><td>Streaming</td><td>Sequential read</td><td>2.3 MiBs/watt</td></tr>
<tr><td>Streaming</td><td>Sequential write</td><td>1.5 MiBs/watt</td></tr>
</table>
</td></tr>
<tr><td>Power supply unit efficiency</td><td>
<table>
<tr><th>Power supply type</th><th>Rated load</th><th>10%</th><th>20%</th><th>50%</th><th>100%</th></tr>
<tr><td>Multi-output (AC/DC)</td><td>All output levels</td><td>N/A</td><td>90%</td><td>94%</td><td>91%</td></tr>
<tr><td>Single-output (AC/DC)</td><td>All output levels</td><td>90%</td><td>94%</td><td>96%</td><td>91%</td></tr>
</table>
</td></tr>
<tr><td>Power supply unit power factor</td><td>≥ 0.95 at 50% load</td></tr>
<tr><td>Power management criteria</td><td>The processors of the server should be able either to:
• Reduce voltage and/or frequency through dynamic voltage and frequency scaling (DVFS); or
• Enable processor or core reduced power states when a core or socket is not in use.</td></tr>
</table>

<table>
<tr><th>Performance criteria</th><th>Standard Procurement Requirements</th></tr>
<tr><td>Idle state maximum power</td><td>
<table>
<tr><th>Product type</th><th>Base idle state power allowance</th></tr>
<tr><td>1-socket servers (neither blade nor multi-node servers)</td><td>25 watt</td></tr>
<tr><td>2-sockets servers (neither blade nor multi-node servers)</td><td>38 watt</td></tr>
<tr><td>Blade or multi-node servers</td><td>40 watt</td></tr>
</table>
Additional idle power allowance: 0.18 W per Gigabyte (GB) for Installed memory greater than 4 GB</td></tr>
<tr><td>Serviceability</td><td>Provide clear instructions to enable a non-destructive repair or replacement of the following components for at least 8 years: data storage devices, memory, processor (CPU), motherboard, expansion cards/graphic cards, power supply unit (PSU), fans and batteries.</td></tr>
<tr><td>Waste management</td><td>The design for recycling should be specified. Verifiable effort to support preparation for reuse.</td></tr>
</table>

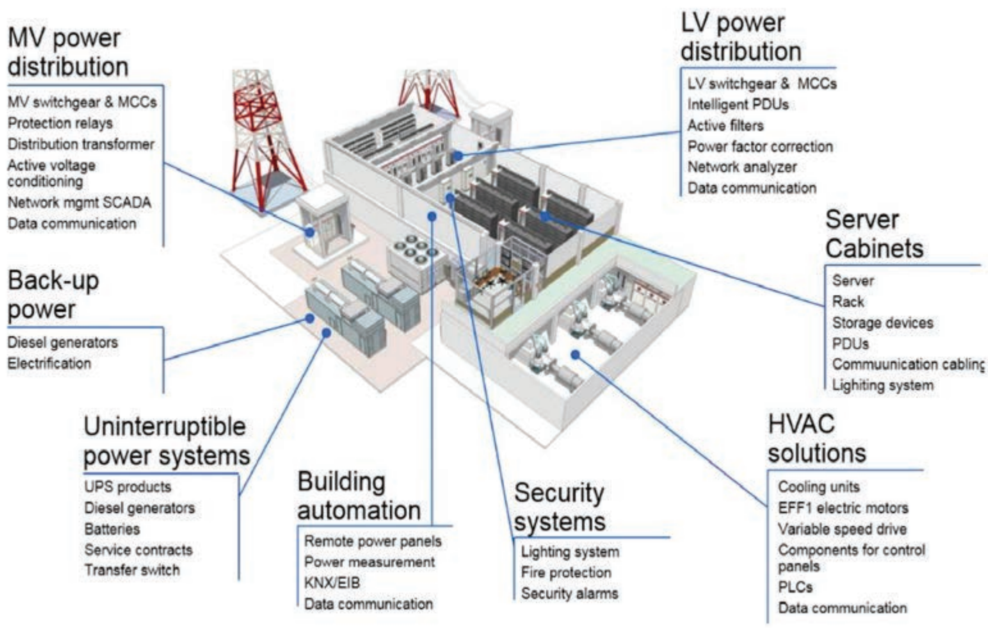
04 Product Overview

Data centre equipment

Data centres support multiple internet services and functions, including websites, email, and streaming media. They operate in conjunction with end-user devices (i.e., computers, smartphones, tablets) and communications technology (ICT)[11] equipment housed in the data centre. Following the definitions from standards bodies (ISO/IEC, ETSI, CEN-CENELEC), a data centre is a structure, or group of structures, dedicated to the centralised accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructure for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability.

Data centre ICT equipment is typically divided into network, storage and computer servers, although the distinctions are increasingly blurred. The infrastructure housing this equipment includes the building envelope, energy and power systems and the environmental controls which securely house the equipment, provide reliable power supply, and ensure a suitable operating environment. A typical data centre electrical distribution system is shown in Figure 2.

Figure 2: Electrical distribution system in a data centre



(Source: http://green-data.blogspot.com/2020/03/electrical-distribution-system-data-center.html)

11 *"Technologies and equipment that handle (e.g., access, create, collect, store, transmit, receive, disseminate) information and communication" - International Telecommunication Union (ITU)*

Data centres vary in size, from small cabinets occupying a few square meters with several servers to hyperscale facilities exceeding 10,000 square meters, owned by companies like Google or Amazon and housing thousands of servers. Data centres are often categorized by ownership and business model, distinguishing between colocation data centres and managed service provider data centres.

In colocation data centres, also known as multi-tenant data centres (MTDC), the owners of the building operate the building infrastructure, including providing cooling, power, and physical space for ICT equipment. Service options and capacity availability are provided as per contractual agreements. In these cases, the ICT equipment may be owned by another business which typically manages and provides cloud platform services. Software is then developed and/or run on that platform, often by another business with which the end user will interact. In the case of colocation data centres, government regulators and procurers can make the communication of aggregated data mandatory from the data centre operator's clients so that the operator can assess the performance of the entire data centre.

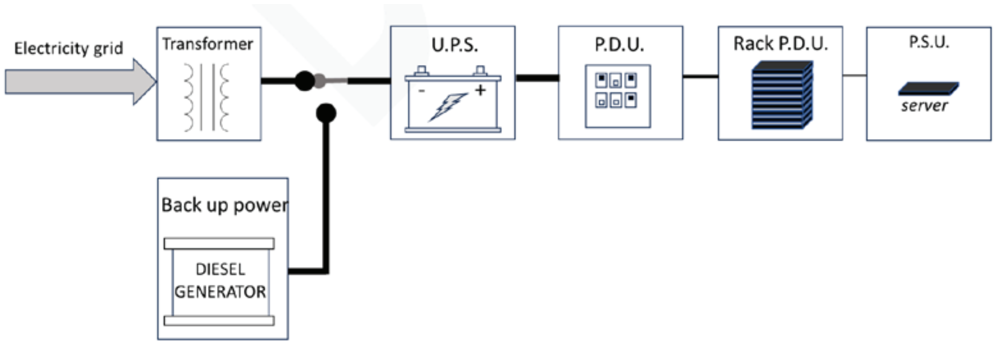
Managed service provider (MSP) is a data centre company offering server and data storage services where the customer pays for a service and the vendor provides and manages the required ICT hardware/software and data centre equipment. This management service includes the co-hosting of multiple customers, which may take the form of a cloud application environment.[12]

A data centre is often characterized by its IT installed power, ranging from few kW for small data centres to a few tens of MW for the largest ones. The primary energy consumption in a data centre is the electricity required to run the IT equipment itself, typically accounting for 40 to 70 per cent of total energy used. The second highest energy consumption is for cooling, typically accounting for 20 per cent to 50 per cent.

The electricity distribution circuit paths to IT loads

The main components of the data centre electricity distribution path to IT loads (servers) are represented in Figure 3

Figure 3: Electrical distribution components in a data centre



12 *Environmental Protection Agency*

Each component has its own efficacy. From left to right, the elements that make up the critical electricity path of a data centre are:

1. A **transformer**, required to have a stable and suitable power supply from the grid.

2. **Diesel generators** which can provide electricity typically for a few hours. Note these diesel generators take time to warm up (a few minutes).

3. **Uninterruptible power supply (UPS)**, made up of electrical batteries which guarantee the continuity of electricity supply to the IT load for a period in case of shortage of grid electricity.

4. **Power distribution unit (PDU)**, which distributes the electricity to the different racks.

5. **Racks PDU**, which distributes the electricity to different servers in the rack.

Lastly, each server has its own **power supply unit (PSU)** which converts, as necessary, alternating current (AC) to direct current (DC). The UPS may be "static" or "rotary". A UPS is called "static" when the output voltage is provided by solid-state power electronic components. A "rotary" UPS provides the output voltage through one or more electrical rotating machines. Static UPS units are generally made of three components. At the input a rectifier converts AC input from the grid into DC to load the batteries. The batteries (mostly lead batteries up until recently) typically store sufficient energy for 5 to 30 minutes of normal operation of the data centre and a static converter that switches the DC current into AC current at the output.

The output current of a UPS may be AC or DC. A DC output UPS is also known as a rectifier. A UPS unit is also characterized by its dependency towards the input characteristic. A voltage and frequency dependent (VFD) UPS produces an AC output where the output voltage and frequency are dependent on the input voltage and frequency. A voltage independent (VI) UPS protects the load against under-voltage or over voltage applied continuously to the input. A voltage and frequency independent (VFI) UPS have an output independent from the input voltage and frequency variations.

Cooling

In addition to IT equipment itself (servers, data storage, and network equipment), cooling is usually the second largest electricity consumer in a data centre. For a server to function properly, it must operate within a specific temperature and humidity range (refer to section "Operating temperature and humidity range") and thus, the ambient in the IT room is continuously monitored and controlled. The central processing unit (CPU) of typical servers generates 70-80 per cent of the heat and the remaining is from peripherals like memory, power supply, hard drives, SSDs, etc. The increasing use of graphics processing units (GPUs) to accelerate computational workloads in fields such as finance, analytics, AI, and scientific research has further increased the heat generated within the IT chassis.

Cooling the servers involves removing the heat generated either by blowing fresh air onto the server (air cooling and liquid-to-air cooling) or by circulating cold liquid on the components (liquid cooling). Often, a combination of these methods is used. Fresh air can be produced by a computer room air conditioning (CRAC), which generates cool air inside the IT room where servers are located. However cold production is most commonly located outside of the IT room. When fresh air comes from a computer room air handler (CRAH) inside the room, the air is cooled as it passes through a cooling coil. The liquid circulating inside the cooling coil is cooled by evaporative cooling, also known as adiabatic cooling. Adiabatic coolers are located outside of the IT room, usually on the roof of the data centre. Most adiabatic coolers can operate in free cooling mode when the outside temperature is low enough to cool the liquid. Liquid cooling refers to a system where coolant liquid is utilized to dissipate the heat generated by the servers. The liquid has higher heat transfer efficiency than air, thereby improving equipment performance, and reducing energy consumption and operating costs.

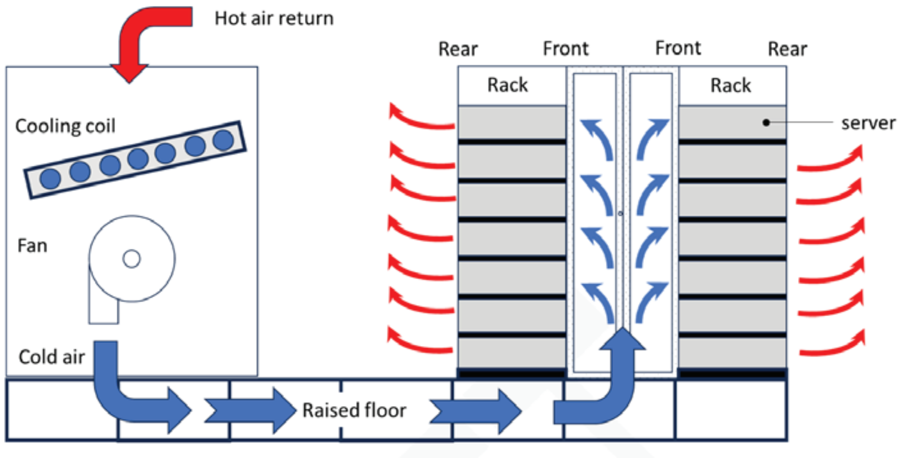
Air cooling

The most common method for cooling a server is by blowing conditioned air across it using a computer room air conditioning (CRAC) unit. CRAC units are similar to household air conditioners, blowing air over a cooling coil filled with refrigerant gas, which is cooled through a refrigeration cycle. Usually, the air is blown from a raised floor through perforated tiles. The extra heat is ejected using a glycol mix, water, or ambient air. Newer models of CRAC units can vary the airflow with the assistance of multistage compressors. However, most older models only have on/off capability. This cooling method works best for small and low power density data centres, typically with electrical loads of less than 200 kilowatts (kW) and lower availability requirements. It is worth mentioning that the use of CRAC units limits the possibility of free cooling.

Liquid to air cooling

Another common cooling system is called a computer room air handler (CRAH). The fresh air is blown by fans over a cooling coil. But instead of local mechanical refrigeration, as used in a CRAC, CRAH uses a water chiller system to remove heat. The chilled water typically comes in a separate chiller or chilled water plant. CRAH units can regulate fan speed, ensuring humidity and temperature levels stay stable while also allowing variability. Because CRAH units do not use compressors, they consume less energy, making them more efficient and requiring less maintenance - all of which can lead to lower costs. This cooling system is typically recommended for electrical loads of 200 kW[13] or more with moderate-to-high availability requirements. The efficiency of a computer room air handling unit improves with increased data capacity, making them the best choice for large data centres. The heat flow in a server room cooled using a CRAH is depicted in Figure 4.

Figure 4: Air flow in a server room cooled by CRAH



13 Environmental Protection Agency (EPA) (n.d.) *CRAC vs. CRAH cooling units: What's the difference?* [online] Available at: https://dataspan.com/blog/crac-vs-crah-cooling-units-whats-the-difference/

Evaporative cooling

Adiabatic cooling, also known as evaporative cooling, uses the evaporation of water phase change to extract heat from the air. Typically, dry, unsaturated air comes into contact with recycled water and cools as it absorbs the latent heat from evaporation.

The adiabatic cooler enclosure features an electric fan that forces the warm dry air through a pre-cooling pad. Water running through the pad lowers the incoming air's dry bulb temperature, resulting in cooler, more humid air. Alternatively, water can be sprayed directly into the airstream. A water tank in the lower part of the cooler collects excess water. Adiabatic cooling systems are effective in environments with ambient temperatures of at least 30°C and relative air humidity below 65 per cent. Cooling towers utilize this principle and can be combined as a chiller with the CRAH.

For adiabatic or evaporative cooling systems, water must be filtered carefully to avoid fouling, scale formation, corrosion and biological growth caused by salt, metal ions and dissolved gases. Water leakage is also a significant concern that must be addressed.

Free cooling

Under certain outside conditions and temperatures, typically around 18°C, the outside air can be blown directly on the servers to cool them down - this is called "direct free cooling". Before entering the room, the outdoor air is treated to avoid dust, moisture or salt. Another common application is "free chilling" which combines direct free cooling with a water-cooling system. In this setup, the chilled water plant is placed outside of the data centre building and the water is chilled by the air through a water to air heat exchanger. This method is referred to as "indirect free cooling" or "free chilling".

Liquid cooling systems

Liquid cooling refers to a system where coolant liquid is utilized to dissipate the heat generated by the server. The liquid has higher heat transfer efficiency than air, thereby improving equipment performance, reducing energy consumption and operating costs. Instead of cooling the whole IT room of a data centre, some data centres just cool the server itself or even the main components of the server (CPU and GPU).

Liquid cooling can be broken into three main categories depending on the way in which the heat-emitting electronic elements and refrigerant are in contact:

1. Freezing plate (or direct liquid cooling)

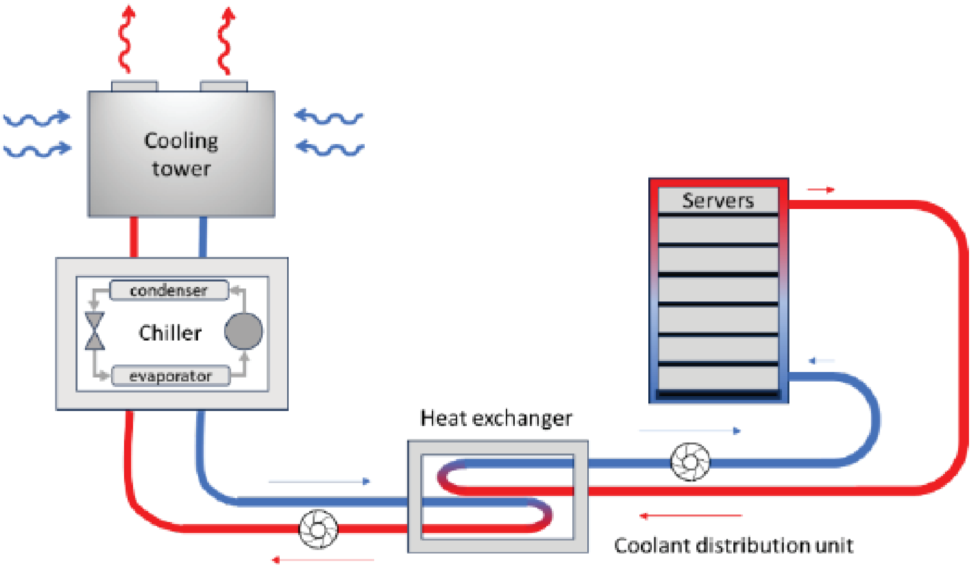
2. Rear door heat exchanger (RDHx)

3. Immersion

For *direct liquid cooling* (1), chilled water (single phase) or cooling fluid (two phases) is circulated through a plate placed upon the server which extracts the heat from the server. A *RDHx* (2) is a close-coupled indirect system where liquid is circulated through coils embedded in cabinet doors to remove server heat before venting into the room. *Immersion cooling* (3) consists of immersing the servers in neutral oil, extracting the heat by natural convection.

In Figure 5, the coolant distribution unit (CDU) is the intermediate device between server and heat rejection unit, which supplies the cold water closely controlled from the external source to the internal closed-loop cooling installed in the electronic device. It is symbolised by the heat exchanger and the pump in Figure 5, and the chiller shown is optional.

Figure 5: Typical liquid cooling system



Compared to traditional air-based cooling systems (CRAC and CRAH), liquid cooling may reduce cooling energy consumption by nearly 90 per cent. Another advantage of liquid cooling is the capacity to cope with higher heat or power density due to higher power Servers for applications such as high-performance computing (HPC), blockchain mining and artificial intelligence (AI). Economically, for installations above 20 kW of installed power per rack, liquid cooling is generally more cost efficient than air cooling. However, these direct liquid cooling technologies are relatively new and not as widely adopted as the aforementioned ones. The development of liquid-cooling systems still faces several challenges. The first challenge is adapting existing server rooms. Traditional server room designs, including load-bearing structures and piping, are based on the specifications of conventional cabinets. With liquid cooling, the deployment environment changes significantly due to the shift in cooling methods. Implementing a liquid-cooling system in a traditional data centre can pose problems in terms of cost and difficulty of deployment[14].

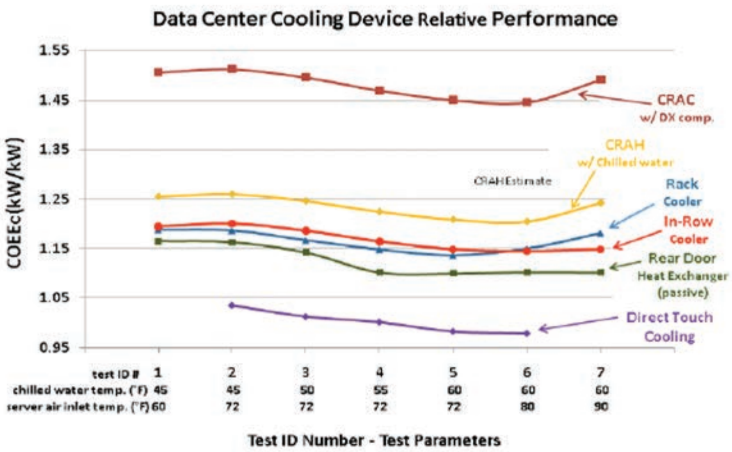
Some DCs are opting for a hybrid cooling environment where air and liquid cooling co-exist in the same facility.

A study from the Lawrence Berkeley National Laboratory (LBNL)[15] shows the relative performance of different types of cooling, as shown in Figure 6.

Note: A hot spot/cold spot is an undesirable, tightly focused local temperature variation that often occurs when data centre equipment is improperly cooled (areas with reduced cold air flow or high recirculation). Hot spots are a serious issue that can result in equipment damage and proper heat management is necessary to overcome it. Temperature at racks level should be monitored in multiple locations. A proper airflow management should minimize bypasses and recirculation.

14 https://c2e2.unepccc.org/wp-content/uploads/sites/3/2021/01/innovative-data-centre-cooling-technologies-in-china-liquid-cooling-solution.pdf
15 User guide for implementing ECBC in data centres, 2021

Figure 6: **Tested efficiency of data centre cooling options**



Waste heat recovery

Waste heat is the heat produced given a running process, of which it is not the ultimate purpose. In data centres, heat is generated at different levels:

- Servers and storage devices: all the electricity consumed by servers and storage devices is converted into heat.
- At the compressor level for air conditioners or heat pumps.

Most of the waste heat is being generated by Servers, and not all the waste heat generated is useful for other applications. The possibility of waste heat recovery depends on the cooling method. If the IT room is cooled using traditional air-cooling methods, capturing the removed heat is very difficult. However, if liquid cooling is used, the waste heat can be relatively easily captured and reused.

The temperature of the liquid that extracts heat from the IT room can reach around 55°C – a temperature level well below the one used in most legacy district heating systems (around 110°C). To inject heat into legacy district heating systems, a heat pump can be used to reach a higher temperature. For low temperature district heating, the waste heat from data centres can be directly injected.

However, one of the most practical ways to efficiently make use of waste heat from data centres is in nearby buildings for space and water heating. When heating is needed (e.g., space heating, industrial process), besides pre-rising the temperature of the fluid transfer, it can be also used to raise temperature in the evaporator, thus increasing the efficiency of the heat pump. European directives on energy efficiency for example, indicate the necessity the obligation of assessing heat recovery from data centres with an installed or planned IT power capacity of more than 1 MW[16].

16 Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955

Computer servers

A computer server, also known simply as a server, provides services and manages networked resources for client devices (e.g., desktop computers, notebook computers, thin clients[17], wireless devices, PDAs, IP telephones, other computer servers, or other network devices). A computer server is sold through enterprise channels to be used in data centres and office/corporate environments. A computer server is primarily accessed via network connections, versus directly-connected user input devices such as a keyboard or the mouse. Computer servers have the following characteristics:

- Marketed and sold as a computer server or server;
- Designed for and listed as supporting one or more computer server operating systems (OS) and/or hypervisors;
- Targeted to run user-installed applications typically, but not exclusively, enterprise in nature;
- Provide support for error-correcting code (ECC) and/or buffered memory - including both buffered dual in-line memory modules (DIMMs) and buffered on board (BOB) configurations.
- Packaged and sold with one or more AC-DC or DC-DC power supplies; and
- Designed such that all processors have access to shared system memory and are revisable to a single OS or hypervisor.

Note: The above refers to the ENERGY STAR® definition of "computer servers" which is equivalent to the European Regulation definition of "servers". In this guideline, computer server are also referred to as "servers".

Key server components

In all kinds of servers, it is possible to find the following components:

- A **motherboard,** which the heart of the server: a printed circuit board which connects every component of the server.
- The **central processing unit (CPU),** also called a processor, which is the computational part of the server performing all the calculations. A server can have one or more central processing units (CPUs). These are installed in interfaces called "sockets" and a server can have one or more processor sockets.
- The **random-access memory (RAM)** is the server's short-term memory and is often found in dual or double (DIMM, dual in-line memory module) format.
- The **input/output device i**s the communication component which provides data input and output capability between a server and other devices. It may be integrated into the motherboard or be connected to the motherboard via extension slots like Peripheral Component Interconnect (PCI) or PCIe (PCI express) slots.

17 Computer that runs resources from another centralized server

- The **storage devices** or hard drives are the long-term memory of the server. The two types of hard drives are Hard Disk Drive (HDD), where data is written on a spinning surface, and Solid-State Drives (SSD), where data is stored on non-volatile flash memory, with no moving parts. Storage devices are hard drives that are directly accessible. Cache memory is not directly accessible. Therefore, this memory type is not considered as a storage device.

- The **power supply unit (PSU)** provides power to the server. A server can have a redundant PSU for reliability. For efficiency purposes, two PSU often run simultaneously. The power is managed between those two PSUs by a Power Distribution Board.

- The **fans** create an air flow from the front to the rear of the server to dissipate the heat, mainly coming from the CPU.

- The **graphics processing unit** (GPU) is a card dedicated to graphics and video. It is optional in servers. However, as it can significantly speed up the processing time of the server, it is often used in demanding application like Artificial Intelligence and is incorporated in high performance computing (HPC) servers.

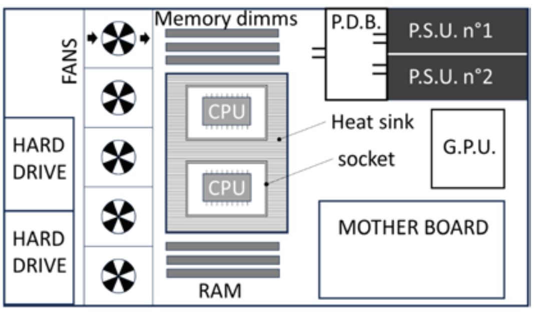
Types of servers

A server can house several nodes. A multi-node server is a system comprising an enclosure where two or more independent computer servers (or nodes) share one or more power supplies. The combined power for all nodes is distributed through the shared power supply(ies). A multi-node server is designed and constructed as a single enclosure, and it is not designed to be hot-swappable.[18]

Servers are fitted into enclosures or chassis of three types: rack, blade or tower. Blade form factor servers are contained in a blade chassis, rack-mounted servers have the so-called rack-form factors whereas servers designed for tower enclosures are referred to as pedestal servers.

The chassis is an enclosure that contains shared resources for the operation of servers, storage, and other form-factor devices. Shared resources provided by a chassis may include power supply units, data storage, and hardware for direct current power distribution, thermal management, system management, and network services. Figure 7 illustrated a typical rack mounted server.

Figure 7: Typical rack mounted server with redundant power supply, two CPUs and GPU



18 European Commission (2019). *Commission Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products*. [online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0424

Blade servers are smaller than rack servers. They are typically stacked vertically inside a chassis whereas a rack server is fitted vertically inside a rack. To maximize their efficiency, blade servers are often dedicated to single-task functionality, whereas rack servers can run as a multi-task computer. A tower server occupies a lot of room and is usually not used in data centres but can handle multi-user tasks.

Some servers might have special functionalities:

- **Resilient server:** a server designed with extensive reliability, availability, serviceability and scalability features integrated in the micro architecture of the system, central processing unit (CPU) and chipset, according to ENERGY STAR® requirements for computers servers.

- **Storage heavy servers (SHS):** a server with greater storage capacity than a standard computer server. These servers support 30 or more internal storage devices as shipped. Unlike dedicated storage products, SHS run computer server operating systems and software stacks.

- **High performance computing (HPC) Server:** a server designed and optimized to execute highly parallel applications, including high-performance computing and deep learning AI applications. HPC servers consist of multiple computing nodes, clustered primarily to increase computational capability and include high speed inter-processing interconnections between nodes.

- **Server with integrated auxiliary processing accelerator (APA)** means a specialized processor and associated subsystem that provides an increase in computing capacity such as graphical processing units or field programmable gate arrays. An APA cannot operate in a server without a CPU. APAs can be installed in a server either on Graphics or Extension add-in cards installed in general-purpose add-in expansion slots or integrated into a server component such as the motherboard.

05 Data Centre Technical Specifications

As economies become increasingly digitalised, a reliable and permanent access to digital infrastructure, especially data centres, is key to ensuring the continuity of vital services, payment systems or critical communications, among other functions. To operate effectively, data centres require a stable and reliable electricity grid system as well as a robust network connection. However, the implementation of data centres can often disturb electricity and water supply in the area, alongside consuming other industry related resources. Consequently, their impact is normally regulated by public authorities.

The sustainable procurement parameters proposed for data centres are outlined in the following sections. They encompass the proper location of a data centre to maximise its use of renewable energy to the right level of redundancy in the equipment, in addition to KPIs that define the performance of the data centre based on power usage effectiveness, water usage effectiveness, the IT equipment's energy efficiency and the cooling effectiveness ratio. A list of the relevant testing standards is given in Annex 1: Testing Standards Reference List.

Data centre energy efficiency criteria

Location considerations

The location of a data centre during the planning and design phase is critical, as it can affect key factors such as electricity consumption, utilisation of waste heat, risk management, data sovereignty, and end-user affordability.

Data centres must have good access to communications networks through an optic fibre cable and to the electricity grid. Big data centres have an IT power demand typically exceeding one MW. The power consumed by supporting infrastructure for larger data centres, mostly due to cooling, is typically about 40 per cent of the power used by the IT equipment. The operation of a data centre can have a significant impact on the electricity grid network and its optimum implementation should be selected in accordance with the appropriate government entities and the electricity utilities responsible for the power system, considering relevant local urban/industrial development plans.

Data centres are also very sensitive to climate hazards, such as flooding and earthquakes (which can dramatically damage the IT equipment), droughts (which can restrict water access for cooling), and high temperatures (which can stress cooling systems).

- An assessment of the site risks should be considered when choosing the location.

Mitigation of climate risks may include effective drainage systems, installation of physical barriers in the design plan to prevent incoming seawater, elevate the IT equipment, among many others.

Considering the capacity to produce renewable energy on site or in the nearest area is essential. Locally generated renewable electricity can enhance the resilience of the data centre against electricity grid outage, reducing reliance on buying clean electricity from an extended grid network.

Waste heat recovery may also be an important driver for data centre location as public authorities may orientate the data centre operator to a location where waste heat could be used, i.e. domestic and office buildings, swimming pool, etc.

Data sovereignty and price affordability are crucial aspects. Deploying data centres in developing countries helps reduce costs and improve speed by allowing popular internet content from overseas to be stored locally, avoiding charges from international carriers. Local internet exchange points (IXP) hosted in data centres enable the local peering of domestic traffic and reduces the number of network hops to exchange traffic. This increases the number of route options available, optimizing the use of international Internet connectivity, improving network resilience (and potentially quality of service), reducing transmission costs and potentially increasing Internet penetration and usage over the long-term.

It is also recommended for data centres using adiabatic or evaporative cooling to have **access to an abundant and secure source of clean water** as this type of cooling can consume a significant amount, at around 2 litres per kWh. Clean water refers to water that does not come from the soil, such as river water or potable tap water.

This type of cooling is unsuitable for regions where water is scarce or where its use for this purpose could negatively impact other critical needs.

To mitigate the environmental impact of new facilities, it is recommended to explore whether the retrofit of existing buildings might yield preferable life-cycle energy, climate and cost benefits relative to new data centre construction.

Resilience

The resilience of a data centre refers to its ability to continue operating during power outage, equipment failure or other disruptions.

A common characteristic of data centres is their capacity to operate continuously – typically running 24/7, all year round. To assess the resilience of a data centre and its ability to provide the expected service, the Uptime Institute19 proposed a widely used tier classification (Tier I, Tier II, Tier III and Tier IV). The ISO/IEC 22237 standard also provide equivalent availability classes.

These tier or class classifications consistently describe the site-level infrastructure required to sustain data centre operations, rather than the characteristics of individual systems or subsystems. Indeed, data centres comprise various infrastructure systems (such as power, cooling and energy back up) that must be successfully integrated to maintain the entire expected operation.

19 https://uptimeinstitute.com/tiers.

The different subsystems include the following:

1. **The cooling capacity components**: on-site power production, UPS module and energy storage, chillers, heat rejection equipment, pumps, cooling units and fuel tanks.

2. **The critical power components**: electrical power distribution circuit paths from the output of the on-site power production system to the input of the IT UPS and the power distribution paths that serves the critical mechanical equipment.

3. **The mechanical path**: distribution circuits or paths for moving heat from the critical space to the outdoor environment. For example, chilled water piping, condenser water piping, refrigerant piping, etc.

Tier classes are the following:

- **Tier I** is the basic data centre site infrastructure. It has a non-redundant capacity component and a single non redundant distribution path serving the critical environment. Tier I infrastructure typically encompasses the following elements:
    - the dedicated space for IT systems
    - a UPS to filter power spikes, sags and momentary outages
    - dedicated cooling equipment
    - on-site power production to protect IT functions from extended power outages
    - twelve hours of on-site fuel storage for on-site power production

- **Tier II**, in supplement to Tier I, has redundant critical power and cooling capacity components. The twelve hours of fuel storage should be designed for the N redundant components.

- **Tier III** is a concurrently maintainable site infrastructure. It means that each and every capacity or distribution component necessary to support the IT processing environment can be maintained on a planned basis without impact to the IT environment. In addition to redundant critical capacity components of Tier II, it has multiple independent distribution paths for power and cooling serving the critical environment. All IT equipment is dual powered.

- **Tier IV** is a fault tolerant site infrastructure. It means that each and every system or component that supports IT operations can be maintained on a planned basis without impact to the IT operations. In addition to Tier III, it has multiple, independent physically isolated systems that provide redundant capacity components and multiple, independent, diverse, active distribution paths simultaneously serving the critical environment. Complementary systems and distribution paths must be physically isolated from one another. Continuous cooling is required.

With "N" representing the number of pieces to satisfy the normal conditions, the requirements for each of the tiers are given in Table 1.

Table 1: Tier data centre infrastructure requirements

Table 1:	Tier I	Tier II	Tier III	Tier IV
Minimum capacity components to support the IT load	N	N + 1	N + 1	N After any Failure
Distribution paths – electrical power backbone	1	1	1 active and 1 alternate	2 simultaneously active
Critical power distribution (from the UPS to the IT assets)	1	1	2 simultaneously active	2 simultaneously active
Concurrently maintainable	No	No	Yes	Yes
Fault tolerance	No	No	No	Yes
Compartmentalization	No	No	No	Yes
Continuous cooling	No	No	No	Yes
Uptime	99.671%	99.749%	99.982%	99.995%
Downtime per year (hours)	28.8	22	1.5	0.04

Please note that a Tier IV system with 2N infrastructure is often not justified and appropriate. Not all data centre applications are critical, so in such cases, the service can be shortly interrupted. Choosing higher Tier classification means more costly equipment while networking and replicating applications in another data centre can be very cost effective. In a single data centre, the IT platform can be split into diverse sites with an increased resilience or availability for critical services. The required resilience may also be obtained by making the applications able to overcome the loss of an individual site inside one data centre.

A single data centre can be designed to provide varying levels of power and cooling resilience across different floor areas. Many co-location providers already offer this, such as optional 'grey' power feeds without UPS or generator backup. Only the level of resilience—and consequently, availability—justified by business requirements and impact analysis should be built or purchased by a co-location customer.

For public procurement, a data centre certified Tier III or class 3 is normally sufficient to guarantee access to data.

Power usage effectiveness (PUE)

Power usage effectiveness (PUE) is the most used and well-known KPI for data centres. It is defined as the ratio of the overall annual energy consumption of the data centre facility to the annual IT equipment energy consumption (Equation 1).

Equation 1: Power usage effectiveness

$$PUE = \frac{Total\ facility\ energy\ consumption}{IT\ energy\ consumption} = \frac{cooling + \ auxiliaries + IT\ energy\ consumption}{IT\ energy\ consumption}$$

- The *IT energy consumption* is defined as the energy consumed by the equipment that is used to manage, process, store, or route data within the computing space. *IT equipment energy* includes the energy associated with all the IT equipment (e.g., computer, storage, and network equipment) along with supplemental equipment (e.g., KVM switches, monitors, and workstations/laptops used to monitor or otherwise control the data centre).

- The *total facility energy consumed* is defined by the energy dedicated solely to the data centre (e.g., the energy measured at the utility meter of a dedicated data centre facility or at the meter for a data centre or data room in a mixed-use facility). *Total facility energy* includes all IT equipment energy consuming equipment as described plus everything that supports the IT equipment that uses energy, such as:

    - Power delivery components, including UPS systems, switchgear, generators, power distribution units (PDUs), batteries, and distribution losses external to the IT equipment;

    - Cooling system components, such as chillers, cooling towers, pumps, computer room air handling units (CRAHs), computer room air conditioning units (CRACs), and direct expansion air handler (DX) units; and

    - Auxiliaries which are miscellaneous component loads, such as data centre lighting.

PUE is a unitless metric that typically ranges from over 2.0 for legacy or small data centres to 1.2 or lower for newly optimized facilities (minimum is 1). It is influenced by the data centre's load. Infrastructure is generally designed to perform optimally at full IT capacity, which is usually achieved only after several years, commonly around five or six.

The PUE value reported by operators is the "PUE by design," which reflects performance at this optimal load. However, during the initial years—known as the "ramp-up period"—actual PUE levels differ from the design value and tend to be higher as the nominal IT capacity has not been reached yet. For this reason, it is recommended to define a PUE during this ramp-up period, to be assessed at the third year of operation. These Guidelines offer recommended target values for both the "PUE by design" expected after the ramp up period and the PUE expected during the ramp-up period (table n°2).

The PUE index is dependent on the temperature of the region where the data centre is located. The temperature in the surroundings of the servers must be monitored and maintained below a certain value, typically around 20 °C. In some cool climate regions, that temperature level can be achieved with free cooling, with the outside air circulated around the server to cool it down.

According to the Climate Neutral Data Centre Pact[20] which is a self-regulatory initiative from data centre operators and trade associations in Europe, the commitment includes the following: "By January 1, 2025, new data centres operating at full capacity in cool climates will meet an annual PUE target of 1.3, and 1.4 for new data centres operating at full capacity in warm climates." As a result, the recommended requirements shall increase in stringency over time and be climate dependent are shown in Table 2. The PUE for Hot and Humid (HH) countries is less stringent than for other countries.

Table 2: Minimum PUE requirements

Year	2025	2027	2029	2031
Existing colocation data centre to host data	PUE ≤ 1.5 HH: PUE ≤ 1.7	PUE ≤ 1.4 HH: PUE ≤ 1.6	PUE ≤ 1.3 HH: PUE ≤ 1.5	PUE ≤ 1.2 HH: PUE ≤ 1.4
New data centre building	By design: PUE ≤ 1.4 HH: PUE ≤ 1.6 During ramp up period of oepratio (at 3 years): PUE ≤ 1.5 HH: PUE ≤ 1.7	By design: PUE ≤ 1.3 HH: PUE ≤ 1.5 During ramp up period of oepratio (at 3 years): PUE ≤ 1.4 HH: PUE ≤ 1.6	By design: PUE ≤ 1.2 HH: PUE ≤ 1.4 During ramp up period of oepratio (at 3 years): PUE ≤ 1.3 HH: PUE ≤ 1.5	By design: PUE ≤ 1.1 HH: PUE ≤ 1.3 During ramp up period of oepratio (at 3 years): PUE ≤ 1.2 HH: PUE ≤ 1.4

Note 1: Hot and Humid climate are corresponding to ASHRAE climate zone 0A (Extremely Hot-Humid), 1A (Very Hot-Humid), 2A (Hot-Humid) and 3A (Warm-Humid). The definitions available at ANSI/ASHRAE Standard 169-2013. Climate group can be determined for the data centre location with the ASHRAE weather data viewer 202121.

Note 2: The norms define three categories for the PUE depending on the IT electrical consumption measurement. The PUE categories from 1 to 3 are defined based on where IT electrical consumption is measured (please refer to Figure 3):

- PUE1: the measurement of the consumption is performed at the output of the UPS
- PUE2: the measurement of the consumption is performed at the output of the PDU
- PUE3: the measurement of the consumption is performed at the output of the rack PDU
- The PUE category 3 value should be preferred if available, otherwise PUE category 2.

Note 3: Even if the data centre operator is forecasting the PUE after three years of operation, the authority should check that the PUE is reached with the operator.

20 https://www.climateneutraldatacentre.net/
21 https://www.ashrae.org/technical-resources/bookstore/weather-data-center

IT room design

Modularity

Data centre operation evolve over time, with new servers being added to the IT room as the business grows. To adapt to these changes and reduce energy consumption due to cooling, incorporating a modular room design is among international best practices. This approach provides the flexibility to segregate the IT area around the server, so it is unnecessary to cool the entire IT room when only a small portion is in use.

- The IT room structure should be modular.

- Cooling plant should also be modular to adapt to cooling needs. Non-utilised equipment should have the capability to be readily shut down.

All areas of the data centre should be designed to maximise the energy efficiency of the facility under partial fill / partial load and variable IT electrical and cooling loads.

- **Pumps, fans and compressors should be monitored and incorporate variable frequency or speed controls as appropriate (i.e. for all the variable loads).**

Non-variable plant such as fixed speed fan CRAC/CRAH units should be turned off in empty areas.

Cooling design

Hot and cold aisles are meant to segregate air flows, so they don't mix, and only cold air is blown on servers. The hot and cold aisles design is essential for maintaining a coherent and optimized air flow through servers. The hot / cold aisle concept aligns equipment air flow to create aisles between cabinets that are fed cold air from which all the equipment draws intake air in conjunction with hot aisles with no cold air feed to which all equipment exhausts air. Note that IT equipment must be compatible with the air flow management or with liquid cooling when this is used, typically from front to rear of the server or from front to top.

The physical layout of the building should not obstruct or restrict the use of free cooling (either air or water), or other equipment with an economisation / free cooling mode.

Motor efficiency

Data centres use multiple motors such as to sustain air flow, in air conditioners and in the operation of fans, pumps and compressors. The share of electricity consumption from motors is estimated at around 30 per cent of data centre load. Therefore, the efficiency of motors and related systems is key to saving energy.

- Is recommended to use IE4, IE5 or NEMA Super Premium electric motors and IE2 variable speed drives. U4E's motors and systems guidelines22 have more details as to efficiency recommendations, with the higher performance levels recommended for public procurement.

22 U4E Model Regulation Guideline for Motors and systems: https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficiency-requirements-for-general-purpose-electric-motors/

In addition to the product efficiency of motors, the correct control strategies for this equipment are critical to ensuring high efficiency in the data centre. The control strategies must minimise air and water bypass and recirculation. Air/water bypass occurs when cool air/water from the HVAC system is returned to the production equipment before effectively cooling the IT equipment. Air/water recirculation occurs when warm air/water that has already cooled the IT equipment is returned to the IT equipment without being treated in the production equipment. Both events lead to significant inefficiencies, as the cooling system must work harder to maintain the desired temperatures at the IT equipment inlet, thus consuming more energy.

Uninterruptible power supply (UPS) efficiency

Uninterruptible power supply (UPS) equipment is crucial for the data centre, filtering power spikes, sags and momentary outages. As mentioned in section 4.3.2 on resilience, UPS units are an integral part of the electricity distribution circuit paths to IT loads in a data centre. Ensuring their efficiency is essential for the overall data centre efficiency.

- To protect the IT load from voltage and frequency fluctuations from the grid, it is recommended to use voltage and frequency independent (VFI) UPS systems.

- The UPS should also be able to withstand a temperature of between 0°C to 40°C. Conformity with the IEC 62040 series for UPS systems is required.

The minimum efficacy requirement depends on the power rating of the UPS and given in Table 3.

Table 3: Minimum efficacy requirement for VFI static UPS units

Power range (kW)	Performance
≥ 0.05 kW to ≤ 0.3 kW	85.5 %
> 0.3 kW to ≤ 3.5 kW	88.0 %
> 3.5 kW to ≤ 10 kW	91.0 %
> 10 kW to ≤ 200 kW	93.0 %
> 200 kW	95 %

Note: The requirements above are in line with ENERGY STAR®.

Distribution transformers

Distribution transformers play a key role in data centres by providing a stable and suitable power supply from the grid, stepping down the voltage to appropriate levels for various equipment in the data centre. They also significantly enhance the overall efficiency of a data centre by allowing the supply of high voltage, reducing losses in long-distance power transmission. Additionally, transformers protect data centre devices from surges and fluctuations. The U4E Model Regulation Guidelines, *"Performance requirements for distribution transformers"*, provides additional recommendations[23] with energy efficiency requirements aligned with European Commission Regulation (EU) 2019/1783[24]. The energy efficiency requirements depend on the power and the technology (liquid immersed or dry-type transformers). For a dry-type transformer, the heat produced by the conversion from higher voltage to lower voltage is dissipated in the air whereas in liquid immersed transformer, the heat is dissipated through oil, silicon or hydrocarbons.

The efficiency index is the ratio of the transmitted apparent power of a transformer minus electrical losses, including the power consumed by the cooling, to the transmitted apparent power of the transformer for a given load factor. The peak efficiency index is the highest value of the efficiency index that can be achieved at the optimum value of load factor. Requirements are given in Table 4.

Table 4: Minimum peak efficiency index requirements for liquid immersed and dry-type large power transformers

	Minimum Peak Efficiency Index (%)	
Rated Power (MVA)	**Liquid immersed large power transformers**	**Dry-type large power transformers**
≤ 0.025	98.251	99.382
0.05	98.891	
0.1	99.093	
0.16	99.191	
0.25	99.283	
0.315	99.32	
0.4	99.369	

23 https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-performance-requirements-for-distribution-transformers/
24 https://eur-lex.europa.eu/legal-content/fr/TXT/?uri=CELEX%3A32019R1783

	Minimum Peak Efficiency Index (%)	
0.5	99.398	99.382
0.63	99.437	
0.8	99.473	
1	99.484	
1.25	99.487	
1.6	99.494	
2	99.502	
2.5	99.514	
3.15	99.518	
4	99.532	
5	99.548	99.387
6.3	99.571	99.389
8	99.593	99.39
10	99.615	99.39
12.5	99.64	99.422
16	99.663	99.464
20	99.684	99.513
25	99.7	99.564
31.5	99.712	99.592
40	99.724	99.607
50	99.734	99.623

Water usage effectiveness (WUE)

Data centres typically use water for their cooling systems and, to a lesser extent, for air humidification, which is often necessary to maintain the required environmental conditions around the servers. For cooling systems, water consumption is particularly high in data centres with adiabatic cooling, reducing the electricity consumption for cooling and leading to better PUE.

For purity reasons and availability, most of the water used is potable. This water is mainly evaporated into the atmosphere via the data centre's cooling tower, necessitating the monitoring and limitation of water consumption. The water usage effectiveness (WUE) is then the ratio of the annual water usage for the data centre operations in litres, divided by the annual energy consumption of the IT computing equipment in kilowatt hours (kWh). Therefore, WUE is signified using the units of litre per kilowatt-hour (L/kWh) (Equation 2).

Equation 2: Water usage effectiveness

$$WUE = \frac{Water\ consumption\ of\ the\ data\ center}{energy\ consumption\ of\ IT\ equipment}$$

Note 1: Data centres using evaporative or adiabatic cooling often have low electricity consumption for cooling, hence a low PUE. It is important to consider both PUE and WUE together.

Note 2: The WUE here does not take into account the water used by the energy source.

- It is recommended to have a WUE ≤ 1.5 L/kWh in 2025 and progressively upgrade to WUE ≤ 1 L/kWh in 2027, as shown in Table 5.

Table 5: Minimum water use effectiveness requirements

Year	2025	2027	2029	2031
Water usage effectiveness	≤ 1.5 L/kWh	≤ 1 L/kWh	≤ 0.5 L/kWh	≤ 0.2 L/kWh

Please note that achieving the recommended maximum water consumption values might not always be compatible with the low PUE requirements (Table 2). A low PUE can be achieved by using water to cool the data centre, particularly through adiabatic cooling. Public authorities may prioritise either a targeted maximum water consumption or a targeted PUE, depending on their preferences and local context.

Renewable energy factor (REF)

Data centres typically operate non-stop throughout the year, making them highly energy intensive. Shifting power consumption from fossil fuels to renewable energy can help reduce greenhouse gas emissions during electricity generation. Many data centres claim to use some form of renewable energy to power their operation. Some operators even produce renewable energy to be used inside their facilities to achieve sustainability goals. Thus, data centre owners can be tenants and developers of renewable energy projects.

The renewable energy factor measures the ratio of renewable energy consumption over the total energy consumed by the data centre (Equation 3).

Equation 3: Renewable energy factor

$$REF = \frac{E_{ren}}{E_{DC}}$$

Where:

- E_{ren} is the renewable energy consumption in kWh of the data centre during a g$_{iv}$en period. Compatible renewable energy can be produced on site, obtained through renewable energy certificates or through the electricity grid supply (with all or part provided by the utility).

- E_{DC} is the total energy consumption of the data centre in kWh during the same p$_{er}$iod.

The renewable energy factor should be measured at least once per season, ideally on a one-year period, to ensure that renewable power sources are used consistently — not just during summer when photovoltaic production is at its peak.

- It is recommended to have a minimum renewable energy factor of 50% in 2025 (thought out all seasons), progressively increasing to a minimum of 80% in 2031, as shown in Table 6.

Table 6: Minimum renewable energy factor

Year	2025	2027	2029	2031
Renewable energy factor	≥ 50%	≥ 60%	≥ 70%	≥ 80%

Note 1: In cases where the production is not local, only energy purchases from PPAs (Power Purchase Agreement) should be taken into account.

Note 2: this KPI should not be considered when assessing the resilience of a data centre to power outage. Indeed, locally produced renewable electricity is compatible for the REF KPI, as is renewable electricity from the electricity grid.

Note 3: Some data centres are already using 100% renewable energies as power sources, while selling the unused part of produced energy to the market, creating a new revenue.

Cooling efficiency ratio (CER)

The cooling efficiency ratio is noted as the R_{CE} and defined as:

Equation 4: Cooling efficiency ratio

$$R_{CE} = \frac{Q_{removed}}{E_{cooling}} = \frac{E_{heat}}{E_{cooling}}$$

Where:

- $Q_{removed}$ is the total amount of heat removed annually from the data centre in kWh
- $E_{cooling}$ is the energy consumption (annually) of the cooling systems (including pumps, valves, fans, compressor, etc) in kWh
- E_{heat}: EIT + E_{losses} with the assumption that all electrical energy used in the DC is transferred to heat
- E_{losses}: include all electrical losses (electrical energy of UPS, energy storage, transformers, power cables, lighting.)
- The recommended CER for existing and new data centres in 2025 and the progressive increase to 2031 is shown in Table 7.

Table 7: **Minimum cooling efficiency ratio requirements**

Year	2025	2027	2029	2031
Existing colocation Data Centre to host data	CER ≥ 2.5	CER ≥ 2.9	CER ≥ 3.8	CER ≥ 5.7
New Data Centre building	CER by design ≥ 2.9 CER after 3 years of operation ≥ 2.5	CER by design ≥ 3.8 CER after 3 years of operation ≥ 2.9	CER by design ≥ 5.7 CER after 3 years of operation ≥ 3.8	CER by design ≥ 10 CER after 3 years of operation ≥ 5.7

Note 1: Volume of the coolant and its heat capacity shall be measured to assess the heat removed. In cases of Direct Free Cooling, every parameter influencing the heat capacity (like humidity) shall be measured for an acceptable accuracy of the calculation of the heat removed. In case of redundant pipes, every pipe shall be measured.

Note 2: The cooling efficiency factor (CEF), noted as FEC, is the inverse of CER

Equation 5: **Cooling efficiency factor**

$$F_{EC} = \frac{1}{R_{CE}} = \frac{E_{cooling}}{E_{heat}}$$

In contrast to CER, CEF enables the efficiency of a cooling system to be expressed in percentage of removed heat. For example, a system with a CEF of 0.25 requires 25 per cent of the removed heat as electrical energy input for the process of heat removal.

Refrigerant used for cooling

The Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer sets out an HFC phasedown to drastically reduce their consumption in terms of CO2 equivalent. The ozone depletion potential (ODP) of refrigerants used in data centres should be 0. In data centres, traditional refrigerants such as hydrofluorocarbons (HFC) are widely used in the cooling and air conditioning equipment, including R-134a and R-410A due to their non-flammable properties. Those types of refrigerants have a high Global Warming Potential (GWP), expressed in CO2 equivalent of 1430 for R134a and 2088 for R-410A. Several alternatives exist for the aforementioned refrigerants, such as R-32 (GWP of 675) to replace R-410A and R1233zd (GWP of 4) or R1234ze (GWP of 7) to replace R-134a[25.]

- The GWP of the refrigerants used in the Data Centre cooling equipment should be lower than 10. For the air conditioning equipment, GWP should be lower than 680 and ODP 0.

Note: The refrigerants R134a, R1233zd and R1234ze could be considered as polyfluorinated alkyl substances (PFAS) according to a joint statement made by Germany, Denmark, Netherlands, Norway and Sweden. PFAS are, or ultimately transform into, persistent substances, leading to irreversible environmental exposure and accumulation.

25 https://www.unep.org/ozonaction/resources/factsheet/ozonaction-kigali-fact-sheet-no-19-phase-down-strategy-impact-gas-choices

Utilisation rate of the IT equipment ($ITEU_{sv}$)

As previously mentioned, servers are often underutilised, leading to unnecessary purchase of new servers, inefficiency of the whole system and unnecessary use of materials. To maximise the running time of a server and its utilisation rate, techniques like virtualisation may be used (see section 6.1.7).

Moreover, servers operate more efficiently under higher utilisation levels. Uptime Intelligence has analysed the efficiency of 429 server platforms using The Green Grid's Server Efficiency Rating Tool (SERT) database[26]. The study concluded that the average efficiency of a server increases by 50 per cent when processor utilisation is doubled from low levels (20 per cent to 30 per cent) to higher levels (40 per cent to 60 per cent).

The utilisation rate of a server is measured using the IT equipment use for server's metric (ITEUsv). This KPI assesses the actual utilisation of servers in the data centre and quantifies the impact of:

- improving the utilisation ratio of servers by using technologies such as virtualisation and server consolidation for sharing server usage.
- reducing the number of servers required to achieve the same level of information processing.

For instance, a colocation data centre may not have all its servers intensively utilised just after commissioning as usually time is needed for clients to request the service. ITEUsv is based on the anticipated annual average server utilisation level depending on the contracting authorities, data handling and processing requirements.

Equation 6: Instantaneous IT equipment use for servers

$$ITEU_{SV}(t) = \sum \frac{CUS_i(t)}{N}$$

Where:

- CUSi(t) is the CPU utilisation ratio of server i at time t (%);
- ITEUsv(t) is the average CPU utilisation of all servers or a group of servers in a data centre at time t;
- N is the number of servers in a data centre or in a group running at time t.

26 "Server energy efficiency: five key insights", May 2023, Uptime Institute

Equation 7: IT equipment use for servers

$$ITEU_{sv} = \frac{1}{a} \times \sum [ITEU_{sv}(t_0 + e_i)]$$

Where the sum is over the interval number i ranging from 1 to "a" and

- a is the number of ITEUsv(t) measurements intervals over "a" year (all intervals should be the same length);
- t0 is the starting time of measurement.
- e is the interval of measurement, where e × a = one year.
- The recommended minimum utilisation rate for existing and new data centres in 2025 and the progressive increase to 2031 is shown in Table 8.

Table 8: Minimum IT equipment utilisation rate requirements

Year	2025	2027	2029	2031
Existing colocation data centre to host data	ITEUsv ≥ 50%	ITEUsv ≥ 60%	ITEUsv ≥ 70%	ITEUsv ≥ 80%
New data centre building	ITEUsv ≥ 50% after 3 years of operation	ITEUsv ≥ 60% after 3 years of operation	ITEUsv ≥ 70% after 3 years of operation	ITEUsv ≥ 80% after 3 years of operation

Note 1: For colocation data centres, the government should make mandatory the communication of aggregated data from the clients to the data centre operator so that the operator can assess the performance of the whole data centre.

Note 2: Measurements of ITEUsv can be complex in some cases as do not consider GPUs which are becoming increasingly important with the rise of AI. However, it remains the only existing standardized KPI at the ISO level that accounts for servers' utilisation rate.

Waste heat recovery (energy reused factor, ERF)

Waste heat from data centres can occasionally be used to meet nearby heating needs. Although waste heat reuse is highly encouraged, technical and economic feasibility of heat recovery must be evaluated.

- An assessment of the waste heat recovery possibility should be conducted for data centres with an installed or planned electrical power capacity of more than 1 MW, to evaluate the economic feasibility of the system.

The KPI used for waste heat is the Energy Reuse Factor (ERF) defined in the standard ISO/IEC 30134-6. Data centres shall measure the heat that is used or reused outside of the data centre boundary, and which substitutes partly or totally energy needed outside the data centre boundary.

- When waste heat recovery is in place, the ERF should meet the requirements shown in Table 9.

Table 9: Minimum energy reused factor requirements

Year	2025	2027	2029	2031
Energy reused factor	≥ 30%	≥ 40%	≥ 50%	≥ 60%

Lighting efficiency

Although IT equipment itself does not require lighting to operate, regular activities such as maintenance, updates and controls are performed by operators. Data centres, or at least the IT room and technical rooms, have no access to natural lighting, requiring artificial lighting for the personnel to perform their tasks. Hence, the efficiency and control of artificial lighting is also a key aspect to consider. LED lighting is favoured over fluorescent lighting due to its higher efficiency, longer lifetime and lower heat irradiance compared to fluorescent lighting, which reduces the cooling load. If fluorescent lighting luminaires are already installed, replacing them by controlled LED lighting is encouraged.

The lighting efficiency levels recommended align with the United for Efficiency Green Public Procurement Technical Guidelines[27] for energy efficient lighting as outlined in Table 10.

Additional criteria from these Guidelines for offices and large buildings should also be applied, including lifetime, safety, quality of light, protection and other parameters that ensure a sustainable lighting installation.

Table 10: Lighting efficiency requirements

Year	2025	2027	2029	2031
Efficacy	≥ 150 lm/W	≥ 170 lm/W	≥ 190 lm/W	≥ 210 lm/W

27 https://united4efficiency.org/resources/green-public-procurement-technical-guidelines-and-specifications-for-energy-efficient-lighting/

06 Server and Data Storage Products Technical Specifications

Servers consume between 60 per cent to 80 per cent of the electricity used in data centres. Therefore, their energy efficiency is crucial in reducing the energy consumption of the facility. The second most energy demanding element is the cooling system. A proper selection of servers able to operate at a temperature of 30°C can significantly reduce the needs for cooling. Servers can also be located in IT rooms inside a tertiary building. The public buyers/authorities may request servers based on the requirements depicted below to ensure efficient data processing and minimal energy consumption. These requirements also apply to servers where public data is stored. Serviceability is also an important aspect, as the easy replacement of server components extends their lifespan and thereby reduces their overall environmental impact. Parts of decommissioned servers may also be reused in other servers.

Server and data storage energy efficiency criteria

Operating temperature and humidity range

Servers consist of electronic circuits and processors that are highly sensitive to temperature change and are designed to operate within a specific range of ambient conditions. Therefore, maintaining reliable, controlled ambient temperature and humidity conditions is critical. Outside their design temperature range, servers operate in low, inefficient mode and are subject to failure. Additionally, humidity must be carefully monitored and controlled as low or high humidity can lead to electrostatic discharge or moisture buildup.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)[28] publish thermal guidelines for data centre processing environments. In its first publication in 2004, the ASHRAE air temperature recommended envelope for data centres was between 20-25°C.

This was a conservative statement, based on the data available at the time, regarding the reliable operation of a data centre. Since then, ASHRAE has recommended a temperature range of 18-27°C and in 2011, published a set of classes (A1 to A4) that allow a temperature range between 5 to 45°C. The allowable envelopes (A1 – A4) are where IT manufacturers test their equipment to verify that it will function properly. It may be possible to have cold aisle air temperatures as high as 40°C or even 45°C during a short period of time for ASHRAE Class A3 or A4 but it is important to note these are typically short term (hours) and not continuous operation at high temperature. The recommended operating range remains 18-27°C.

In a traditional data centre cooling system, the cold-aisle air temperature is controlled within a narrow range of 1-3°C. Chiller stages or direct expansion (DX) air conditioning units are often cycled on and off to keep this narrow air temperature range. However, chiller and DX cycling can create very high instantaneous rates of air temperature change, albeit over a very small range

28 https://www.ashrae.org/

of temperature, i.e. 1-3°C at most. Most components inside data centre equipment, such as hard drives, have enough thermal mass to remain unaffected by these high instantaneous rates of air temperature change. The response time for these components to a temperature change is much longer than the duration of the change. The allowable classes for server temperature and humidity range may enable facilities in many geographical locations to operate year-round without mechanical refrigeration, leading to significant savings in capital and operating expenses in the form of energy use.

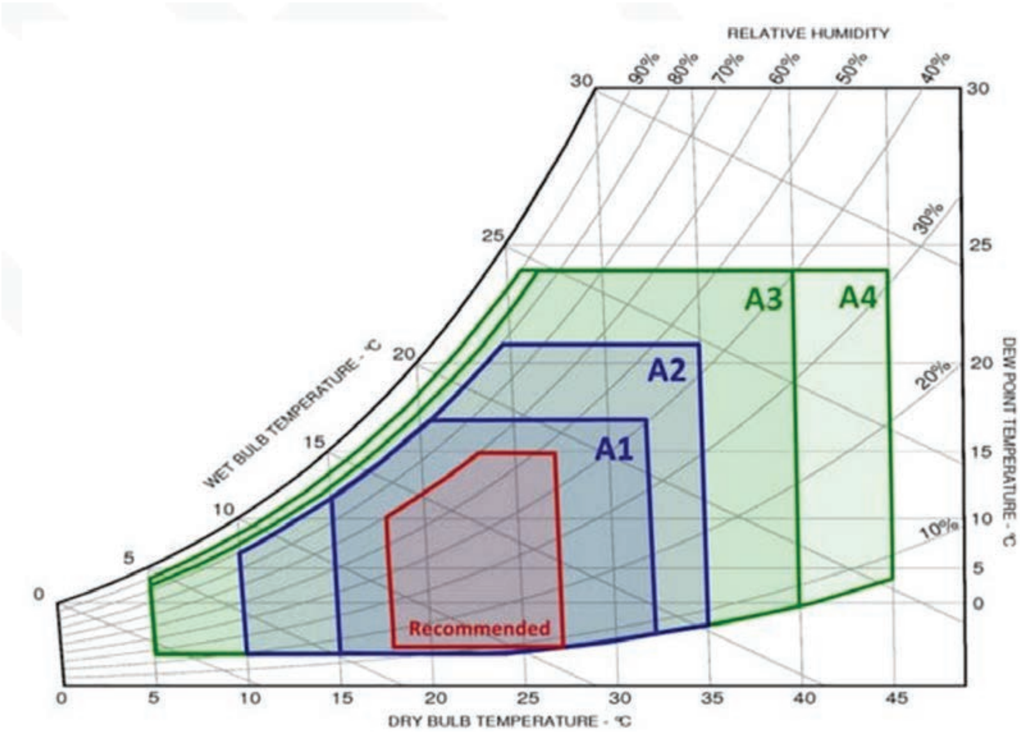
The different allowable ASHRAE envelope classes are described below:

- **Class A1:** typically, a data centre with tightly controlled environmental parameters (dew point, temperature, and relative humidity) and mission critical operations.

- **Classes A2/A3/A4:** typically, an information technology space or office or lab environment with some control of environmental parameters (dew point, temperature, and relative humidity). In Figure 7, the suitable temperature range for the dry bulb, wet bulb and dew point regarding the relative humidity can be seen. These environmental envelopes pertain to air entering the IT equipment (conditions at sea level).

These are illustrated in Figure 8.

Figure 8: **ASHRAE Thermal Guidelines for Datacom Equipment fourth edition psychrometric chart.**

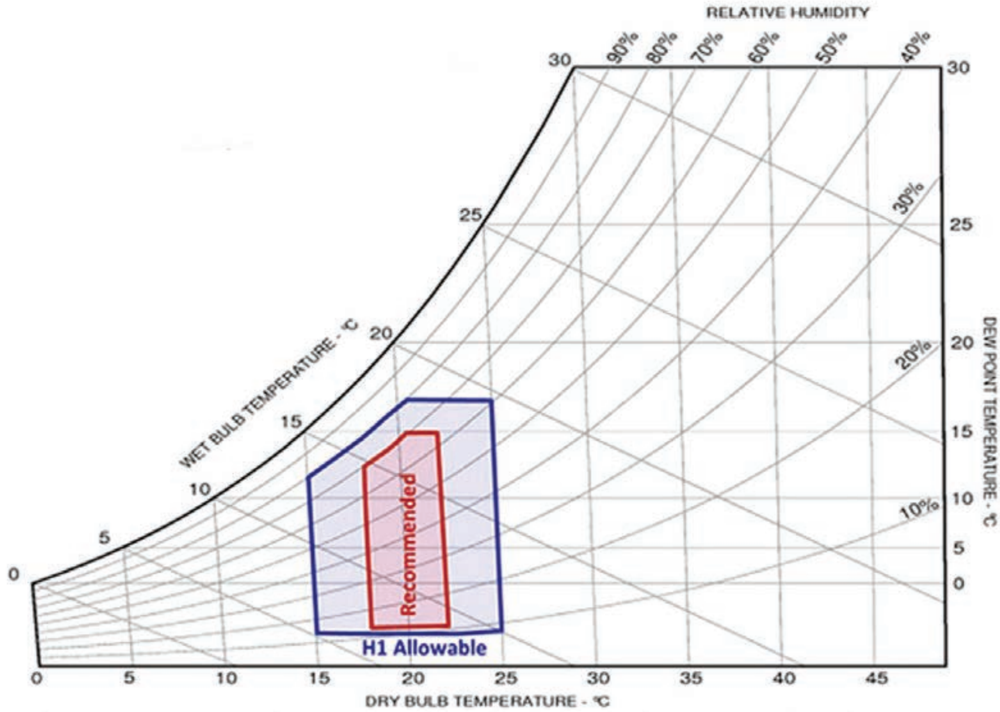


ASHRAE Technical Committee 9.9 published its fifth edition in 2021. This publication considers possible pollutant gases, and the recommended relative humidity is set back to 50 per cent. Indeed, copper corrosion can occur at a humidity range higher than 50 per cent in the presence of chlorine and hydrogen sulphide[29]. Without those two strong catalyst gases, no significant corrosion is found up to 70 per cent of relative humidity, even in presence of ozone, nitrogen dioxide and sulphur dioxide. A test can be performed using metal strips or "reactivity coupons", measuring the corroded layer formation.

29 https://journal.uptimeinstitute.com/new-ashrae-guidelines-challenge-efficiency-drive/

A new class was also introduced in the fifth edition for high-density IT systems that tightly integrates a number of high-powered components (server processors, accelerators, memory chips and networking controllers). For dense systems, there is typically not enough room in the unit for higher performance heat sinks and fans that could keep components below temperature limits across the generic (classes A1 through A4) recommended envelope. In this case the envelope in the psychrometric chart is represented in Figure 9.

Figure 9: 2021 recommended and allowable envelopes for ASHRAE class H1.



Note: The recommended envelope is for low levels of pollutants, verified by coupon measurements.

The European code of conduct (V15.1) from 2024 recommends purchasing new equipment that can operate within ASHRAE Class A4. This extended range allows operators to potentially eliminate the capital cost of providing mechanical cooling capability in some hotter climate regions. However, the availability of A4 servers is not guaranteed in all regions neither every server types.

- Only class A3 IT equipment should be purchased.

Note 1: In traditional data centres, servers need to be replaced every 3 to 5 years. Both new and legacy servers may coexist in the same IT room or compartment. The environmental control of this room or compartment should meet the requirements of the legacy servers. When IT compartments or rooms exist, priority should be given to upgrading to A3 class equipment within the same compartment or room to enable for higher operational temperature and/or humidity.

Note 2: handling of the temperature inside the IT room shall ensure a suitable environment for human operators.

Server efficiency

The server can be in either an idle state or active state. In the idle state, the server efficiency is measured by idle power. In the active state, the efficacy depends on the tasks being performed.

The active state efficiency is measured using the Server Efficiency Rating Tool (SERT) 2 methodology[30] in programmes including ENERGY STAR®, the European regulation 2019/424, the European code of conduct. The SERT Suite is an established industry standard published by the Standard Performance Evaluation Corporation (SPEC) for measuring and analysing the energy efficiency of servers. The SERT suite measures server efficiency using multiple workloads, which in turn are executed by running multiple small scale mini workloads, called worklets, in series. More details on the methodology can be found in Annex 3 –Server Efficiency Rating Tool (SERT) methodology.

In European regulations, servers are tested in the low-end and high-end performance configuration whereas for ENERGY STAR®, the product is tested in a "typical performance configuration", which is defined as "*a product configuration that lies between the Low-end Performance and High-end Performance configurations and is representative of a deployed product with high volume sales*."

The minimum efficacy for a server measured in a typical performance configuration is given in Table 11[31].

Table 11: Minimum active state efficiency of servers

Product Type	Minimum Eff_{server}
One socket *(one processor)*	
Rack	26.4
Tower	24.4
Resilient	6.6
Two sockets *(two processors)*	
Rack	30.4
Tower	26.5
Blade or multi-node	29.1
Resilient	6.0
More than two sockets *(more than two processors)*	
Rack	31.9
Blade or multi-node	26.8

Minimum efficacy requirements above do not apply to SHS servers, HPC servers and servers with integrated APA

30 https://www.spec.org/sert2/SERT-metric.pdf
31 Based on ENERGY STAR Computer Servers Version 4.0 Final Specification - April 12, 2023

Note: The Uptime Institute intelligence study on server energy efficiency, referenced earlier, showed that capacity needs to be put to work. In fact, newer generation servers typically achieve significant efficiency gains only when handling larger workloads. A simple one-to-one machine migration may result in little to no efficiency improvement.

The IT equipment energy efficiency for servers ($ITEE_{sv}$)

That ITEEsv is an average of the energy effectiveness of all servers or a group of servers in a data centre. The indicator describes the maximum performance per kW of all servers or a group of servers in the data centre, based upon a specification or their potential performance. It is not a measure of the efficiency of the servers themselves when used but rather processing capacity per unit of electric power.

It is used to quantify the impact of introducing new servers with high capability per unit of energy. Data centres with larger $ITEE_{sv}$ values indicates, on average, installation of servers with higher energy efficiency. $ITEE_{sv}$ intends to assist in improving the aggregate energy effectiveness of servers in a given data centre.

Equation 8: IT equipment energy efficiency for servers

$$ITEE_{sv} = \frac{\sum SMPE_{(i)}}{\sum SMPO_{(i)}}$$

Where:

- $SMPE_{(i)}$ is the maximum performance of a server i;
- $SMPO_{(i)}$ is the maximum power consumption of a server i in kW;

The norm ISO 30134-4 specifies that $ITEE_{sv}$ can be calculated using a choice of pre-existing or context specific server performance benchmarks, taking into account the server's application. For example, for a data centre targeted at high performance computing, the LINPACK benchmark[32] may be used to determine SMPE and SMPO. For volume servers SPEC power or SERT may be used, depending on the measurement method. Note that for SERT, the active state energy effectiveness benchmark in ISO/IEC 21836:2020 "SEEM" and SPEC SERT v2.x can be used for the SMPE value.

If the benchmark chosen for SMPE provides both performance and power values, the measuring option for SMPO must be the same as the benchmark method for SMPE. If the benchmark chosen for SMPE does not provide power value, it is recommended that the SMPO data be obtained from the server manufacturer or measured.

The data centre owner can define any server group according to its needs for energy effectiveness analysis if a single benchmark method is applied to all servers in the group. By defining a group by an application system, the data centre owner can analyse the energy effectiveness of the target application system. To determine $ITEE_{sv}$ for the common group of servers, a single system shall be sufficient to represent the capacity per group. This value is the modulo for capacity planning of that server model. The total capacity is the multiplication of the number of servers to that modulo. Conversely, the compute capacity for a provisioned amount of power would be provisioned power multiplied by the modulo.

32 The software routines for LINPACK are publicly available at the following URL: http://www.netlib.org/benchmark/hpl/

ITEEsv should be calculated for existing servers and data centres to establish a baseline.

- When a server is replaced, the ITEEsv of the new server must be higher than the average ITEEsv of a group of servers analyzed with the same benchmark method or at least that of the replaced server. When a server is added to increase capacity, the expected value of ITEEsv for the group should be higher than before, indicating an improvement in overall energy effectiveness.

Data storage efficiency

Data storage efficacy can be gauged by the operations per second performed during the active state. The active state refers to the period a storage product is processing external I/O requests. The Storage Networking Industry Association's (SNIA) Emerald offers a standardized and reproducible evaluation of energy efficiency for commercial storage products which is used in ENERGY STAR® endorsement specifications.

The evaluation measures input/output operations per second (IOPs) per watt for random workloads (including random read, random write, and a mix of both). For sequential workloads (such as sequential read or sequential write) and file access workloads, the operations rate is the average data transfer rate in mebibytes[33] per second (MiB/s) within time interval T.

The minimum performance per watt is detailed in Table 12.

Table 12: Active state requirements for block I/O storage products

Workload type	Specific workload test	Minimum performance
Transaction	Hot band	28.0 IOPs/watt
Streaming	Sequential read	2.3 MiBs/watt
Streaming	Sequential write	1.5 MiBs/watt

The test is conducted on the optimal configuration for a storage product or product family. This requirement is applicable to on-line storage products as defined by the SNIA Emerald Taxonomy[34]. When both the read and write streaming performance per watt value are submitted, at least one of these values must exceed the minimum performance threshold.

33 Contraction of mega binary byte. Storage capacity unit equivalent to 1,048,576=2^{20} bytes
34 https://www.snia.org/emerald/taxonomyoverview

Power supply unit (PSU) efficiency

Each Server has one or more PSU that convert Alternating Current (AC) or Direct Current (DC) input power to one or more DC power outputs to power a Server or a data storage product. The PSU of a Server or data storage product must be self-contained, physically separable from the motherboard and connected to the system via a removable or hard-wired electrical connection.

The PSU efficiency depends on the IT load and whether it has one or more output as seen in Table 13.

Table 13: Minimum PSU efficiency

Power Supply Type	10%	20%	50%	100
Rated output power ≥ 750 Watt				
Multi-output (AC-DC)	N/A	90%	94%	91%
Single-output (AC-DC)	90%	94%	96%	91%
Rated output power < 750 Watt				
Multi-output (AC-DC)	N/A	87%	90%	87%
Single-output (AC-DC)	83%	90%	94%	91%

Above efficiency requirements are set only for AC/DC converter. They do not apply to direct current servers. For blade and multi nodes servers, all PSUs supplying power to the chassis should meet the requirements.

Power supply unit (PSU) power factor

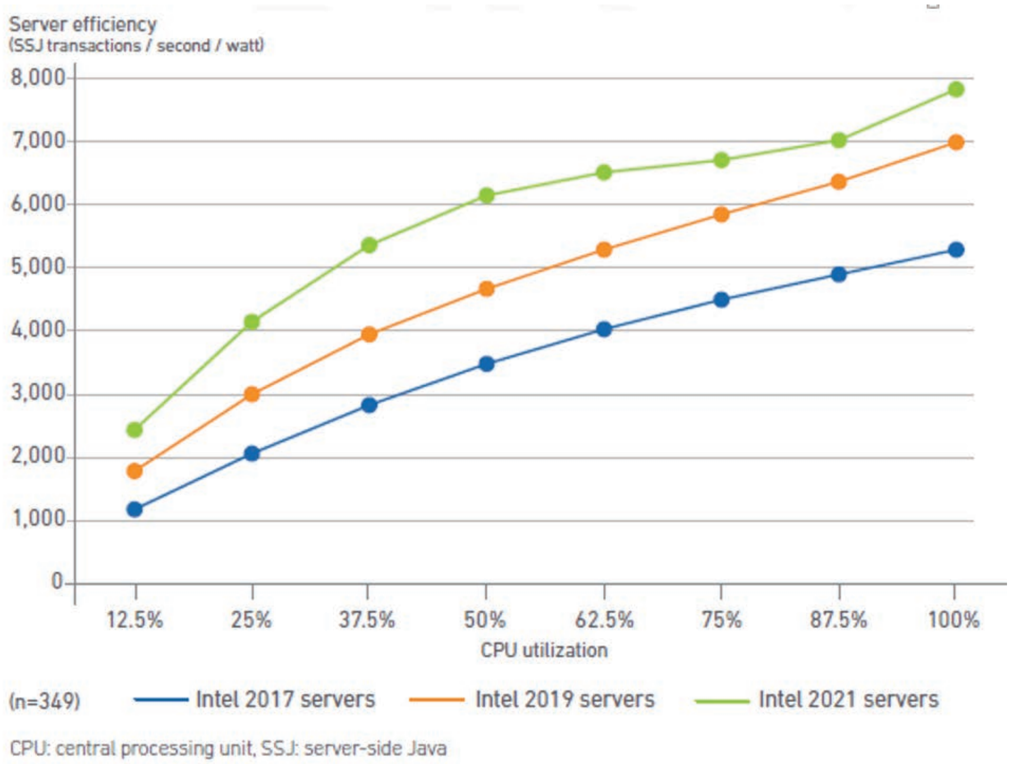
- The minimum PSU power factor at 50 per cent load should be 0.95.

Power management criteria

A server is not often used at 100 per cent of its capacity whereas for most servers, the efficiency improves with the CPU utilization as seen in Figure 10 from the Uptime Institute35.

35 Server energy efficiency: five key insights – May 2023

Figure 10: **Server efficiency increased based on CPU utilization**



Note: the server efficiency metric used here is SSJ transactions per second per watt and is not the efficiency of the server calculated with the SERT2 methodology in section 6.1.2.

To minimise server energy consumption during its low utilisation state, the server processors should be able either:

- To reduce their voltage and/or frequency through Dynamic Voltage and Frequency Scaling (DVFS) or

- To enable processor or core reduced power states when a core or socket is not in use.

Note: Green Grid´s white paper36 emphasis the issue of using power management under certain circumstances due to reduced server performance and increased response time (exit latency). While the implementation of a power management profile can be beneficial in many instances, it should be carefully considered for applications such as high-speed financing trading, network provider, or high-performance computing.

36 Trade-offs of processor power management functions of servers

Idle state efficiency

A server is in idle state when it can complete workload transactions, although no active workload transactions are requested or pending by the system (i.e., the server is operational but not performing any useful work). The active state is when the server carries out work in response to prior or concurrent external requests.

Idle state power depends a lot on server components:

- CPU performance
- Data storage technology - hard disk drive (HDD) or solid-state drive (SDD)
- Additional power supply unit (PSU)
- Additional memory
- Additional buffered double data rate (DDR) channel
- Additional I/O devices

However, to simplify the purchase of IT equipment and because idle power is usually a few per cent (1 to 5 per cent) of active state power, one single additional idle state power allowance is given per product type as shown in Table 14. According to a recent review, the pass rate for servers placed on the market the last 5 years (since 2019) is 28[37].

Table 14: Idle state power allowances

Product type	Base idle state power allowance
1 socket servers (neither blade nor multi-node servers)	25 watts
2 sockets servers (neither blade nor multi-node servers)	38 watts
Blade or multi-node servers	40 watts

Additional idle power allowance: 0.18 W per GB for installed memory greater than 4 GB

For blade servers, Pidle is calculated as the total measured power divided by the number of installed blade servers in the tested blade chassis. For multi-node servers, the number of sockets is counted per node while Pidle is calculated as the total measured power divided by the number of installed nodes in the tested enclosure.[38]

Note: A server with low power consumption when idle, but spending 90 per cent of its time in idle mode, can have higher overall energy consumption in idle than a server with higher power consumption but only 50 per cent of the time in idle.

37 Study for the review of Commission Regulation 2019/424, June 2024
38 European Commission (2019). *Commission Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products*. [online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0424

Serviceability

The tenderer must provide clear instructions to enable the non-destructive repair or replacement of the following components:

- Data storage devices,
- Memory,
- Processor (CPU),
- Motherboard,
- Expansion cards/graphic cards,
- Power supply unit (PSU),
- Fans,
- Batteries
- Such instructions must be made available by the manufacturer of the server for a minimum of 8 years.

Waste management

The ICT equipment contain critical raw materials and precious metals. They are referred to as e-waste or Electrical and Electronic Equipment Waste (WEEE). E-waste contains toxic additives or hazardous substances, commonly including heavy metals such as mercury, cadmium and lead, and chemicals such as brominated flame retardants. These substances can pollute land, air and aquatic environments and pose significant health risks, especially if treated inadequately.

- Recyclability depends on decisions at the design phase, information to assist in the disassembly and processing, and end-of-life processing. In the tendering process, the design for recycling should be specified and could be part of the technical specifications: marking of plastic casings, enclosures and bezels for the correct indication of the chemistry, with exceptions when unfeasible.
- Recyclability of plastic casings, enclosures and bezels – separable inserts and fasteners for computers and displays, where the presence of paints and coatings does not significantly impact the resilience of plastic recyclability produced from these components upon recycling.
- Declaration of critical raw materials.

Please note that maximising the adequacy of a product and component for reuse is more environmentally sound than dismantling to recover certain raw materials or energy. Therefore, any verifiable effort to support preparation for reuse must be encouraged. However, methodological developments are needed to be able to measure it in a standardized and manageable way[39].

39 Recommendation ITU-T L.1061 - Circular public procurement of information and communication technologies

Annex 1: Testing Standards Reference List

A. Servers and data storage devices

Table 15: **Testing Standards Reference List for Servers and data storage devices**

Indicator	Measurement procedure
Operating temperature and humidity range	The unit under test is placed at a temperature corresponding to the highest allowable temperature for the specific operating condition class (A1, A2, A3 or A4), which the model is declared to be compliant with. The unit shall be tested with SERT and run test cycle(s) for a duration of 16 hours. The unit shall be considered to comply with the declared operating condition, if SERT reports valid results (i.e., if the unit under test is in its operational state for the whole duration of the 16 hours test). The unit under test shall be placed in a temperature chamber which is then elevated in temperature to the highest allowable temperature for the specific operating condition class (A1, A2, A3 or A4) at a maximum rate of change of 0.5 °C per minute. The unit under test shall be left in an idle state for 1 hour to attain a state of temperature stability prior to the start of testing.
Server efficiency **Idle state efficiency**	**ISO/IEC 21836** "Server energy effectiveness metric" ETSI EN 303470 "Energy efficiency measurement methodology and metrics for servers"
Data Storage products	**ISO/IEC 24091** "Power efficiency measurement specification for data centre storage"
Power supply unit (PSU) efficiency **Power supply unit (PSU) power factor**	Generalized Test Protocol for Calculating the Energy Efficiency of Internal AC-DC and DC-DC Power Supplies Revision 6.7.2 of September 2022
Utilization rate	**ISO/IEC 30134-5** "IT Equipment utilization for servers (ITEUsv)"

Note: the latest published version of the standards must be used.

B. Data centre

Table 16: Testing Standards Reference List for Data Centres

Indicator	Measurement procedure
Power usage effectiveness (PUE)	ISO/IEC 30134-2
Cooling effectiveness ratio (CER)	ISO/IEC 30134-7
Water usage effectiveness (WUE)	ISO/IEC 30134-9
Renewable energy factor (REF)	ISO/IEC 30134-3
Information Technology Equipment Energy Efficiency for servers (ITEEsv)	ISO/IEC 30314-4
Uninterruptible Power Supply	IEC 62040-3
Resilience	Uptime Institute classification - norm ISO/IEC 22237

Note: the latest published version of the standards must be used.

Annex 2: Award Criteria for Tenders

Throughout these Guidelines, energy and performance criteria recommendations have been defined for application by procurers and other stakeholders. These recommendations apply for several situations: selecting a data centre to host public data, authorising the permitting and construction of a data centre, or procuring the purchase of servers and data storage products.

In the case of a tender procurement process, countries can apply different systems, and therefore, the recommendations of these Guidelines can be adapted to the following scenarios:

Scenario #1: In some countries the public authority specifies the **minimum performance threshold** for an offer to be eligible. For the bids that meet the requirements, the choice is **driven by the price:** in this case, the minimum performance values to be applied are recommended in the Guideline.

Scenario #2: For other countries, the public authority may specify **targeted performance values which can be exceeded by the offers**. For the bids that meet the requirements, the choice is **driven by the best technical option** → in this case, the policy makers could make use of the award criteria.

If the second case and given the variety of products and options a tender might receive, it is suggested to focus on some specific key performance indexes to help discriminate and select the best bid among different options that still comply with the requirements.

Table 17 provides an example using five key performance criteria, which can assist in weighting the relative best and worst alternatives.

Note that the award criteria for tenders could also serve as a basis for specifying a label for data centres and/or servers.

Table 17: Award criteria weight example for data centres

KPI	Points	Weighting
Energy management (PUE) (see section 5.1.3)	PUE ≤ 2.0: 1 point PUE ≤ 1.8: 2 points PUE ≤ 1.6: 3 points PUE ≤ 1.4: 4 points PUE ≤ 1.2: 5 points	30%
Cooling efficiency ratio (CER) (see section 5.1.10)	CER ≥ 2.5: 1 point CER ≥ 2.9: 2 points CER ≥ 3.8: 3 points CER ≥ 5.7: 4 points CER ≥ 10: 5 points	20%
Water consumption (WUE) **(see section 5.1.8)**	• WUE ≤ 2 L/kWh: 1 point • WUE ≤ 1.8 L/kWh: 2 points • WUE ≤ 1.6 L/kWh: 3 points • WUE ≤ 1.4 L/kWh: 4 points • WUE ≤ 1.2 L/kWh: 5 points	20%
Renewable energy ratio (REF) **(see section 5.1.9)**	• REF ≥ 50%: 1 point • REF ≥ 60%: 2 points • REF ≥ 70%: 3 points • REF ≥ 80%: 4 points • REF ≥ 90%: 5 points	20%
Utilization ratio of servers: The IT equipment utilization for servers ($ITEU_{sv}$) **(see section 5.1.11)**	• ITEUsv ≥ 30%: 1 point • ITEUsv ≥ 40%: 2 points • ITEUsv ≥ 50%: 3 points • ITEUsv ≥ 60%: 4 points • ITEUsv ≥ 70%: 5 points	10%

The five KPIs consider energy management inside the data centre (PUE), cooling efficiency (CER), water consumption (WUE), the renewable energy factor (REF) and the utilization ratio of the IT equipment itself (ITEUsv). The selection of the parameters and weight to be applied to each of them might be adapted depending on the project priorities. In the example below, a score (expressed as an integer number from 1 to 5) will be attributed to each KPI depending on its value - the higher the eco-efficiency performance is, the higher is the score. The overall rating is calculated by applying the weighting factor to each KPI score and the weighting may be adjusted based on the priorities of each country/region, e.g. water scarcity.

As an example, two offers corresponding to a call for tender are shown in Table 18.

Table 18: Example of tender scoring and weighting for a data centre bid

	Data Centre #1		Data Centre #2	
Criteria	**Value**	**Criteria Score**	**Value**	**Criteria Score**
PUE	1.5	3	1.3	4
CER	6	2	8	4
WUE	1.3	4	1.6	3
REF	70%	3	50%	1
ITEUsv	50%	3	30%	1
Global Score	**3.0**		**2.9**	

Similarly, award criteria for products like servers and data storage can include operating temperature and humidity range, server efficiency, data storage efficiency, power supply efficiency and idle state efficiency, as shown in Table 19.

Table 19: Award criteria weight example for servers and data storage devices

KPI	Points	Weighting
Operating temperature and humidity range (see section 5.2.1)	ASHRAE class H1 ≤ 2: 1 point ASHRAE class A1: 2 points ASHRAE class A2: 3 points ASHRAE class A3: 4 points ASHRAE class A4: 5 points	30%

<table>
<tr><th>KPI</th><th>Points</th><th>Weighting</th></tr>
<tr><td>Server efficiency(see section 5.2.2)</td><td>
<table>
<tr><th>Server type</th><th>Rack</th><th>Tower</th><th>Resilient</th><th>Blade or multi node</th></tr>
<tr><td>One socket</td><td>≥ 24.0: 1 pt
≥ 25.0: 2 pt
≥ 26.0: 3 pt
≥ 27.0: 4 pt
≥ 28.0: 5 pt</td><td>≥ 22.0: 1 pt
≥ 23.0: 2 pt
≥ 24.0: 3 pt
≥ 25.0: 4 pt
≥ 26.0: 5 pt</td><td rowspan="2">≥ 4.0: 1 pt
≥ 5.0: 2 pt
≥ 6.0: 3 pt
≥ 7.0: 4 pt
≥ 8.0: 5 pt</td><td rowspan="2">≥ 25.0: 1 pt
≥ 27.0: 2 pt
≥ 29.0: 3 pt
≥ 31.0: 4 pt
≥ 33.0: 5 pt</td></tr>
<tr><td>Two or more sockets</td><td>≥ 26.0: 1 pt
≥ 28.0: 2 pt
≥ 30.0: 3 pt
≥ 32.0: 4 pt
≥ 34.0: 5 pt</td><td>90%</td></tr>
</table>
</td><td>20%</td></tr>
<tr><td>Data storage efficiency
(see section 5.2.2)</td><td>
<table>
<tr><th>Hot band</th><th>Sequential read</th><th>Sequential write</th></tr>
<tr><td>(IOPs/watt)</td><td>(MiBs/watt)</td><td>(MiBs/watt)</td></tr>
<tr><td>≥ 24.0 : 1 point
≥ 26.0 : 2 points
≥ 28.0 : 3 points
≥ 30.0 : 4 points
≥ 32.0 : 5 points</td><td>≥ 4.0: 1 point
≥ 5.0: 2 points
≥ 6.0: 3 points
≥ 7.0: 4 points
≥ 8.0: 5 points</td><td>≥ 0.5: 1 point
≥ 1.0: 2 points
≥ 1.5: 3 points
≥ 2.0: 4 points
≥ 2.5: 5 points</td></tr>
</table>
</td><td>20%</td></tr>
<tr><td>Power Supply Efficiency
(see section 5.2.3)</td><td>
<table>
<tr><th>Power Supply Type</th><th>10% rated load</th><th>20% rated load</th><th>50% rated load</th><th>100%</th></tr>
<tr><td>Multi-output (AC-DC)</td><td>N/A</td><td>≥ 22.0: 1 pt
≥ 23.0: 2 pt
≥ 24.0: 3 pt
≥ 25.0: 4 pt
≥ 26.0: 5 pt</td><td>94%: 1 pt
95%: 2 pts
96%: 3 pts
97%: 4 pts
98%: 5 pts</td><td>91%: 1 pt
92%: 2 pts
93%: 3 pts
94%: 4 pts
95%: 5 pts</td></tr>
<tr><td>Single-output (AC-DC)</td><td>90%: 1 pt
91%: 2 pts
92%: 3 pts
93%: 4 pts
94%: 5 ptst</td><td>94%: 1 pt
95%: 2 pts
96%: 3 pts
97%: 4 pts
98%: 5 pts %</td><td>96%: 1 pt
97%: 2 pts
98%: 3 pts
99%: 4 pts
100%: 5 pts</td><td>91%: 1 pt
92%: 2 pts
93%: 3 pts
94%: 4 pts
95%: 5 pts</td></tr>
</table>
</td><td>20%</td></tr>
</table>

KPI	Points		Weighting
	Product type	**Base idle state power allowance**	
Idle state efficiency (see section 5.2.6)	1 socket servers (neither blade nor multi-node servers)	25 Watt ≤ 1 point 24 Watt ≤ 2 points 23 Watt ≤ 3 points 22 Watt ≤ 4 points 21 Watt ≤ 5 points	10%
	2 sockets servers (neither blade nor multi-node servers)	38 Watt ≤ 1 point 37 Watt ≤ 2 points 36 Watt ≤ 3 points 35 Watt ≤ 4 points 34 Watt ≤ 5 points	
	Blade or multi-node servers	40 Watt ≤ 1 point 39 Watt ≤ 2 points 38 Watt ≤ 3 points 37 Watt ≤ 4 points 36 Watt ≤ 5 points	

Annex 3: Server Efficiency Rating Tool (Sert) Methodology

The SERT 2 metric, also called the SERT 2 Efficiency Score, is a final aggregate of all the power and performance values measured during a SERT run. The SERT suite features three separate workloads for CPU, Memory, Storage and idle state. Each of these workloads consist of a number of separate mini workloads, called worklets. The SERT suite features three separate workloads for CPU, Memory, and Storage. Each of these workloads consist of a number of separate mini workloads, called worklets. Each of the worklets, except for idle, is executed at several load levels (100 per cent, 75 per cent, 50 per cent, and 25 per cent by default). The SERT load levels are defined using the transaction rate at which the worklet is run. Each worklet's performance and power consumption are measured separately for each load level and the energy efficiency and normalized energy efficiency are calculated based on the measured results. The workload score is an aggregate of all the worklet scores using the geometric mean and provides a workload efficiency score on how well the tested system performed for all the worklets in the specified category. The geometric mean has been chosen in favour of the arithmetic mean or sum. The major difference between the geometric mean and arithmetic mean is that the arithmetic mean favours load levels with higher efficiency scores. Traditionally, higher load levels also feature higher efficiency scores on most systems. As a result, the arithmetic mean usually favours the results of high load levels. Idle is the only workload that does not have a performance metric as it does not perform any actions on the tested system but keeps it in an idle state to measure idle power consumption.

The efficiency of the server is calculated as follows:

Equation 9: Efficiency of a server

$$Eff_{server} = exp\left[W_{CPU} * \ln\left(Eff_{cpu}\right) + W_{memory} * \ln\left(Eff_{memory}\right) + W_{storage} * \ln\left(Eff_{storage}\right)\right]$$

Where:

- Wi is the weighting factor, e.g.: W_{CPU} = 0.65; W_{memory} = 0.30; $W_{storage}$ = 0.05

The efficiency of the CPU alone is the product of the efficiency calculated for seven specific worklets:

Equation 10: Efficiency of the CPU

$$Eff_{cpu} = \exp\left(\frac{1}{n} \mathrm{x} \sum_{i=1}^{7} \ln(Eff_i)\right)$$

- i = 1 for worklet Compress; i = 2 for worklet LU;
- i = 3 for worklet SOR; i = 4 for worklet Crypto;
- i = 5 for worklet Sort; i = 6 for worklet SHA256;
- i = 7 for worklet Hybrid SSJ;

The efficiency of the memory alone is the product of the efficiency calculated for two specific worklets:

Equation 11: Efficiency of the memory

$$Eff_{memory} = \exp\left(\frac{1}{n} \text{x} 1 \sum_{i=1}^{2} \ln(Eff_i)\right)$$

- i = 1 for worklet Flood3;
- i = 2 for worklet Capacity3;

The efficiency of the storage is the product of the efficiency calculated of two specific worklets:

Equation 12: Efficiency of the storage

$$Eff_{storage} = \exp\left(\frac{1}{n} \text{x} \sum_{i=1}^{2} \ln(Eff_i)\right)$$

- i = 1 for worklet Sequential;
- i = 2 for worklet Random;

With

Equation 13: Efficiency related to performance and power

$$Eff_i = \exp\left(\frac{1}{n} \text{x} \sum_{i=1}^{n} \ln\left(Eff_{load_i}\right)\right) \text{x } 1000 = 1000 \frac{Perf_i}{Pwr_i}$$

Where:

- i = Represents each worklet referenced in Equations for $Eff_{\text{cpu, memory and storage}}$
- $Perf$ = Geometric mean of the normalized interval performance measurements;
- *Pwri* = Geometric mean of the measured interval power values.

The efficiency load is defined per load level as:

$$Eff_{load} = \frac{Normalized\ Performance}{Power\ consumption}$$

Normalised performance refers to the normalised throughput for most worklets, with memory worklets being a notable exception. Power consumption, in this context, is the average measured power consumption for each load level. Consequently, the energy efficiency metric per load level represents the number of (normalised) transactions executed per unit of energy (Joule).

Annex 4: Resilient Server

According to ENERGY STAR® criteria[40], a Resilient Server shall have the following characteristics:

A. Processor RAS: The processor must have capabilities to detect, correct, and contain data errors, as described by the following:

- Error recovery by means of instruction retry for certain processor faults.
- Error detection on L1 caches, directories, and address translation buffers using parity protection; and
- Single bit error correction (or better) on caches that can contain modified data. Corrected data is delivered to the recipient as part of the request completion.

B. System Recovery and Resiliency: No fewer than six of the following characteristics shall be present in the server:

- Error recovery and containment by means of (a) data poison indication (tagging) and propagation which includes mechanism to notify the OS or hypervisor to contain the error, thereby reducing the need for system reboots and (b) containment of address/command errors by preventing possibly contaminated data from being committed to permanent storage;
- The processor technology is designed to provide additional capability and functionality without additional chipsets, enabling the design into systems with four or more processor sockets;
- Memory Mirroring: A portion of available memory can be proactively partitioned such that a duplicate set may be utilized upon non-correctable memory errors. This can be implemented at the granularity of DIMMs or logical memory blocks;
- Memory Sparing: A portion of available memory may be pre-allocated to a spare function such that data may be migrated to the spare upon a perceived impending failure;
- Support for making additional resources available without the need for a system restart. This may be achieved either by processor (cores, memory, I/O) on-lining support, or by dynamic allocation/deallocation or processor cores, memory, and I/O to a partition;
- Support of redundant I/O devices (storage controllers, networking controllers);

40 Product Specification for Computer Servers; Eligibility Criteria Version 3.0

4. Has I/O adapters or storage devices that are hot-swappable;

5. Can identify failing processor-to-processor lane(s) and dynamically reduce the width of the link to use only non-failing lanes or provide a spare lane for failover without disruption;

6. Capability to partition the system such that it enables running instances of the OS or hypervisor in separate partitions. Partition isolation is enforced by the platform and/or hypervisor and each partition is capable of independently booting; or

7. Uses memory buffers for connection of higher speed processor-memory links to DIMMs attached to lower speed DDR channels. Memory buffer can be a separate, standalone buffer chip which is integrated on the system board or integrated on custom-built memory cards.

C. Power Supply RAS: All power supplies installed or shipped with the server shall be redundant and concurrently maintainable. The redundant and repairable components may also be housed within a single physical power supply but must be repairable without requiring the system to be powered down. Support must be present to operate the system in a degraded mode.

D. Thermal and Cooling RAS: All active cooling components shall be redundant and concurrently maintainable. The processor complex must have mechanisms to allow it to be throttled under thermal emergencies. Support must be present to operate the system in a degraded mode when thermal emergencies are detected in the system components.

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