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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Best practices for green data centres

Recommendation ITU-T L.1300

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Summary

Recommendation ITU-T L.1300 describes best practices aimed at reducing the negative impact of data centres on the climate. It is commonly recognized that data centres will have an ever-increasing impact on the environment in the future. The application of the best practices defined in this Recommendation can help owners and managers to build future data centres, or improve existing ones, to operate in an environmentally responsible manner. Such considerations will strongly contribute to a reduction in the impact of the information and communication technology (ICT) sector on climate change.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1300	2011-11-29	5	11.1002/1000/11429
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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Best practices for green data centres

1 Scope

This Recommendation specifies best practices aimed at developing green data centres. A green data centre can be defined as a repository for the storage, management, and dissemination of data in which the mechanical, lighting, electrical and computer systems are designed for maximum energy efficiency and minimum environmental impact. The construction and operation of a green data centre includes advanced technologies and strategies. The Recommendation provides a set of rules to be referred to when undertaking improvement of existing data centres, or when planning, designing or constructing new ones.

The proposed best practices cover:

- data centre utilization, management and planning;
- ICT equipment and services;
- cooling;
- data centre power equipment;
- data centre building;
- monitoring.

The environmental impact of a data centre should be assessed in line with [ITU-T L.1400], [ITU-T L.1410] and [ITU-T L.1420].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.1400] Recommendation ITU-T L.1400 (2011), *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies*.

[ITU-T L.1410] Recommendation ITU-T L.1410 (2012), *Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services*.

[ITU-T L.1420] Recommendation ITU-T L.1420 (2012), *Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations*.

[ETSI EN 300 019-1-3] ETSI EN 300 019-1-3 V2.3.2 (2009), *Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-3: Classification of environmental conditions; Stationary use at weather protected locations*.

[ETSI TR 102 489] ETSI TR 102 489 V1.2.1 (2010), *Environmental Engineering (EE); European telecommunications standard for equipment practice; Thermal Management Guidance for equipment and its deployment*.

[ISO/IEC 62040-3] ISO/IEC 62040-3 Ed2.0 (2011), *Uninterruptible Power Systems (UPS) – Part 3: Method of specifying the performance and test requirements*.

3 Definitions

3.1 Term defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 power density: The energy consumption of ICT equipment per rack cabinet of floor area of a server room.

3.2.2 space efficiency: The ratio of floor area employed for ICT equipment in relation to the total floor area of the building.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AHU Air Handling Unit

ATS Automatic Transfer Switch

BC Business Continuity

BIOS Basic Input-Output System

BREEAM Building Research Establishment Environmental Assessment Methodology

CFD Computational Fluid Dynamics

COP Coefficient Of Performance

CRAC Computer Room Air Conditioner

DC Data Centre

DCMI Data Centre Manageability Interface

DX Direct expansion

DR Disaster Recovery

HVAC Heating Ventilation and Air Conditioning

ICT Information and Communication Technology

IGBT Insulated-Gate Bipolar Transistor

IPMI Intelligent Platform Management Interface

LEED Leadership in Energy and Environmental Design

M&E Maintenance and Engineering

OA Outdoor Air

PDU Power Distribution Unit

PSU	Power Supply Unit
PUE	Power Usage Effectiveness
RA	Return Air
REACH	Registration, Authorization and restriction of Chemical substances
RH	Relative Humidity
RoHS	Restrictions of Hazardous Substances
RT	Refrigerant Ton
SA	Supply Air
SMASH	Systems Management Architecture for Server Hardware
SNMP	Simple Network Management Protocol
Tri-Gen	Tri-Generation
UPS	Uninterruptible Power Supply
VFI	Voltage and Frequency Independent
WEEE	Waste Electrical and Electronic Equipment

5 Introduction to best practices for green data centres

In order to improve the energy efficiency of data centres, it is necessary to consider all stages from design through to construction. Even after the building of data centres is complete, they must continue to be managed and maintained to ensure efficient energy consumption.

This Recommendation describes best practices for energy-efficient construction, operation and management of green data centres that contain a number of essential components, including ICT equipment and services, cooling, power equipment, data centre building, etc.

The best practices discussed herein have been numbered for easy reference.

Best practices have been identified and divided into different clauses to cover the following different components of a data centre:

- planning, utilization and management;
- ICT equipment and services;
- cooling;
- data centre power equipment;
- other data centre equipment;
- data centre building;
- monitoring;
- design of network;
- cloud data centre;
- optimization of energy management of the whole data centre.

5.1 Role of best practices

This Recommendation is provided as a comprehensive guide to assist data centre operators in identifying and implementing measures to improve energy efficiency of their data centres.

The full list of best practices that are specified in this Recommendation can be of practical help for those who are pursuing green data centres.

5.2 Value of practices

Each practice has not been assigned a qualitative value to indicate the level of benefit to be expected from an action and the relative priorities that should be applied to it.

When there is a choice of practices, a preference should be given to the one having the least impact on the environment.

6 Planning, utilization and management of data centres

It is important to develop a holistic strategy and management approach to the data centre to support economic efficiency and environmental benefits.

6.1 Involvement of organizational groups

Effective communication between different departments working in the data centres is crucial to ensure efficiency and thereby avoid capacity and reliability issues.

To ensure effective communication, the following steps are proposed:

No.	Name	Description
6.1.1	Group involvement	Establish an "Approval Board" composed of representatives from different departments (e.g., software, ICT, power cooling and other facilities). Submit all important decisions for board approval to ensure that all possible impact has been fully understood and that an effective solution has been identified. For example, one of the decisions could be the definition of standard ICT hardware lists through considering the maintenance and engineering (M&E) implications of different types of hardware.

6.2 General policies

These policies apply to all aspects of the data centre and its operation.

No.	Name	Description
6.2.1	Consider the embedded energy in devices	Carry out an audit of existing equipment to ensure that optimal use is made of existing capability before making any new investment.
6.2.2	Mechanical and electrical equipment environmental operating ranges	Recommend the selection and deployment of mechanical and electrical equipment which does not itself require refrigeration. Note that this refers to mechanical compressors and heat pumps, any device which uses energy to raise the temperature of the rejected heat.
6.2.3	Lifecycle Analysis	Introduce a plan for lifecycle assessment (LCA) in accordance with [ITU-T L.1410].

6.3 Resilience level and provisioning

One of the most significant sources of inefficiency in a data centre is the over-provision of space, power or cooling, and the use of existing facilities operating at partial capacity. Monolithic design, as opposed to modular design, of facilities is also frequently an unnecessary capital expenditure.

No.	Name	Description
6.3.1	Build resilience to business requirements	Build or, in the case of a co-location customer, purchase only the level of resilience actually justified by business requirements and an impact analysis. Full backup (1+1) of infrastructure is frequently unnecessary and inappropriate. Resilience for a small portion of critical services can be obtained by using disaster recovery (DR)/business continuity (BC) sites.
6.3.2	Consider multiple levels of resilience	Build a single data centre to provide multiple levels of power and cooling resilience to different floor areas. Many co-location providers already deliver this, for example, as optional "grey" power feeds without uninterruptible power supply (UPS) or generator back up.
6.3.3	Design effective resilience	Utilize appropriate levels of resilience at the data centre ICT equipment, software and network levels to achieve the required service resilience. High resilience at the physical level is rarely an effective overall solution.
6.3.4	Lean provision of power and cooling for a maximum of 18 months of data floor capacity	Avoid unnecessary fixed losses as a result of the provision of excess power and cooling capacity in the data centre. Plan a data centre for modular (scalable) expansion and then build upon this capacity in a rolling programme of deployment. This design is more efficient, allows the technology "generation" of ICT equipment, and supports the match of M&E infrastructure, thereby improving both efficiency and the ability to respond to business requirements.
6.3.5	Design to maximize the partial load efficiency once provisioned	All areas of the data centre should be designed to maximize the efficiency of the facility under partial fill and variable ICT electrical load. This is in addition to one-off modular provisioning and considers the response of the infrastructure equipment to dynamic loads, e.g., variable frequency (or speed) drives for pumps and fan units.

7 ICT equipment and services

ICT equipment creates the demand for power and cooling in the data centre. Any reduction in power and cooling used by, or provisioned for ICT equipment will have magnified effects for the utility energy supply.

The purpose of environmental specifications of equipment, as outlined in the next clause, is to ensure that new equipment is capable of operating under the wider ranges of temperature and humidity, thus allowing the operator a greater flexibility in operating temperature and humidity.

7.1 Selection of new ICT equipment

Once ICT equipment is purchased and installed in the data centre, it is usually in use for several years, consuming power and creating heat. The appropriate selection of hardware and deployment methods can provide significant long-term savings.

No.	Name	Description
7.1.1	Multiple tender for ICT hardware – power	Include energy efficient performance of the ICT device as a high priority decision factor in the tender process e.g., through application or deployment of specific user metrics more closely aligned to the target environment, which may include service level or reliability components. The energy consumption of the device, at the expected utilization or applied workload, should be considered in addition to peak performance per watt figures.

No.	Name	Description
7.1.2	Multiple tender for ICT hardware – operating temperature and humidity range at equipment intake Low priority practices	Include the operating temperature and humidity ranges at the intake of new equipment as high priority decision factors in the tender process. The minimum range, at the air intake to servers, is 18°C-32°C and 5.5°C dew point up to 15°C dew point and 60% RH. This is defined in [b-ASHRAE TC 9.9].
7.1.3	Multiple tender for ICT hardware – extended operating temperature and humidity range High priority practices	Introduce a stronger requirement for new ICT equipment stipulating the need for them to withstand the air inlet temperature and relative humidity (RH) ranges of 5°C to 40°C and 5% to 80% RH, non-condensing respectively, and under exceptional conditions up to +45°C, as described in [ETSI EN 300 019-1-3] Class 3.1. All vendors should indicate the maximum allowable temperature and humidity for all equipment, to maximize the efficiency opportunities in refrigeration and free cooling. It should be noted that where equipment with differing environmental requirements are not segregated, the equipment with the more restrictive temperature range will influence the cooling conditions and corresponding energy consumption for all ICT equipment. From 40°C to 45°C intake temperature, it is acceptable for equipment to implement performance reduction mechanisms to continue delivering the intended service at a lower speed whilst preventing damage. These mechanisms should not reduce performance to below 80% of the nominal for that device. Where such performance reduction mechanisms are used, a clear description of the operating parameters and performance impact should be provided.
7.1.4	Environmental exclusions	Exclusions from the requirement for ICT equipment to meet the ETSI specification will be considered under the following specific conditions: – equipment that requires tighter environmental controls to meet the requirements of storage media such as tapes; – equipment that requires tighter environmental controls to meet long warranty durations (10+ years); – devices whose primary cooling method is not air (directly liquid cooled). These exclusions would require that equipment unable to meet best practice 7.1.3 should be deployed with separate airflow and cooling provision. This allows data centre cooling plants to be set up using equipment that has a less restrictive environmental range without compromising the eco-efficiency of the entire data centre.
7.1.5	Multiple tender for ICT hardware – compliance with green regulations	Tender processes for new ICT equipment that are compliant with green regulations, will be considered as high-priority decision factors. Environmental pollution can be reduced by selecting equipment that is compliant with green regulations of each region or country (e.g., restrictions of hazardous substances (RoHS), registration, authorization and restriction of chemical substances (REACH), and waste electrical and electronic equipment (WEEE)).

No.	Name	Description
7.1.6	Select equipment suitable for the data centre – power density	Select and deploy equipment according to the defined power density (per rack or square metre) of the data centre to avoid running the cooling system outside design parameters. Note that increasing power density may create cooling and airflow management problems, thereby reducing both capacity and efficiency. Power and cooling need to be considered as a capacity constraint in addition to a physical space constraint.
7.1.7	Select equipment suitable for the data centre – airflow direction	When selecting equipment for installation into racks, ensure that the airflow direction matches the airflow design for that area. This is commonly front-to-rear or front-to-top. If the equipment uses a different airflow direction to that defined for the area into which it is installed (such as right-to-left when the rack is intended to be front-to-back), then it should only be used with a correction mechanism such as ducts, or special racks that divert the airflow to the defined direction. Uncorrected equipment with non-standard airflow will compromise the airflow management of the data centre, and therefore restrict temperature set points. It is possible to mitigate this issue by segregating such equipment.
7.1.8	Select free-standing equipment suitable for the data centre – airflow direction	When selecting equipment which is free-standing, or supplied in custom racks, the airflow direction of the enclosures should match the airflow design in that area of the data centre. This is commonly front to rear or front to top. Specifically, the equipment should match the hot/cold aisle layout or containment scheme implemented in the facility. Uncorrected equipment with non-standard airflow will compromise the airflow management of the data centre and therefore restrict temperature set points. It is possible to mitigate this compromise by segregating such equipment. Suggestions on airflow management are present in an annex to this Recommendation and in [ETSI TR 102 489].
7.1.9	Enable power management features	Formally change the deployment process to include the enabling of power management features on ICT hardware as it is deployed. This includes basic input-output system (BIOS), operating system and driver settings.
7.1.10	Provision to the as-configured power	Provision of power and cooling only to the as-configured power draw capability of the equipment, and not the power supply unit (PSU) or nameplate rating. Note that this may require changes to provisioning if the ICT equipment is upgraded internally.
7.1.11	Energy efficiency compliant hardware	ICT equipment with energy efficiency labels, such as the Energy Star labelling programmes, should be used as a guide to server selection when and where available for that class of equipment. Operators who are able to determine the in use energy efficiency of hardware through more advanced or effective analysis, should select the most efficient equipment for their scenario.
7.1.12	Energy and temperature reporting hardware	Select equipment with power and inlet temperature reporting capabilities, preferably reporting energy used as a counter in addition to power as a gauge. Where applicable, industry standard reporting approaches should be used, such as intelligent platform management interface (IPMI), data centre manageability interface (DCMI) and systems management architecture for server hardware (SMASH).

No.	Name	Description
		To assist in the implementation of temperature and energy monitoring across a broad range of data centres, all devices with an IP interface should support simple network management protocol (SNMP) polling of inlet temperature and power draw. Note that event based SNMP traps and SNMP configuration are not required. The intent of this practice is to provide energy and environmental monitoring of the data centre through normal equipment churn.
7.1.13	Control of equipment energy use	Select equipment that provides mechanisms to allow the external control of its energy use. An example of this would be the ability to externally restrict a server's maximum energy use or trigger the shutdown of components, entire systems or sub-systems.
7.1.14	Operating temperature range – liquid cooled ICT equipment	These devices should be able to operate with supply coolant liquid temperatures equal to the air temperatures specified in best practice 7.1.3, i.e., from 10°C to 35°C (50°F to 95°F).
7.1.15	ICT equipment power against inlet temperature	When selecting new ICT equipment, require the vendor to supply at minimum, either the total system power or the cooling fan power for temperatures covering the full allowable inlet temperature range for the equipment under 100% load using a specified benchmark such as [b-SPECPower]. Data should be provided for 5°C or smaller steps of inlet temperature.

7.2 Selection of new telecom equipment

Once ICT equipment is purchased and installed in the data centre, it typically remains in use for several years, consuming power and creating heat. The appropriate selection of hardware and deployment methods can provide significant long-term savings.

No.	Name	Description
7.2.1	New equipment selection	Processes should be put in place to select new telecom equipment solutions that take into consideration the energy efficiency of the equipment and of the related infrastructure required for the correct operation of the telecom product.

7.3 Deployment of new ICT services

The service architecture, software and deployment of ICT services have an impact at least as great as that of the ICT hardware.

No.	Name	Description
7.3.1	Deploy using grid and virtualisation technologies	Processes should be put in place to require senior business approval for any new service that requires dedicated hardware and will not run on a resource-sharing platform. This applies to servers, storage and networking aspects of the service. This can improve available floor space, cost savings, rack utilization, ICT equipment utilization, and energy efficiency.
7.3.2	Reduce ICT hardware resilience level	Determine the business impact of service incidents for each deployed service and deploy only the level of hardware resilience actually justified.
7.3.3	Eliminate traditional 2N hardware clusters	Determine the business impact of short service incidents for each deployed service and replace traditional active/passive server hardware clusters with fast recovery approaches, such as restarting virtual machines elsewhere. (This does not refer to grid or high performance computer clusters.)

No.	Name	Description
7.3.4	Reduce hot/cold standby equipment	Determine the business impact of service incidents for each ICT service and deploy only the level of BC/DR standby ICT equipment and resilience that is actually justified by the business impact.
7.3.5	Select/develop efficient software	Make the energy use performance of the software a significant selection factor. Whilst forecasting and measurement tools and methods are still being developed, approximations can be used such as the (under-load) power draw of the hardware required to meet performance and availability targets. If outsourcing software development, then consider the energy use of the software in the bonus/penalty clauses of the contract.
7.3.6	Further development of software efficiency definitions	There is much research and development needed in the area of defining, measuring, comparing and communicating software energy efficiency. Suggested examples are: Software could be made resilient to delays associated with bringing off-line resources on-line, such as the delay of drive spin, which would not violate the service level requirements. Software should not gratuitously poll or carry out other unnecessary background "housekeeping" that prevents equipment from entering lower-power states; this includes monitoring software and agents.

7.4 Management of existing ICT equipment and services

It is common to focus on new services and equipment to be installed in the data centre, but there are also substantial opportunities to achieve energy and cost reductions from within the existing service and physical installation.

No.	Name	Description
7.4.1	Audit existing physical equipment and services	Audit the existing physical equipment and services to establish what equipment is in place and what service(s) it delivers. Consider the implementation of an ITIL type configuration management database and service catalogue.
7.4.2	Decommission unused ICT equipment/services	Completely decommission and remove the supporting hardware for unused ICT equipment/services.
7.4.3	Decommission low business value services	Identify services whose business value is low and does not justify the financial or environmental cost. Decommission or archive these services.
7.4.4	Shut down idle equipment	Servers, networking, and storage equipment that lie idle for a significant period of time, and cannot be virtualized and archived, should be shut down or put into a low power sleep mode. It may be necessary to validate the ability of legacy applications and hardware to survive these state changes without loss of function or reliability.
7.4.5	Virtualize and archive legacy services	Servers which cannot be decommissioned for compliance or other reasons, but which are not used on a regular basis, should be virtualized and then the disk images archived to a low-power media. These services can then be brought online when actually required.
7.4.6	Consolidation of existing services	Existing services that do not achieve high utilization of their hardware should be consolidated through the use of resource sharing technologies to improve the use of physical resources. This applies to servers, storage and networking devices.

No.	Name	Description
7.4.7	Control of system energy use	Consider resource management systems capable of analysing and optimizing where, when and how ICT workloads are executed, and their consequent energy use. This may include technologies that allow remote deployment or delayed execution of jobs, or the movement of jobs within the infrastructure, to enable shutdown of components, entire systems or sub-systems. The desired outcome is to provide the ability to limit localized heat output or to constrain system power draw to a fixed limit, at a data centre, row, rack or sub-DC level.
7.4.8	Audit of exiting ICT environmental requirements	Identify the allowable intake temperature and humidity ranges for existing ICT equipment.

7.5 Data management

Storage is a major growth area in both cost and energy consumption within the data centre. It is generally recognized that a significant proportion of the data stored is either unnecessary or duplicated and does not require high performance access, and that this represents an organisational challenge. Some sectors have a particular issue due to very broad and non-specific data retention directions from governments or regulating bodies. Where there is little structure to the data storage, implementation of these regulations can cause large volumes of data that are not required by the regulations to be unnecessarily heavily protected and archived.

No.	Name	Description
7.5.1	Data management policy	Develop a data management policy to define which data should be kept, for how long and at what level of protection. Communicate the policy to users and enforce it. Particular care should be taken to understand the impact of any data retention requirements.
7.5.2	Separate user logical data storage areas by retention and protection policy	Provide users with multiple data storage areas that are clearly identified by their retention policy and level of data protection. Communicate this policy to users to enable them to store data in an area that matches the required levels of protection and retention. This is particularly valuable where strong retention requirements exist, as it allows data subject to those requirements to be separated at source, thereby presenting substantial opportunities for cost and energy savings. Where possible automate the application of these policies.
7.5.3	Separate physical data storage areas by protection and performance requirements	Create a tiered storage environment utilising multiple media types that deliver the required combinations of performance, capacity and resilience. Implement clear guidelines on usage of storage tiers, with defined SLAs for performance and availability. Consider a tiered charging model based on usage at each tier.
7.5.4	Select lower power storage devices	When selecting storage hardware, evaluate the energy efficiency in terms of the service delivered per watt between options. This may be deployment-specific and should include the achieved performance and storage volume per watt, as well as additional factors where appropriate, such as the achieved levels of data protection, performance availability and recovery capability required to meet the business service level requirements defined in the data management policy. Evaluate both the in-use power draw and the peak power of the storage device(s) as configured, both impact per device cost and energy consumption through provisioning.

No.	Name	Description
7.5.5	Reduce total data volume	Implement an effective data identification and management policy and process to reduce the total volume of data stored. Consider implementing "clean up days" where users delete unnecessary data from storage.
7.5.6	Reduce total storage volume	Implement the data management policy to reduce the number of copies of data, both logical and physical (mirrors). Implement storage subsystem space saving features, such as space efficient snapshots/copies or compression. Implement storage subsystem thin provisioning features where possible.
7.5.7	Further development of storage performance and efficiency definitions	Storage performance has multiple dimensions, including throughput and latency, not all of which can be measured at the storage layer. Capacity also has multiple dimensions, allocation and usage, not all of which can be measured at the storage layer. Technologies such as de-duplication, compression, snapshots, and thin provisioning also need to be accounted for in a consistent and informative manner.

8 Cooling

Cooling of the data centre is frequently the largest energy loss in the facility and as such represents a significant opportunity to improve efficiency.

8.1 Airflow design and management

The objective of airflow management is to minimize bypass air that returns to the computer room air conditioner (CRAC) units without performing its cooling function. The resultant recirculation and mixing of cool and hot air, increases the equipment intake temperatures. To compensate, CRAC unit air supply temperatures are frequently reduced, or airflow volumes are increased, which has an energy penalty. Addressing these issues will deliver more uniform equipment inlet temperatures and allow set points to be increased (with the associated energy savings), without the risk of equipment overheating. Implementation of air management actions alone does not result in energy saving – they are enablers which need to be tackled before set points can be raised.

No.	Name	Description
8.1.1	Design – contained hot or cold air	There are a number of design concepts which intend to contain and separate the cold air from the heated return air on the data floor: – hot aisle containment; – cold aisle containment; – contained rack supply, room return; – room supply, contained rack return, (including rack chimneys); – contained rack supply, contained rack return. This action is expected for air-cooled facilities over 1 kW per square meter power density. Note that the in-rack cooling options are only considered to be containment where the entire data floor area is cooled in rack, not in mixed environments where they return cooled air for remix with other airflow.

No.	Name	Description
8.1.2	Design – hot/cold aisle	As the power densities and airflow volumes of ICT equipment have increased, it has become necessary to ensure that equipment shares an airflow direction, within the rack, in adjacent racks and across aisles. The hot/cold aisle concept aligns equipment airflow to create aisles between racks that are fed cold air from which all of the equipment draws intake air in conjunction with hot aisles with no cold air feed, to which all equipment exhausts air.
8.1.3	Design – contained hot or cold air – retrofit	Where hot/cold aisle separation is already in use, but there is no containment of hot or cold air, it is possible to retrofit to provide basic separation.
8.1.4	Rack airflow management – blanking plates	Installation of blanking plates where there is no equipment to reduce cold air passing through gaps in the rack. This also reduces air heated by one device being ingested by another device, increasing intake temperature and reducing efficiency.
8.1.5	Rack airflow management – other openings	Installation of aperture brushes (draught excluders) or cover plates to cover all air leakage opportunities in each rack. This includes: – floor openings at the base of the rack; – gaps at the sides, top and bottom of the rack between equipment or mounting rails and the perimeter of the rack.
8.1.6	Rack airflow management – obstructions	The main cause of rack airflow obstruction is the cables behind racks. Unorganized cables may block hot airflow from ICT equipment and cause re-intake of the air by the rack front, further increasing the equipment inlet temperature. Therefore, cables behind racks should be organized to secure adequate amount of cold airflow.
8.1.7	Raised floor airflow management	Close all unwanted apertures in the raised floor. Review placement and opening factors of vented tiles. Maintain unbroken rows of cabinets to prevent bypass air – where necessary fill with empty fully blanked racks. Managing unbroken rows is especially important in hot and cold aisle environments. Any opening between the aisles will degrade the separation of hot and cold air.
8.1.8	Raised floor airflow management – obstructions	Review the placement and level of obstruction created by cabling, cable trays and other structures in the airflow paths to enable unobstructed airflow and prevent turbulence and increased resistance. The use of overhead cabling trays for signalling, for example, can substantially reduce the energy requirements for air movement.
8.1.9	Design – raised floor or suspended ceiling height	If, when designing a data centre, spaces are created by raising the floor level or suspending the ceiling, such air chambers are commonly used to feed cold air to equipment, or extract hot air from it. Where such voids are utilized, the increased spaces can significantly reduce fan loss in moving the air.
8.1.10	Design – return plenums	Consider the use of return dedicated ducts to return heated air from the ICT equipment to the air conditioning units.

No.	Name	Description
8.1.11	Design – perforated tiles	Mixed use of two or three perforated tiles with different aperture ratios is more advisable than using perforated tiles having the same aperture ratio in all spots of the computer room. In general, areas closer to CRAC units have higher air volume and static pressure, which enables provision of a sufficient amount of cold air to ICT equipment, even with perforated tiles having low aperture ratios. In the areas farther from CRAC units, provision of cold air can be controlled by using perforated tiles with high aperture ratios. It is recommended not to install perforated tiles in areas that are too close to CRAC units. In these areas, the fast airflow under the raised floor creates negative pressure on perforated tiles and causes Venturi reversal, in which the air above the raised floor is pulled down under. The Venturi reversal rather draws hot air to ICT equipment while causing a lack of cold air provision to the equipment.
8.1.12	Equipment segregation	Deploy groups of equipment with substantially different environmental requirements and/or equipment airflow direction in a separate area. Where the equipment has different environmental requirements, it is preferable to provide separate environmental controls. The objective of this practice is to address the issue of the data centre cooling plant settings being constrained by the ICT equipment with the most restrictive environmental range, or poor airflow control, as this compromises the efficiency of the entire data centre.
8.1.13	Disposition of high-heat equipment	As energy consumption and heat from blade servers or large equipment increase, disposition of such high-heat equipment often affects the efficiency of the entire computer room. It is appropriate to position high-heat equipment in places where most cold air is provided. – CRAC units are often installed facing each other in the computer room. In this situation, the air temperature is lowest in the centre of the room. Therefore, high-heat equipment should be installed in the centre of the computer room, rather than in places near CRAC units. – If it is uncertain which place receives the most amount of cold air, it is recommended to measure the temperature of each area and install the high-heat equipment in the place with the lowest temperature.
8.1.14	Provide adequate free area on rack doors	Solid doors can be replaced (where doors are necessary) with partially perforated doors to ensure adequate cooling airflow within the enclosed cabinet further increasing the equipment intake temperature.

No.	Name	Description
8.1.15	Separate from external environment	The more contact the computer room has with the outer environment (outside air and solar heat), the more it is exposed to influences on temperature and humidity, further decreasing the entire air conditioning efficiency. Therefore, blocking contacts with the outer environment is a significant factor that is directly related to reducing energy consumption. For separation from the external environment, the following activities are required: • designing a windowless room or sealing windows; • installing double doors or an automatic door; • restricting entry/exit of unnecessary persons; • blocking channels connected to the outside, such as an outlet, etc. To prevent temperature increase from solar heat in the computer room, it is necessary to deploy a windowless design or shield windows (by way of window shades, curtains, solar screen panels, etc.)

8.2 Cooling management

The data centre is not a static system and the cooling systems should be tuned in response to changes in the facility thermal load.

No.	Name	Description
8.2.1	Scalable or modular installation and use of cooling equipment	Cooling plants should be installed in a modular fashion allowing operators to shut down unnecessary equipment. This should then be part of the review at each cooling load change.
8.2.2	Shut down unnecessary cooling equipment	If the facility is not yet fully populated or space has been cleared through consolidation, non-variable plants, such as fixed speed fan CRAC units, can be turned off in the empty areas. Note that this should not be applied in cases where operating more plants at a lower load is more efficient, e.g., variable speed drive CRAC units.
8.2.3	Review of cooling before ICT equipment changes	The availability of cooling, including the placement and flow of vented tiles, should be reviewed before each ICT equipment change to optimize the use of cooling resources.
8.2.4	Review of cooling strategy	Periodically review ICT equipment and cooling deployment against strategy.
8.2.5	Review CRAC/air handling unit (AHU) settings	Ensure that CRAC/AHU units in occupied areas have an appropriate and consistent temperature, and relative humidity settings, to avoid units working against each other. For example, many CRAC/AHU units now have the option to connect their controls and run together when installed in the same area.
8.2.6	Dynamic control of building cooling	It is possible to implement control systems that take many factors into account, including cooling load, data floor air temperature and external air temperature, to optimize the cooling system (e.g., chilled water loop temperature) in real time.
8.2.7	Effective regular maintenance of cooling plant	Effective regular maintenance of the cooling system is essential to maintain the design operating efficiency of the data centre, e.g., belt tension, condenser coil fouling (water or air side), evaporator fouling, filter changes, etc.

No.	Name	Description
8.2.8	Evaporative cooling method and the spot cooling method	Evaporative cooling method and the spot cooling method were proposed as best practice for data centres, with high-density ICT devices (see Annex B).

8.3 Temperature and humidity settings

Facilities are often over-cooled, bringing about air temperatures (and hence chilled water temperatures, where used) that are colder than necessary and resulting in an energy penalty. Increasing the set range for humidity can substantially reduce humidifier loads. Reviewing and addressing air management issues is required before set points can be changed in order to avoid risk to operational continuity. Expert advice should be sought before changing the environmental range for the facility. An increase in chilled water temperature set points provides enhanced efficiency for free cooling economizers and a reduction in compressor energy consumption. Unnecessary humidifier loads, generated by water loop or evaporator temperatures below the working dew point causing dehumidification-humidification loops, should be eliminated through adjustment of the lower humidity set point.

The specification of wider operating humidity and temperature ranges for the data floor should be performed in conjunction with changes in ICT equipment procurement policy. Over time, narrow tolerance equipment will be naturally cycled out and replaced.

No.	Name	Description
8.3.1	Expanded ICT equipment inlet environmental conditions (temperature and humidity) High priority practices	Where appropriate and effective, the data centre can be designed and operated within the air inlet temperature and relative humidity ranges of 5°C to 40°C and 5% to 80% RH, non-condensing respectively, and under exceptional conditions up to +45°C as described in [ETSI EN 300 019-1-3], Class 3.1. It is necessary to consider that some ICT equipment may exhibit significant increases in fan energy consumption as intake temperature is increased (e.g., above 25°C). Validate that your ICT equipment will not consume more energy than is saved in the cooling system.
8.3.2	Review and, if possible, raise target ICT equipment intake air temperature Low priority practices	Data centres should be designed and operated at their highest efficiency within the current environmental range of 18°C to 32°C. This is defined by ASHRAE as allowable for class 1 data centres [b-ASHRAE TC 9.9]. Operations in this range enable energy savings by reducing or eliminating over-cooling. This range applies to legacy data centres with existing equipment. Note that other best practices for airflow management (containment, hot aisle/cold aisle, blanking plates, and sealing leaks) may need to be implemented at the same time to ensure successful operations.
8.3.3	Review and increase the working humidity range Low priority practices	Reduce the lower humidity set point(s) of the data centre within the range (5.5°C dew point) to eliminate loop dehumidification and re-humidification. Review and, if practical, increase the upper humidity set point(s) of the data floor within the current environmental range of 20°C dew point and 80% RH to decrease the humidity control loads within the facility.

No.	Name	Description
8.3.4	Review set points of air and water temperatures	Once air management issues have been addressed and ICT equipment target temperatures have been agreed upon, these temperatures can be increased (using less energy), without increasing server inlet temperatures beyond acceptable levels. It is necessary to consider that some ICT equipment may exhibit significant increases in fan energy consumption as intake temperature is increased (e.g., above 25°C). Validate that your ICT equipment will not consume more energy than is saved in the cooling system.
8.3.5	Review and, if possible, raise chilled water temperature	Review and, if possible, increase the chilled water temperature set points to maximize the use of free cooling economizers and reduce compressor energy consumption. Where a direct expansion (DX) system is used, the evaporator temperatures should be reviewed.
8.3.6	Control to a humidity range	Controlling humidity within a range of humidity ratio or relative humidity can reduce humidification and dehumidification loads.

8.3.1 Free and economized cooling

Free, or economized cooling designs, use cool ambient conditions to meet part, or all, of the facilities cooling requirements. Hence, compressor work for cooling is reduced or removed, which can result in significant energy reduction. Economized cooling can be retrofitted to some facilities. The opportunities for the utilization of free cooling are increased in cooler climates and where increased temperature set points are used.

No.	Name	Description
8.3.1.1	Direct air free cooling	External air is used to cool the facility. Chiller systems are present to deal with humidity and high external temperatures, if necessary. Exhaust air is re-circulated and mixed with intake air to avoid unnecessary humidification/dehumidification loads.
8.3.1.2	Indirect air free cooling	Re-circulated air within the facility is primarily passed through a heat exchanger against external air, to remove heat to the atmosphere.
8.3.1.3	Direct water free cooling	Chilled water cooled by the external ambient air, via a free cooling coil, may be achieved by dry (adiabatic) coolers, or by evaporative assistance through spray onto the dry (adiabatic) coolers.
8.3.1.4	Indirect water free cooling	Chilled water is cooled by the external ambient conditions via a heat exchanger which is used between the condenser and chilled water circuits. This may be achieved by dry (adiabatic) coolers, evaporative assistance through spray onto the dry (adiabatic) coolers or cooling towers.
8.3.1.5	Sorption cooling (absorption/adsorption)	Waste heat, produced close to the data centre as a by-product of power generation or other processes, is used to power the cooling system in place of electricity. This is frequently part of a tri-generation (Tri-Gen) combined cooling heat and power system. These systems should be assessed for viability over their full lifetime against an optimized, economically efficient cooling plant.

8.3.2 High efficiency cooling plant

The next preferred cooling technology is the use of high-efficiency cooling plants. Designs should operate efficiently at system level and employ efficient components. This demands an effective control strategy, which optimizes efficient operation, without compromising reliability.

No.	Name	Description
8.3.2.1	Select adequate cooling methods of CRAC units	Methods of cooling CRAC units mainly consist of air-cooling, water-cooling, and chilled water-cooling. The costs for initial installation, operation and purchasing of CRAC units may significantly depend on which method is selected. This is why the most optimal method should be chosen after considering the features, strengths and weaknesses of each method as well as the data centre environment. – In general, using the air-cooling method is recommended for small-sized computer rooms (with less than 10 CRAC units), as long as the conditions allow for this. – For mid- or large-sized computer rooms (with 10 or more CRAC units), it is recommended to use either chilled water or a water-cooling method, depending on the building conditions. (This will save operational costs.)
8.3.2.2	Select adequate cooling towers	Cooling towers are used to exchange inside heat with outside air under water or chilled water cooling methods and are largely divided into a closed type and an open type. It is recommended to select closed cooling towers, built solely for ICT equipment despite the high installation cost.
8.3.2.3	Chillers with high coefficient of performance (COP)	Make the COP of chiller systems through their likely working range a high priority decision factor during procurement of a new plant.
8.3.2.4	Select adequate refrigerants	Refrigerants are used inside air-cooled and water-cooled CRAC units to discharge inside heat effectively. Each type of the refrigerants (R-22, R-134a, R-404a, R-407c, R-410a, etc.) has different prices, cooling efficiency and legal restrictions. Therefore, the most appropriate one should be selected after considering the strengths and weaknesses of each refrigerant. – Serious consideration is especially required with regard to using R-22, for it may destroy the ozone layer and be restricted by international regulations.
8.3.2.5	Cooling system operating temperatures	Evaluate the opportunity to decrease the condensing temperature or increase the evaporating temperature; reducing the difference between these temperatures means less work is required in the cooling cycle, hence improving efficiency. These temperatures are dependent on required internal air temperatures (see clause 8.3).
8.3.2.6	Efficient partial load operation	Optimize the facility for the partial load – it will persist for most of the operational time, rather than for the maximum load. e.g., sequence chillers, operate cooling towers with a shared load for an increased heat exchange area.
8.3.2.7	Variable speed drives for compressors, pumps and fans	Reduce energy consumption for these components in the partial load condition, where they operate for much of the time.
8.3.2.8	Select systems which facilitate the use of economizers	Select systems which facilitate the use of cooling economizers. In some buildings it may be possible to use air-side economizers. Others may not have sufficient space available, and may require a chilled liquid cooling system to allow effective use of economized cooling.

No.	Name	Description
8.3.2.9	Selection of adequate cooling methods considering space efficiency	Four air conditioning methods are available for the typical data centre: 1) Conventional air conditioning cools by supplying the entire room with cold air, cooled with chilled water from a chilling system, which flows through perforated tiles on the floor's surface. Energy consumption of both the water chilling units and the blower that circulates the chilled air through the entire room is high. 2) The outdoor air cooling method introduces cold air from outdoors directly into the room for cooling, permitting a reduction in the chilling system's energy consumption. This system can be envisaged when the outdoor temperature is higher than –30°C but lower than the room temperature. 3) The evaporative cooling method sprays water into cold outdoor air, and cools by heat exchange between the cooled air and the return air from the room, permitting a reduction in the chilling system's power consumption. This system can be envisaged when the outdoor temperature is higher than –5°C but lower than the room temperature. 4) The spot cooling method employs spot cooling units on top of racks (in ceiling) for local cooling and cools high temperature exhaust air from the servers around the server racks. Space efficiency of a data centre is influenced by its power density. Space efficiency indicates the ratio of floor area employed for ICT equipment to the total floor area of the building. The higher the value, the smaller the floor area occupied by the air conditioning equipment, and the more effective the use of the floor area. Power density indicates the energy consumption of ICT equipment per rack/cabinet of the server room floor area. As the power density of a data centre increases, the footprint for the air conditioning system and the required height of the floor chamber will also increase, affecting the initial cost because of architectural structural changes. On the other hand, the footprint of a spot cooling system does not increase based on power density, because cooling units are implemented on server racks. In the case of data centres with high power density (e.g., higher than 5-6 kW/racks, or 8 kW in the case of a high raised floor), a spot cooling system should be selected based on space efficiency. Suggestions on possible climatic range for the selection of adequate cooling methods can be found in [b-ITU-T Val]
8.3.2.10	Selection of adequate cooling methods considering outdoor air condition	The wet-bulb temperature of outdoor air affects the energy consumption of a cooling system. Wet-bulb temperature is the indication of the energy condition of air switches. When the wet-bulb temperature for a location is lower, energy consumption for the outdoor air cooling and evaporative cooling method is reduced due to effective use of cold outdoor air. In a location where the wet-bulb temperature of outdoor air is low, the energy efficiency of these cooling systems becomes higher than conventional systems. On the other hand, when the wet-bulb temperature of outdoor air is high, the energy efficiency of spot cooling systems becomes higher than conventional systems due to the effect of the reduction of distribution power, such as fans and pumps.

No.	Name	Description
		In the case of a data centre location with a low wet-bulb temperature (e.g., lower than 15°C), the outdoor air-cooling method, or the evaporative cooling method, should be selected based on energy efficiency. (This type of indication considers both temperature and humidity conditions). Also, in the case of a data centre location with a high wet-bulb temperature (e.g., higher than 15°C), the spot cooling method should be selected based on its energy efficiency. It is necessary to consider that in some locations it is useful to implement not only one of the previous techniques (see best practice 8.3.2.9), but a combination of different technologies.
8.3.2.11	Selection of energy and space efficient cooling system	The power density of a data centre affects cooling system space efficiency and has a big impact on initial costs. Also, the outdoor air condition impacts the energy efficiency of a cooling system. We should consider these two factors when selecting an efficient cooling method. If the data centre is located in a warmer zone (e.g., higher than 15°C), a spot cooling system should be selected because of its advantages with regard to maximum space efficiency and maximum energy efficiency.
8.3.2.12	Do not share data centre chilled water system with comfort cooling	Do not share the data centre chilled water system with comfort cooling in other parts of the building. The required temperature to achieve latent cooling for comfort cooling is substantially below that required for sensible cooling of the datacentre and compromises the efficiency of the datacentre cooling system.
8.3.2.13	Do not allow non ICT equipment to dictate cooling system set-points	Where other equipment requires a more restrictive temperature or humidity control range than the ICT equipment this should not be permitted to dictate the set points of the cooling system responsible for the ICT equipment.

8.4 Computer room air conditioners

The second major component of most cooling systems is the air conditioner units within the computer room. The computer room side of the chiller plant in older facilities is frequently poorly designed and poorly optimized.

No.	Name	Description
8.4.1	Select adequate CRAC units	There are many criteria for selecting a CRAC unit – cooling capacity, operational conditions (dry-bulb temperature and relative humidity), amount of airflow, etc. – and the process should be taken seriously from a long-term point of view, because the life span of a CRAC unit ranges from 7 to 15 years after installation. – In many cases, refrigerant ton (RT) is mainly considered when determining the cooling capacity of a CRAC unit. However, CRAC units having the equivalent RT level may have different cooling capacities, depending on the manufacturer. Therefore, units such as kcal/h or kW, rather than RT, should be considered when measuring the cooling capacity (1RT = 3 024 kcal/h, 1 kW/h = 860 kcal/h). – Among many CRAC units having the equivalent level of cooling capacity, it is recommended to select those with lower dry-bulb temperatures (hot air temperature returned into the CRAC unit) because they have a higher cooling capacity. – Relative humidity of returned air into the CRAC units also affects cooling capacity. Because manufacturers of CRAC units specify the cooling capacity of each product under a certain level of relative humidity, it is necessary to compare them under the same relative humidity conditions. – The amount of airflow is related to the size of motors in CRAC units and therefore should not always be large. The larger the amount of airflow, the more energy is consumed, and it is important to select the optimal amount of airflow.
8.4.2	Variable speed fans	Many old CRAC units operate fixed speed fans which consume substantial power and obstruct attempts to manage the data floor temperature. Variable speed fans are particularly effective where there is a high level of redundancy in the cooling system, low utilization of the facility or highly variable ICT electrical load. These fans may be controlled by factors such as the return air temperature or the chilled air plenum pressure. Note that CRAC units with fixed speed compressors have minimum flow requirements which constrain the minimum operating load.
8.4.3	Calculate adequate cooling capacity and quantity of CRAC units	The cooling capacity and quantity of CRAC units are measured mostly based on the expected amount of heat from ICT equipment, and partly based on the safety factor. However, more factors should be accurately determined in addition, such as the location of computer rooms and the amount of load from solar heat.
8.4.4	Disposition of CRAC units	The most important thing to be considered when installing a CRAC unit is that the focus should be put more on facilitating hot air return than on providing cold air. Returning of hot air depends on the location of the CRAC unit and has a great influence on the temperature and humidity of the computer room. When the installation structure of ICT equipment consists of a cold aisle and a hot aisle, the best place for CRAC unit disposition will be the end of the hot aisle, where the unit shall be placed in a vertical direction. This is very important in that it will help secure the shortest route for heated air to return to the CRAC unit without affecting racks. If a CRAC unit is placed in the same direction as the racks, the heated air returning to the CRAC unit will affect the row of racks located behind the unit.

No.	Name	Description
8.4.5	Run variable speed CRAC units in parallel	It is possible to achieve efficiency gains by running CRAC units with variable speed fans in parallel to reduce the total electrical power necessary to achieve the required air movement, as electrical power is not linear with airflow. Care should be taken to understand any new failure modes or single points of failure that may be introduced by any additional control system.
8.4.6	Sequencing of CRAC units	In the absence of variable speed fans, it is possible to turn entire CRAC units on and off to manage the overall airflow volumes. This can be effective where there is a high level of redundancy in the cooling system, low utilization of the facility or highly variable ICT electrical load.
8.4.7	Management of back-up CRAC units	Failure of one CRAC unit may significantly increase the temperature in several zones. This is because even with the sufficient capacity of the entire CRAC unit in a computer room, there are limitations to the processing coverage of each CRAC unit. Therefore, installation of back-up CRAC units needs to be considered, based on the fact that a back-up CRAC unit should be placed for each zone that can be covered by one CRAC unit (N+1). In general, one back-up CRAC unit is recommended for 5-6 CRAC units. However, conditions may vary and it would be advisable to carry out a simulation test based on a computational fluid dynamics (CFD) analysis prior to installation. Setting only one CRAC unit for back-up operation is not recommended due to its impact on even consumption of parts, lifecycle of the CRAC unit, and uncertainties in case of emergency. Therefore, it is better to take turns on regular cycles and make all CRAC units run for a certain period of time. (Naturally, the conditions of all units can be checked.)
8.4.8	Control on CRAC unit supply air temperature	Controlling supply temperature ensures that the server supply air (SA) (key temperature to control) is satisfactory, without possible over-cooling of air which may result when controlling return temperature (where sensor location may impact).
8.4.9	Direct liquid cooling of ICT devices	In the place of chilling air, it is possible to directly liquid cool part or all of some ICT devices. This can provide a more efficient thermal circuit and allow the coolant liquid system temperature to be substantially higher, further improving efficiency, and allowing for increased or exclusive use of free cooling or heat re-use. Note that this practice applies to devices which deliver cooling fluid directly to the heat removal system of the components, such as water-cooled heat sinks or heat pipes, and not the delivery of cooling liquid to an internal mechanical refrigeration plant or in chassis air cooling systems.
8.4.10	Do not control humidity at CRAC unit	Humidity control at the CRAC unit is unnecessary and undesirable. Do not control humidity at the CRAC unit on recirculating air instead control the specific humidity of the make-up air at the supply AHU. The chilled water loop or DX evaporator temperature should in any case be too high to provide de-humidification.

8.5 Re-use of data centre waste heat

Data centres produce significant quantities of waste heat. Whilst this is typically at a relatively low temperature, there are some applications for the re-use of this energy. As ICT equipment is increasingly used through consolidation and virtualisation, the exhaust temperature is likely to increase, thus providing greater opportunity for waste heat to be re-used. Direct liquid cooling of ICT equipment can further reduce any detrimental impact on the environment by utilizing the capacity of coolant to provide heat.

No.	Name	Description
8.5.1	Waste heat re-use	It may be possible to provide low grade heating to industrial space, or to other targets such as swimming pools, directly from heat rejected from the data centre. This recycling can ameliorate energy use elsewhere, reducing the total energy use of the data centre and the client using the waste heat.
8.5.2	Heat pump assisted waste heat re-use	Where it is not possible to directly re-use the waste heat from the data centre due to the temperature being too low, it can still be economic to use additional heat pumps to raise the temperature to a useful point. For example, this can supply heating for offices or the district utilities.
8.5.3	Use data floor waste heat to warm generator and fuel storage areas	Reduce or eliminate the electrical preheat loads for generators and fuel storage by using warm exhaust air from the data floor to maintain temperature in the areas housing generators and fuel storage tanks.

9 Data centre power equipment

The other major part of the facility infrastructure is the power conditioning and delivery system. This normally includes UPSs, power distribution units (PDUs), and cabling, but may also include backup generators and other equipment.

9.1 Selection and deployment of power equipment

Power delivery equipment has a substantial impact upon the efficiency of the data centre and tends to remain operational for many years once installed. Careful selection of power equipment at the design stage, can deliver substantial savings throughout the lifetime of the facility.

No.	Name	Description
9.1.1	Power equipment with consideration of further extension	Power equipment such as power reception/distribution/transformation systems, and cabinet panels can be extended phase-by-phase. To extend the power equipment, energy consumption data of the entire data centre should be monitored to an accurate level and the room for extension must be planned in the first place. Cabinet panels, which are the most sensitive to extension or transformation of ICT equipment, have a significant influence on the power capacity, space, and amount of airflow of CRAC units. Therefore, extra sub-circuit breakers should be prepared for cabinet panels in case of ICT equipment extension, and extra circuit breakers should be prepared for the main cabinet panels that are for extending sub-cabinet panels. The need for extensions should be considered at the design stage.

No.	Name	Description
9.1.2	Modular UPS deployment	It is now possible to purchase modular (scalable) UPS systems across a broad range of power delivery capacities. Physical installation, transformers and cabling are prepared to meet the design electrical load of the facility but the sources of inefficiency, (such as switching units and batteries), are installed, as required, in modular units. This substantially reduces both the capital cost and the fixed overhead losses of these systems. In low power environments, these may be frames with plug in modules, whilst in larger environments these are more likely to be entire UPS units.
9.1.3	High efficiency UPS	High efficiency UPS systems of any technology, including electronic or rotary, should be selected to meet site requirements.
9.1.4	Use efficient UPS operating modes	UPS should be deployed in their most efficient operating modes, such as line interactive. Technologies such as rotary and high voltage direct current (DC) can also show improved efficiency, as there is no dual conversion requirement.
9.1.5	Efficient battery selection and deployment	Select batteries that are eco-friendly (free from hazardous substances and heavy metal). Moreover, select those that are less likely to be self-discharged and that consume less charging power. Extending the back-up time of the batteries to longer than 30 minutes for securing availability of the data centre is unnecessary. Instead, it is recommended to design 15-20 minute battery back-up time, depending on the field conditions.
9.1.6	Up to 400 V DC power distribution	Consider the use of up to 400 V DC power distribution within the data centre. This can reduce the overall power conversion and distribution losses within the facility.
9.1.7	Power reception, distribution and transformation system	Selection of the method of power reception and transformation between one-step and two-step methods may vary according to the characteristics of the data centre. However, selecting the one-step vertical drop method is recommended to reduce no-load loss of electrical transformers. In addition, application of one method to all systems can also be possible to prevent undue financial investment incurred by excessive duplex configuration and an increase in the amount of power consumed. – Use highly efficient switch gears and electrical transformers. – Use active filters to improve power quality and reduce power loss. – Use tuned and de-tuned filters to improve harmonics and power factors. – Deploy peak power control systems to efficiently use electrical power and manage peak power in a reasonable manner.

No.	Name	Description
9.1.8	Cabinet panel deployment	With the increasing amount of power consumption by ICT equipment, cabinet panel deployment should satisfy the following conditions: – Provide single-phase power to each server rack with a power requirement of 4 kW or less. – If server racks have power requirements of more than 4 kW, providing three-phase power to rack-typed and measurable cabinet panels will be more efficient. – Power supply can be made easier by installing a rack-typed cabinet panel next to each server rack, which can also contribute to easier facility extension in the case of an increase in the number of ICT equipment (the more three-phase breakers, the easier equipment extension will be in the future). – This method also needs fewer cables than when providing power supply from cabinet panels to each server rack, which will further facilitate cooled air provisioning under the raised floor and reduce harmonics and heating of neutral conductors by maintaining load balance.
9.1.9	Power distribution unit (PDU) deployment	Specifications of PDUs should be differentiated according to the power capacity demanded by servers. As there are an increasing number of high-capacity servers, it is impossible to deploy a common PDU to all servers but PDUs should be customized to each in-rack server and installed.
9.1.10	Use new and renewable energy	Actively consider use of new renewable energies to cope with the increasing energy cost and the amount of carbon emissions. – New renewable energies include, fuel cell and hydrogen energy, which are based on new physical power and new substances. – Renewable energies include solar thermal energy, solar photovoltaic energy, biomass, wind power, tidal power, hydraulic, and geothermal power generation.
9.1.12	Elimination of isolation transformers	For the energy saving of data centre, isolation transformers in power distribution to ICT equipment are typically not required and should be eliminated from designs as they introduce additional transformer losses.

9.2 Management of power equipment

No.	Name	Description
9.2.1	Optimal power density	Guideline recommendations on the most efficient range for power density.
9.2.2	Reduce engine-generator heater temperature set-point	When using engine heaters to keep generators ready for rapid starts, consider reducing the engine heater set-point. Block heaters for the standby generators should be controlled to operate only when the temperature conditions warrant it.

No.	Name	Description
9.2.3	Wiring of power cables	All power cables connected to ICT equipment should be wired under the raised floor and the cables must not be installed in the cold aisle to prevent blocking of cold air for CRAC units. In exceptional cases cable wiring can be placed above the ceiling when it is high enough. In order to prevent any failures (electromagnetic interference, noise, optical cable damage, etc.) caused by installing power cables and communication cables together under the raised floor, it is necessary to set up power cables under the raised floor before installing communication trays on the floor. EMC aspects shall be considered. Separating power cables and other wires will allow easier identification and management of them and improve efficiency in air conditioning.
9.2.4	Power factor management	Considering that the higher the power factor, the lower the proportion of reactive power – and thus, the less power loss; it is recommended to use independent equipment that can maintain the power factor at the most appropriate level. – Using de-tuned filters is the least costly yet the most reasonable way to lower harmonics and improve power factor in electric power systems.
9.2.5	Load balance management	The current value of each phase reaching the load at the end of the electrical transformer in fact varies from each other. Intensified imbalance may cause an excessive load level and heating in the power distribution system and joint parts. This can be a serious threat to safety and ultimately bring about unnecessary energy consumption. Therefore, not only the entire amount of electricity used, but also the amount of energy consumed in each phase, should be monitored at the same time.
9.2.6	Heat management on joint parts	Heat is generated on parts where there is an increasing level of resistance in power distribution and arrangement system. The main causes of such increasing resistance are equipment malfunction, loose connection, and current level exceeding the stable capacity level. If the heat is left unmanaged, it can lead to fire, thereby threatening data centre stability. Since the energy loss caused by the heat is also too great to be neglected, regular check-ups and fastening of joint parts is necessary. In most cases, thermal burn cameras are used to monitor abnormal heating.

10 Other data centre equipment

Energy is also used in the non-data floor areas of the facility, in office and storage spaces. Energy efficiency in non-data centre areas should be optimized based on relevant building standards, such as relevant EU standards, leadership in energy and environmental design (LEED), building research establishment environmental assessment methodology (BREEAM), etc.

10.1 General practices

These general practices apply to the data floor and may be extended to the remainder of the building if no sustainable building standard is in use.

No.	Name	Description
10.1.1	Turn off lights	Lights should be turned off, preferably automatically, whenever areas of the building are unoccupied, for example, by switches that turn off lighting within a specified time following manual activation. Motion-detector activated lighting is generally sufficient to support security camera systems.
10.1.2	Low energy lighting	Low energy lighting systems should be used in the data centre.

11 Data centre building

The location and physical layout of the data centre building is important to achieving flexibility and efficiency. Technologies, such as fresh-air cooling, require significant physical plant space and air duct space that may not be available in an existing building.

11.1 Building physical layout

The physical layout of the building can present fundamental constraints on the applicable technologies and achievable efficiencies.

No.	Name	Description
11.1.1	Locate M&E plant outside the cooled area	A heat-generating mechanical and electrical plant should be located outside the cooled areas of the data centre wherever possible, to reduce the loading on the data centre cooling plant.
11.1.2	Select a building with sufficient ceiling height	Insufficient ceiling height in the data centre will obstruct the use of efficient air-cooling technologies, such as raised floor, and suspended ceiling or ducts.
11.1.3	Optimize orientation of the data centre	Optimize the layout and orientation of the building to reduce insulation heat loads and optimize the efficiency of heat transfer.
11.1.4	Facilitate the use of economizers	The physical layout of the building should not obstruct the use of economizers (either air or water).
11.1.5	Location and orientation of plant equipment	Cooling equipment, particularly dry (adiabatic) coolers, should be located in an area of free air movement to avoid trapping it in a local hot spot. Ideally, this equipment should also be located in a position on the site where the waste heat does not affect other buildings and create further demand for air conditioning.
11.1.6	Minimize insulation heating	Minimize solar heating of the cooled areas of the data centre by providing shade or increasing the albedo of the building through the use of light-coloured roof and wall surfaces. Shade may be constructed, or provided by trees or "green roof" systems. Low e-coating, which deposits a thin metal film on a glass surface, reflects radiant heat to the inside of the room in cold weather and to the outside in hot weather. Low e-coating on double-glazed glass will reduce cooling or heating expenditure as effectively as more costly transparent triple-glazed glass.

No.	Name	Description
11.1.7	Other technologies for energy efficient building – double skin	Double skin technology uses the air convection between the outside and the inside of the room by making a layer of space in between. In summer, the air heated inside the double skin rises and is emitted, carrying the heated air inside the room with it and further lowering the temperature. On the other hand, the air cooled inside the double skin flows into the room, leading to energy savings.
11.1.8	Other technologies for energy efficient building – light shelf	A light shelf is energy-saving lighting equipment which uses the solar light reflected from a shelf installed in the top-lower part of the vertical window into the room. The most efficient distance range for using the natural light in a room is 4-6 metres from the window. Natural light has better luminous efficiency in terms of light quality than artificial light. The light shelf is also easy to build and can achieve a quality lighting environment and energy saving at lower cost.
11.1.9	Utilize heavy water	Utilizing grey water means the use of advanced treatment of sewage water, such as waste water, river water and groundwater, so as to provide water for non-drinking purposes (e.g., flush toilets, cooling air conditioners, cleaning, sprinkling, landscaping and fire-fighting). An eco-friendly data centre which uses the grey water system reduces river pollution by decreasing the amount of newly-produced sewage water as much as the grey water used. In addition, it can save a significant amount of water for enabling data centres, mostly using a large amount of water, to reduce cooling water consumption. In general, grey water can be easily recycled as cooling water after being filtered and chlorinated only.
11.1.10	Utilize rainwater	Utilizing rainwater means collection, filtering and storing the rainwater on the roof and then using it for non-drinking purposes.
11.1.11	Other water sources	Use of other local non-utility water sources for evaporative cooling or other non-potable purposes may reduce overall energy consumption
11.1.12	Metering of water consumption	The site should meter water consumption from all sources. The site should seek to use this data to manage and reduce overall water consumption. Note that water consumption cannot be directly compared with energy efficiency (PUE) unless the energy intensity of the water source is understood. Comparing water consumption between buildings is therefore not useful.

11.2 Building geographic location

Whilst some operators may have no choice of the geographic location for a data centre, it nevertheless impacts achievable efficiency, primarily through the impact of the external climate.

No.	Name	Description
11.2.1	Locate the data centre where waste heat can be re-used	Locating the data centre in places where there are available uses for waste heat can save substantial energy globally. For example, heat recovery can be used to heat office or industrial space, hydroponic farming and even swimming pools.

No.	Name	Description
11.2.2	Locate the data centre in an area of low ambient temperature	Free and economized cooling technologies are more effective in areas of low ambient external temperature and/or humidity. Note that most temperature climates, including much of Northern, Western and Central Europe, present significant opportunity for economized cooling.
11.2.3	Avoid locating the data centre in high ambient humidity areas	Free cooling is particularly impacted by high external humidity as dehumidification becomes necessary; many economizer technologies are also less effective.
11.2.4	Locate near a source of free cooling	Locating the data centre near a source of free cooling, such as a river, subject to local environmental regulation.
11.2.5	Co-locate with power source	Locating the data centre close to the power generating plant can reduce transmission losses and provide the opportunity to operate sorption chillers from power source waste heat.

12 Monitoring

The development and implementation of an energy monitoring and reporting management strategy is core to operating an efficient data centre.

12.1 Energy use and environmental measurement

Most data centres currently have little or no energy use or environmental measurement capability. Many do not even have a separate utility meter or bill. The ability to measure energy use and factors impacting energy use is a prerequisite to identifying and justifying improvements. It should also be noted that measurement and reporting of a parameter may also include alarms and exceptions if that parameter passes outside of the acceptable or expected operating range.

No.	Name	Description
12.1.1	Incoming energy consumption meter	Install metering equipment capable of measuring the total energy use of the data centre, including all power conditioning, distribution and cooling systems. Again, the measured energy shall be separate from any non-data centre building loads. Note that this shall be required for an energy efficiency meter indicator.
12.1.2	ICT energy consumption meter	Install metering equipment capable of measuring the total energy delivered to ICT systems, including PDUs. This may also include other power feeds where non-UPS protected power is delivered to the racks. Note that this should be required for an energy efficiency meter indicator.
12.1.3	Room level metering of supply air temperature and humidity	Install metering equipment at room level, capable of indicating the supply air temperature and humidity for the ICT equipment.
12.1.4	CRAC/AHU unit level metering of supply or return air temperature and humidity	Collect data from CRAC/AHU units on supply or return (dependent upon operating mode) air temperature and humidity.
12.1.5	PDU level metering of ICT energy consumption	Improve visibility of ICT energy consumption by metering at the PDU inputs or outputs.
12.1.6	PDU level metering of mechanical and electrical energy consumption	Improve visibility of data centre infrastructure overheads.

No.	Name	Description
12.1.7	Row or rack level metering of temperature	Improve visibility of air supply temperature.
12.1.8	ICT device level metering of temperature	Improve granularity by using built-in device level metering of intake and/or exhaust air temperature as well as key internal component temperatures.
12.1.9	ICT Device level metering of energy consumption	Improve granularity and reduce metering cost by using built in ICT device level metering of energy consumption.

12.2 Energy use and environmental collection and logging

No.	Name	Description
12.2.1	Periodic manual readings	Entry-level energy, temperature and humidity reporting can be performed with periodic manual readings of consumption meters, thermometers and hygrometers. This should occur at regular times, ideally at peak load.
12.2.2	Automated daily readings	Automated daily readings enable more effective management of energy use. Supersedes periodic manual readings.
12.2.3	Automated hourly readings	Automated hourly readings enable effective assessment of how ICT energy use varies with ICT workload. Supersedes periodic manual readings and automated daily readings.
12.2.4	Reading of economized cooling hours – new build DC	Require collection and logging of full economizer, partial economizer and full mechanical hours throughout the year. The intent being to record the amount or time and energy spent running mechanical cooling versus relying of free cooling. The site design, cooling system operational set-point sand ICT equipment environmental control ranges should allow the data centre to operate without refrigeration for a significant part of the year with no refrigeration for the ICT cooling load as evaluated against a typical meteorological year for the site. Note that this refers to mechanical compress or sand heat pumps, any device which uses energy to raise the temperature of the rejected heat.

12.3 Energy use and environmental reporting

Energy use and environmental (temperature and humidity) data need to be reported to be of use in managing the energy efficiency of the facility.

No.	Name	Description
12.3.1	Written report	Entry-level reporting consists of periodic written reports on energy consumption and environmental ranges. This should include determining the averaged PUE over the reporting period.
12.3.2	Energy and environmental reporting console	An automated energy and environmental reporting console to allow M&E staff to monitor the energy use and efficiency of the facility provides enhanced capability. Averaged and instantaneous PUE are reported. Supersedes written report.

No.	Name	Description
12.3.3	Integrated ICT energy and environmental reporting console	An integrated energy and environmental reporting capability in the main ICT reporting console allows integrated management of energy use and comparison of ICT workload with energy use. Averaged, instantaneous and working range PUE are reported and related to ICT workload. Supersedes written report (best practice 12.3.1) and energy and environmental reporting console (best practice 12.3.2). This reporting may be enhanced by the integration of effective physical and logical asset and configuration data.
12.3.4	Reporting of economized cooling hours – new build DC	Require reporting to log full economizer, partial economizer and full mechanical hours throughout the year. The intent being to record the amount or time and energy spent running mechanical cooling versus relying of free cooling. The site design, cooling system operational set-point sand ICT equipment environmental control ranges should allow the data centre to operate without refrigeration for a significant part of the year with no refrigeration for the ICT cooling load as evaluated against a typical meteorological year for the site. Note that this refers to mechanical compress or sand heat pumps, any device which uses energy to raise the temperature of the rejected heat.

12.4 ICT reporting

Utilization of the ICT equipment is a key factor in optimizing the energy efficiency of the data centre.

No.	Name	Description
12.4.1	Server utilization	Reporting of the servers' processor utilization globally or grouped by service/location. Whilst effective metrics and reporting mechanisms are still under development, a basic level of reporting can be highly informative.
12.4.2	Network utilization	Reporting of the network utilization globally or grouped by service/location. Whilst effective metrics and reporting mechanisms are still under development, a basic level of reporting can be highly informative.
12.4.3	Storage utilization	Reporting of the storage utilization globally or grouped by service/location. Whilst effective metrics and reporting mechanisms are still under development, a basic level of reporting can be highly informative. The meaning of utilization can vary depending on what is considered available capacity (e.g., ports, raw versus usable data storage) and what is considered used (e.g., allocation versus active usage). Ensure the definition used in these reports is clear and consistent. Note that mixed incentives are possible here through the use of technologies such as de-duplication.

13 Design of network

This clause contains requirements on network design to connect equipment present in the data centre and the data centre with other data centres.

No.	Name	Description
13.1	Equipment selection	Select network equipment (switches, routers, firewalls, etc.) with best energy efficiency.
13.2	Network design	Consider the network design (topology, DC interconnection map and constituent network devices) to maximize egress bandwidth (effective cumulative throughput towards connected DC elements or external networks) relative to energy footprint. Minimize the number of "internal" network elements and interconnects ("grey ports") that are not delivering traffic towards data processing and storage equipment or external networks.
13.3	Plan for run-time energy consumption profiling of the network	Consider installing power meters and/or using embedded energy monitoring tools to profile energy utilization within all network devices. In combination with the practices of clause 12, this gives data to assess the efficiency of a network in real-time and plan for extended energy conservation policies.
13.4	Establish extended energy conservation policies for network devices	Using information derived from practices outlined in the EU Code of Conduct on Data Centres v4.0.5, consider analysis of productivity patterns and identify opportunities to enable extended energy conservation features within network devices (such as automatic capacity downgrade during certain times of the day).
13.5	Use a network as medium to propagate energy conservation policies throughout DC	Consider integration of DC idling and sleep policies (such as best practice 7.4.4) within the network. For instance, implement on-demand reconfiguration of server clusters using "wake-on-LAN" technology.

14 Cloud data centre

The cloud data centre, due to high-density and high integration, requires a more advanced energy-saving approach than the existing data centre from the perspectives of construction, electric power, air conditioning, and other infrastructures. The excessive initial investment cost can be reduced by designing the infrastructure facilities such that phased extension is supported. Moreover, the infrastructure facilities can be operated in an energy-efficient manner by implementing the different availability and power density requirements on a per-module basis.

Therefore, the dedicated cloud data centre should 1) support a high-density environment, 2) house highly energy-efficient equipment to address the problem of high power consumption and high heat emission, and 3) be flexible and scalable to cope with the rapidly changing environment. Lastly, it should have a management system that can control the large-scale ICT resources efficiently and in a cost-effective manner.

14.1 High flexibility

The data centre should have flexible scalability to cope with the quick increase of ICT environment resources based on the high-density environment. To implement the data centre in this manner, the space or server room should be implemented with modularized design, unlike traditional centre planning.

No.	Name	Description
14.1.1	Module composition	The server room modules will consist of the floor module configuration plan (unit of facilities extension) and a plan that can specify the floor module. The detailed plan by phase will be established for the entire space or server room of the data centre considering the facilities area and power usage.
14.1.2	Establishment of modularized space or server room plan	The space plan for facilities room modularization will be applied to support the standardized server room module. The minimum unit area will be calculated for expansion through the analysis of the centre's space or server room use plan, which will be configured as the basic module. The space expansion pattern via modularization should consider two patterns: horizontal expansion and vertical expansion. The standardized pattern will be applied to the modularized space or server room so that phased extension can be implemented within a short period of time and according to the business requirements.
14.1.3	Applying modularization to the infrastructure space	The infrastructure space plan supporting the modularized space or server room should consist of the common facilities space and modularized facilities space by module. The common facilities space is not affected by the module, e.g., main power receiving and transformation facilities, whereas the modularized facilities space can accommodate the facilities changed by the power requirement of the server room module such as the UPS and battery room, which should be designed as part of the module composition together with the server room.
14.1.4	Applying multi-tier that satisfies the availability requirement by module	The infrastructure composition by module will be designed such that it can be differentiated by module according to the availability requirement by individual server room module. Availability by module can be configured with the same or below-tier level with common infrastructure availability and applied differently according to the importance of the system.
14.1.5	Flexible configuration of electric power density of the space or server room by module	Independent capacity increase and power density increase will be supported by configuring the individual facilities independently for each module of the modularized data centre. The facilities by module – which should be considered for this -- includes low-voltage substation facilities, mechanical equipment, UPS, battery, PDU, and low voltage cabling, which should be designed according to the requirements of the server to be extended.
14.1.6	Applying the common facilities and the modularized facilities by module	The common facilities are configured regardless of module configuration, such as the power substation and power generation facilities. The modularized facilities consist of the UPS, battery, and thermo-hygrostat. The facilities will be designed such way that facilities by module can be configured flexibly based on the common facilities.
14.1.7	Implementation of container-type modular data centre	As one of the actual implementation methods of the modularized data centre, the container-type data centre integrates various ICT infrastructures in a cargo container. When this type of centre is introduced, 5~30 k-level, high-density servers can guarantee higher energy efficiency than the existing centre by overcoming the limitation of the place and infrastructure and utilizing effective cooling in airtight rooms. This type also allows flexible extension, since the container park-type, large-size centre can be built by piling up container centres.

No.	Name	Description
14.1.8	Implementation of the building-type modular data centre	One of the modular centres, the building-type modular centre, constructs individual server rooms in the centre on a scale of 300~1 200 m2. Compared with the container centre, there are limitations in terms of the place and construction period. Note, however, that it is more flexible than other centre construction methods; implementing the high-density, high-integrity centre is also easy, which makes it suitable for the cloud centre.

14.2 High-density data centre

There is an essential need for the proper control and management of high density, high heat generating data centres. Cloud data centres are likely to have a high concentration of systems on each rack resulting in increased and concentrated power dissipation.

While a conventional data centre has 2~4 kW power density per rack, a cloud data centre has to maintain power density of 8~10 kW or higher; hence the need for a different power distribution and cooling system architecture from that of conventional data centres.

Appropriate partitioning and capacity setting are particularly needed to provide agility and easy provisioning (as the features of a cloud service) to build more facilities alongside the expansion of ICT systems. The investment cost and operating cost can be reduced only through such phased expansion and operation.

No.	Name	Description
14.2.1	Application of high-efficiency solution based on ICT rack standardization	Cold aisle or hot aisle containment should be included in the standardized ICT rack to block heat recycling at the roof; high-density cooling system should be applied for cooling efficiency. Use the standard rack-type high-density PDU to supply appropriately the high power required by the high-density ICT systems. A 3-phase power strip to supply 15 A or higher per phase power should be installed on each rack.
14.2.2	Application of high-density cooling system based on chilled water	Use the high-density cooling system based on chilled water to cool the high heat-emission rack system. The cooling system is made up of chiller, computer room air handler (CRAH), in-line or overhead cooling system, etc., and combined with a containment system to maximize performance. For high-density systems with around 30 kW per rack, use a closed cooling system so that the heat is not discharged to the data centre.
14.2.3	Application of power solution to provide high energy density	Use a power solution suitable under the high-density environment to provide high energy density in a small installation space. UPS should be a modular type and voltage and frequency independent (VFI) type [ISO/IEC 62040-3] based on insulated-gate bipolar transistor (IGBT) structure. It should be online hot-swappable equipment so that its capacity can be easily expanded. Use Li-ion batteries or Li-ion polymer batteries with smaller installation space and weight to overcome the spatial limitation and operation temperature limitation of the building at the same time.
14.2.4	Delivery of scalability through modularization of common infrastructure	For scalability, common infrastructure should be partitioned into smaller units so that the data centre modules can be easily expanded. Use two-step transformation method and install low-voltage transformers near each module to reduce the noise and power transmission loss. Use an integrated free cooling chiller to enable phased expansion and energy saving through free cooling at the same time. The overall piping system should be simplified to save space.

No.	Name	Description
14.2.5	Maintenance of high availability ICT system availability in high heat-generating environment	The response time to a cooling system problem becomes more critical as heat generation per rack increases. To deal with the root cause of the problem, supply UPS power to the cooling system or CRAH. In the case of CRAH and cooling tower, install a system to enable redundancy of the power source such as an automatic transfer switch (ATS). Use a thermal storage tank to supply chilled water for 4 to 15 minutes (depending on cooling or electrical technical solution) and maintain operability until the cooling system is restored after it is shut down.
14.2.6	Energy-efficient cooling system architecture	Seal the data centre and concentrate on sensible heat cooling to minimize external factors and maintain suitable temperature. Essentially the role of cooling system is control the temperature and humidity to protect from overheat and electrostatic disturbance. The trend of data centre cooling system is increasing the chilled water temperature from a range of 7°C to 12°C to a range of 15°C to 20°C, or more high temperature, to prevent the condensation to achieve more energy saving based on sensible heat cooling structure. This trend is more helpful to increase the free-cooling efficiency. Free cooling using water side economizer or air side economizer will save the electric energy for cooling system greatly from longer free cooling period minimum 70% of the time per year in middle latitude area as some case study.

14.3 Management optimization

Since a cloud data centre has a system environment that is different from that of the conventional data centre, its management should consider the cloud systems. A cloud system under a virtualized environment can often perform logical formations and changes of many servers; hence the need to manage the resource availability data and utilization status data accurately.

Moreover, new measures for network cable configuration and management are needed to support frequent changes of the system architecture. The data centre equipment also needs to be changed considering the nature of cloud systems.

No.	Name	Description
14.3.1	Comprehensive inventory tracking	Since a cloud system logically organizes multiple Windows servers using clustering technology, it should properly manage the configuration data related to the physical system. It also needs an asset management system supporting the system architecture and utilization since it can save on equipment cost (power and heating ventilation and air conditioning (HVAC)) only when it increases the utilization of the resources and restrains power usage by idle resources.
14.3.2	Unified networking	Most data centres separately use data network cable and storage area network cable. Note, however, that unifying the data and storage area networks using 10-gigabit Ethernet cable will not only save on cable cost but also reduce the HVAC cost by simplifying the data centre infrastructure architecture and complex cable configuration. It also has the additional benefit of reducing cable consumption and decreasing resource wastage.

No.	Name	Description
14.3.3	Intelligent cable management System	Since the cloud environment makes the system architecture more complex, effective measures for managing the network cables are needed. A cable management system (CMS), an intelligent network management system, can effectively manage the network cables (by monitoring the cable operation status in real time and remotely controlling the port data with the software in case of a problem) and manage the task history.
14.3.4	Dynamic smart cooling	One of the features of a cloud-based data centre is that the allocation and reclaiming of resources occur frequently. Since power consumption and heat generation by the server increase when resources are allocated more often, the system should also control HVAC operation to maintain constant temperature at the same time to reduce the waste of HVAC. In other words, measures for linking infrastructure operation with resource utilization are needed.
14.3.5	Consolidated IT and facilities monitoring system	Unlike before, in a cloud-based data centre, the equipment is operated according to the system architecture. Therefore, the system administrator and infrastructure manager should cooperate more closely to exchange information. Until now, system and equipment events were not integrated but managed separately with no data exchange. Addressing such problems requires a system for integrating the system and infrastructure events.

15 Optimization of energy management of whole data centre

In order to reduce energy consumption of the whole data centres, not only energy efficiency for each device such as ICT devices and air-conditioning equipment but also energy optimization for all devices is important.

15.1 Optimization of energy management by an integrated control of ICT devices and facility

The power consumption of ICT devices and facility, especially air-conditioning equipment, occupies the most part of total energy of a data centre. To optimize the energy management of the whole data centre, it is efficient to conduct the integrated control of both elements.

No.	Name	Description
15.1.1	Integrated control and management of ICT devices and facility	It is more efficient to link ICT devices and facility and to control both elements optimally on the basis of these operating states in order to improve an energy efficiency of a whole data centre. A proposal of the integrated control is present in the Annex.
15.1.2	Total optimization by using energy consumption characteristic of each device constituting a data centre	Each device has an energy consumption characteristic influenced by external conditions, such as operating states of ICT devices and facility, and measurement data from sensors. It is better to grasp the characteristic of all devices and set the control parameters of these devices to minimize total energy consumption. Furthermore, it is capable of more optimization to consider a layout of server room and a characteristic of data centre equipment.

Annex A

Possible methodology for cooling data centres by using renewable energy in cold regions

(This annex forms an integral part of this Recommendation.)

A.1 Data centres in cold regions

A.1.1 Conditions of data centre location

The location of a data centre should be selected with various factors in mind, including security from external forces such as earthquakes and floods, availability of a communication infrastructure, stable supply of electric power, convenience of transportation, and recruitment of people to work in the data centre. From the viewpoint of energy efficiency, it is also important to examine whether renewable energy can be used or not.

A.1.2 Use of renewable energy in cold regions

Renewable energy may be used in various ways, for example, in the generation of electric power and as a heat source. In cold weather regions, efficient cooling becomes possible by using low air temperature, or accumulated snow, as a cold heat source of air conditioning systems at data centres.

A.2 General matters relating to data centre cooling

A.2.1 Air conditioning systems for data centres

At data centres, floor-diffused air conditioning systems with raised floors are generally adopted. Figure A.1 shows an example of air conditioning system components. Cool supply air emitted from the air conditioner is heated by a server in the server room, and the heated return air (RA) is returned to the air conditioner. The cycle is repeated. Equipment, such as chillers and water-cooling towers, are required for producing cooling water using electric power, and cooling coils and fans for producing cool air using cooling water. The cooling operation takes place throughout the year at data centres because servers generate a large amount of heat.

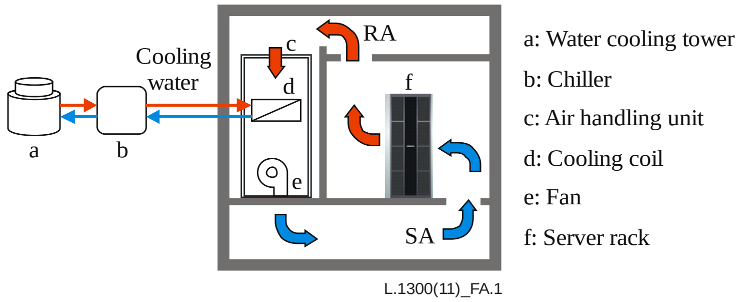


Figure A.1 – Air conditioning system components at a data centre

A.3 Outdoor air cooling

Data centres that require cooling throughout the year could use low-temperature outdoor air in winter for cooling.

A.3.1 Outdoor air cooling systems

The modes of cooling systems using the cold heat of low temperature outdoor air are classified into the following categories:

(1) Direct use of cold heat

Low temperature outdoor air is taken directly into the server room for cooling. It is taken into the air conditioner and mixed with high temperature return air from the server room, or is directly taken into the server room.

(2) Indirect use of cold heat

Cold heat of low temperature outdoor air is used indirectly by performing heat exchange.

(3) Selection of the mode of use

In the mode of direct use, cold heat of outdoor air is directly used and high thermal efficiency is achieved. The mode of indirect use is applicable even in cases where no outdoor air can be taken directly because of conditions such as the quality of outdoor air, temperature and humidity. When planning a data centre, various conditions should be comparatively examined and an optimum mode should be selected. Both modes may be used interchangeably in different periods as outdoor air conditions vary.

A.3.2 Mechanism of outdoor air cooling and considerations

A.3.2.1 Mechanism of outdoor air cooling and temperature and humidity control

At data centres, conditions for supplying air to servers are held in a designated range, so air supply conditions should be held at a certain level when adopting the outdoor air direct use mode.

(1) Temperature control methods

Low temperature outdoor air (OA) is taken into the air conditioner and mixed with return air (RA) from the server room. The temperature of supply air (SA) can be kept constant by adjusting the outdoor air/return air mix proportions according to the variation of outdoor air temperature. Unnecessary exhaust heat from the server is discharged outdoors as exhaust air (EA) (Figure A.2).

(2) Humidity control methods

In cases where outdoor air is dry, as in winter, humidity should be controlled through humidification. Humidification is achieved by various methods, such as supplying steam, atomizing and vaporizing. Using humidifiers of the drip infiltration vaporization type enables humidification without using any electric power (Figure A.3).

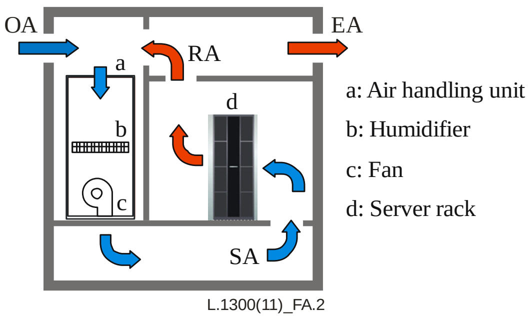
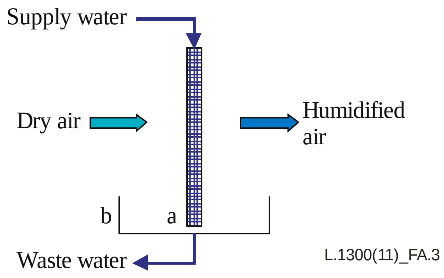


Figure A.2 – Direct use of outdoor air for cooling



a: Humidifier b: Waste water pan

Figure A.3 – Humidifier of drip infiltration vaporization type

A.3.2.2 Cooling cycles and system installation conditions

Changes in air condition during outdoor air cooling, and the ranges of air conditions in which outdoor air cooling can be done, are shown on a psychometric chart (Figure A.4).

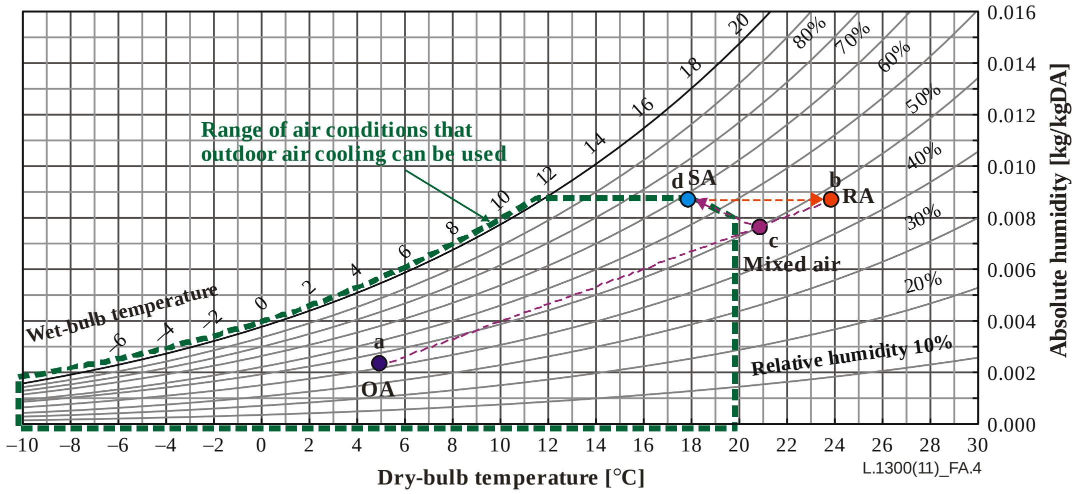


Figure A.4 – Changes in air condition during outdoor air cooling

Outdoor air (OA ,point a) and return air (RA, point b) are mixed to create the state of mixed air (point c). Humidity is evaporated by the humidifier and the mixed air is cooled or humidified to create the state of server supply air (SA, point d). The temperature and humidity of outdoor air vary according to the season or time. An appropriate air condition can, however, be created through the adjustment of mix proportions and humidification. If the temperature and humidity of outdoor air meet certain requirements, outdoor air cooling becomes possible. For example, if temperature, relative humidity and absolute humidity are assumed to be 18°C, 65% and 0.0085 kg/kgDA respectively, as water supply conditions of the air conditioner, the range in which outdoor air cooling can be done is represented by the following parameters:

(1) Outdoor air temperature < 20°C (Note)

(2) Absolute humidity < Supply air humidity (0.0085 kg/kgDA)

(3) Wet bulb temperature < Wet bulb temperature of supply air (14°C)

NOTE – Determined by the capacity of the humidifier.

Even in cases where the outdoor air condition does not meet the above requirements, cooling by using an electric heat source to compensate for the lack of cold heat enables the reduction of electric power consumption. The range in which outdoor air cooling (combined use) can be done, then expands.

A.3.2.3 Other considerations

(1) Removal of impurities

In areas where impure substances are mixed with the air, such as in coastal and volcanic areas, air purity should be kept at a certain level using filters and other equipment.

(2) Compatibility between construction and equipment planning

At data centres, a large amount of heat is generated and a large amount of cool air is required. Full consideration should, therefore, be made of construction planning such as creating openings on exterior walls of the building that are sufficiently large to taken in outdoor air.

A.4 Snow and ice cooling

In regions of heavy snowfall, high costs are incurred for ploughing, storing and melting snow in built-up areas and on arterial highways. However, in such regions, snow may be a source of renewable energy if, instead of being discarded as useless, it is stored in winter and used in summer, when no outdoor air cooling is possible, to cool data centres.

A.4.1 Snow and ice cooling systems

The cooling and snow storage methods of snow and ice cooling systems are classified into the following categories:

(1) Cooling methods

Use of air: air is chilled by means of direct contact between air and snow. The method is suitable in cases where a relatively small amount of air is handled. High power is required for conveying the heat, because gas is used as the heating medium.

Use of snowmelt water by performing heat exchange: the cold heat of snowmelt water is used by performing heat exchange. Heat can be conveyed easily, even over a long distance between the snow storage pit and the place to be cooled, because liquid is used as the heating medium.

(2) Snow storage methods

Indoor storage: a building is constructed exclusively for storing snow, or a part of an existing building (e.g., basement) is used as a snow storage facility.

Outdoor storage: a snow pile is constructed outdoors and the equipment and piping required for obtaining cold heat are installed.

(3) Selection of an appropriate method

At data centres, servers generate a large amount of heat and, therefore, a large amount of heat is also required for cooling. Using snowmelt water by performing heat exchange is considered more beneficial in view of the efficiency of heat exchange and the ease of heat conveyance. Outdoor storage that requires no building is more appropriate because a large snow pile needs to be constructed.

A.4.2 Mechanism of snow and ice cooling and considerations

A.4.2.1 Mechanism of snow and ice cooling

Snowmelt water obtained from snow and ice produces water for cooling via a heat exchanger. Warm water produced by the heat exchanger returns to the snow pile as circulating water and is used again for melting snow and ice (Figure A.5).

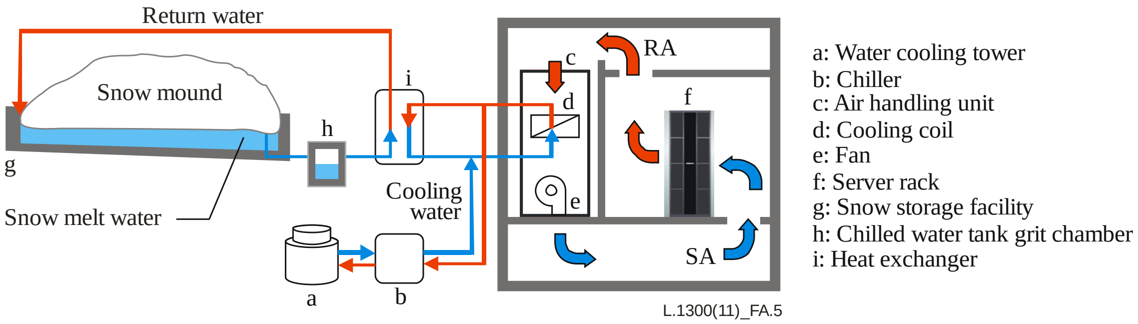


Figure A.5 – Systems for circulating snowmelt water and storing snow outdoors

A.4.2.2 Operation and management of snow and ice cooling systems

(1) Supplying snow and ice

Snow and ice cooling requires the collection of snow and ice that provide the amount of heat required for cooling data centres. Acquiring the cooperation of a local autonomous body, or other organization that manages snow removal in the vicinity, may reduce the running costs during the collection, transport and storage of snow. Securing a large space for snow storage facilities adjacent to the site of a data centre is also necessary.

(2) Securing necessary cold heat

As the snow melts, voids are formed between the snowmelt water and snow pile. If the voids become larger, the area of contact between the snowmelt water and snow pile is reduced and the amount of heat obtained is also reduced. If the voids become even larger, the snow pile collapses and the contact between the snowmelt water and snow pile is restored. In the cycle, the temperature of snowmelt water obtained from snow and ice varies. The amount of cold heat can, however, be kept at a certain level by adjusting the flow of cooling water sent to the air conditioner via a heat exchanger.

(3) Managing snow storage facilities

The snow collected on the streets contains mud and various types of impurities. Impurities should be removed completely via mud pits or filters. Applying heat-insulating sheeting for storing snow and ice until summer, reduces natural thawing in outdoor snow storage facilities and enables efficient use of snow and ice. Regularly removing deposited impurities, and properly managing the level of snowmelt water, enable stable cooling.

A.5 Method of cooling data centres in cold regions

A.5.1 Cooling facilities for data centres in cold regions

At data centres, stable operation is required around the clock, all year round. It is therefore preferable for data centres in cold regions to be equipped with hybrid cooling facilities that make the best use of renewable energy and also use an electric heating source as a backup (Figure A.6).

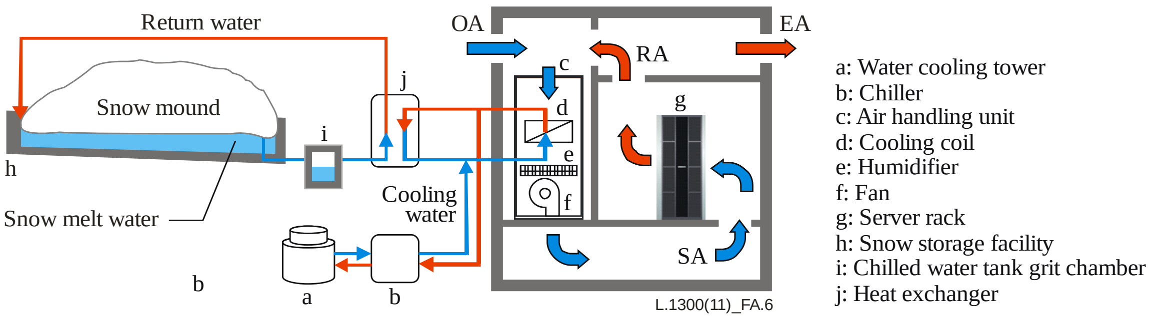


Figure A.6 – Equipment with hybrid cooling facilities

A.5.2 Energy efficiency and optimum operation control for respective cooling systems

Outdoor air cooling: cooling can be done only by fan drive power without using any electric heating source. Energy consumption can be greatly reduced.

Snow and ice cooling: electric power is used by pumps for circulating snowmelt water, but no electric cold heat source is used. Electric energy consumption can therefore be reduced.

For cooling, outdoor air, snow and ice and electric heat source cooling systems, are available in the descending order of energy efficiency for cooling. In cold regions, cooling systems can be operated most efficiently by making the best use of outdoor air cooling, and adopting snow and ice cooling, or electric heat source cooling, during the period in which no outdoor air cooling is possible.

A.5.3 Maximization of data centre cooling efficiency

In cold regions, using outdoor air or snow and ice for cooling data centres makes contributions to the reduction of power consumption. Cooling efficiency can be maximized by using outdoor air or snow and ice, in combination with solar radiation, wind power and other types of renewable energy, or with other methods for increasing cooling efficiency.

Annex B

Possible methodology for cooling data centres with high-density ICT devices

(This annex forms an integral part of this Recommendation.)

B.1 Outline of air conditioning methods

B.1.1 Conventional air conditioning

B.1.1.1 Air conditioning system outline

Figure B.1 shows the conventional air conditioning system in a data centre. Floor supply air conditioning in which multiple floor supply air conditioners (e.g., CRAC) are installed in the room. A large number of server devices are installed on the raised floor in the room, and arranged in a regular pattern, alternately facing the cold aisle (towards which the server device air inlets are directed) and the hot aisle (towards which the exhausts are directed).

Hot interior air, discharged from the hot aisle into the interior upper airspace, is drawn from the top of the floor supply air conditioning equipment, dehumidified and cooled to the specified temperature with chilled water inside the air conditioning equipment, and supplied to an under-floor chamber. This cold air is supplied to the cold aisle from outlets (gratings) in the cold aisle on the raised floor and, after passing through and removing the heat generated by the server devices, it is discharged to the hot aisle as high-temperature exhaust air.

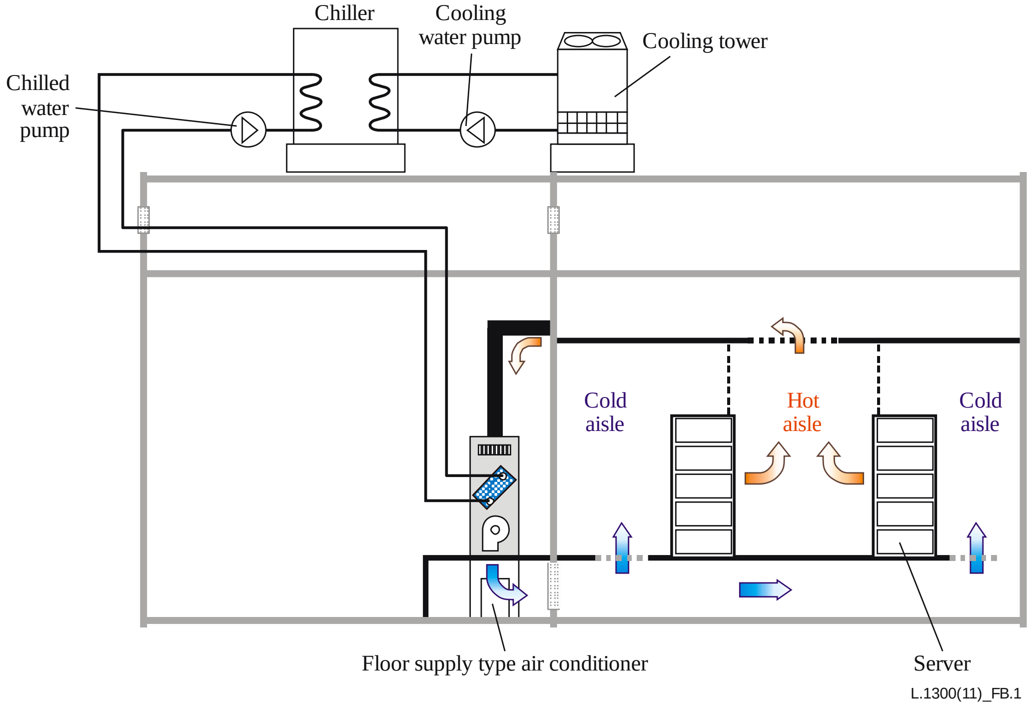


Figure B.1 – Conventional air conditioning system

B.1.1.2 Control system and operating status

With the floor supply conventional air conditioning system, the amount of chilled water passed through the cooling coils is controlled to maintain the air supplied to the room at a constant temperature. With this method, the cooled air is supplied from the outlets on the floor, mixed with the air in the room, and drawn into the server devices. In the typical server room, allowable server inlet air temperature is around 25°C, and supply air temperature necessary to keep the server inlet temperature lower than allowable temperature is generally approximately 18°C. Humidity is adjusted by dehumidifying with the cooling coils and by evaporative humidification.

B.1.1.3 Problems

Figure B.2 shows the problems associated with the conventional air conditioning system. This cold air is introduced from the server inlet side facing onto the cold aisle and, after cooling the devices, it is discharged from the rear side of the rack as hot air. If part of the high-temperature exhaust air is circulated into the inlet side, a hot spot occurs in which the temperature at the server rack inlet increases, with the associated risk of performance deterioration of the ICT devices and other damage due to high temperatures, and the ultimate danger of a halt to service.

Since low-temperature air is supplied from the under-floor chamber to the entire room with a conventional air conditioning system, the proportion of electric power required to distribute the large volume of air is considerable because of excessive operation of the air conditioning equipment to prevent hot spots happening. This may result in reduced efficiency of the air conditioning operation, and a consequent increase in air conditioning power consumption.

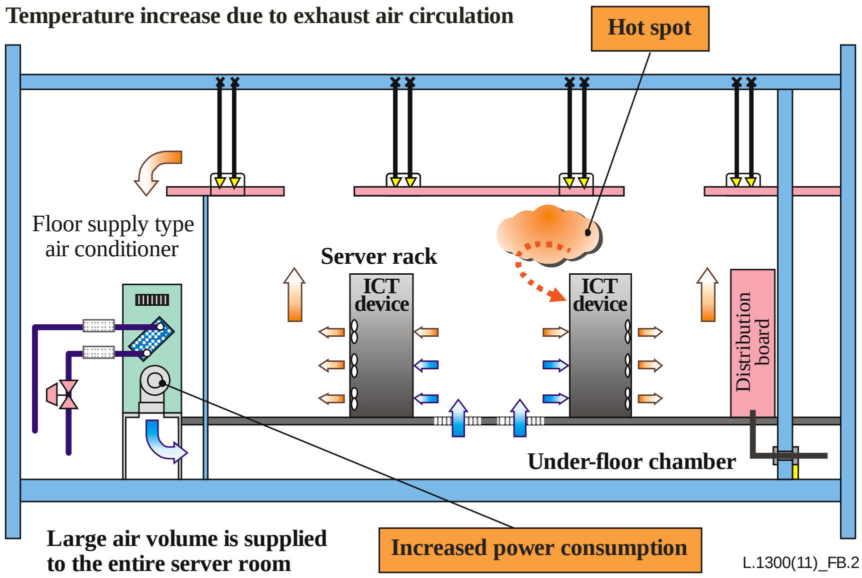


Figure B.2 – Problems with typical air conditioning

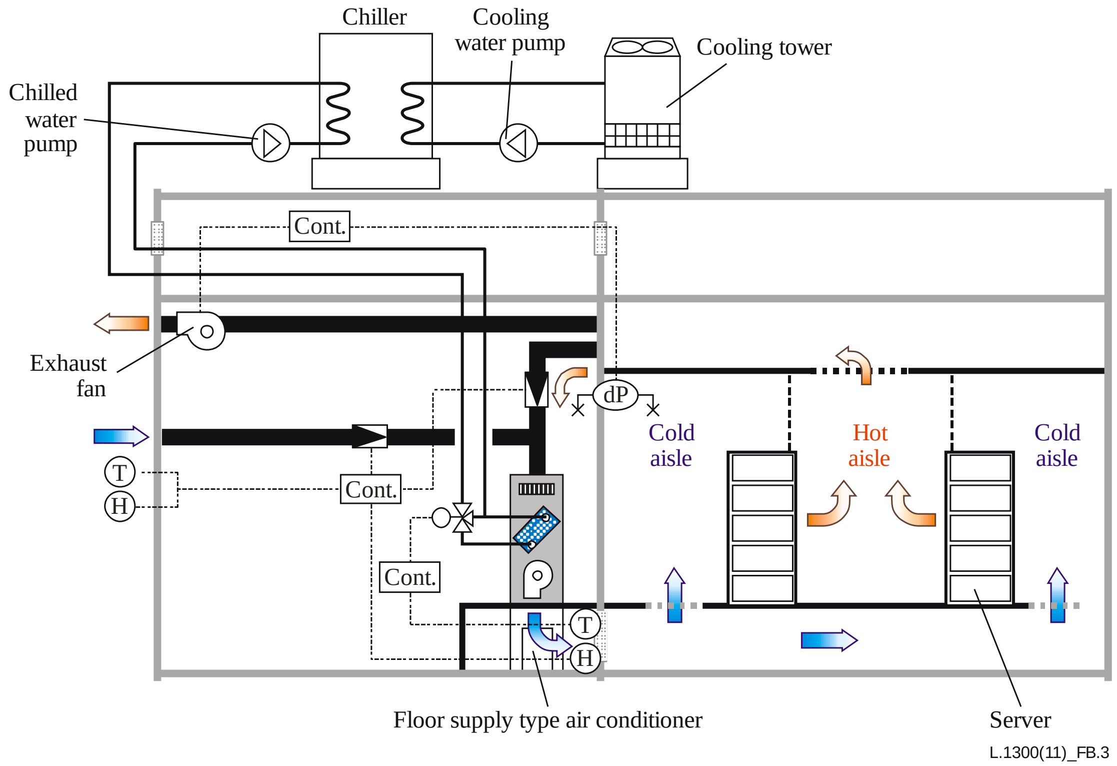
B.1.2 Outdoor air cooling system

B.1.2.1 Air conditioning system outline

Figure B.3 shows the configuration of the outdoor air cooling system. With outdoor cooling, in addition to floor-supply air conditioners supplying cooled air to the room as with conventional air conditioning, the air conditioning system incorporates exhaust fans discharging air from the room to the outside, and outdoor air ducting introducing outdoor air to the air conditioners.

A large number of server devices are installed in server racks on the raised floor in the room, arranged in a regular pattern alternately facing the cold aisle (towards which the server device air inlets are directed) and the hot aisle (towards which the exhausts are directed).

With this method, as with conventional air conditioning, air cooled with multiple floor supply air conditioners (e.g., CRAC) installed in the room is supplied to the room for cooling. During the intermediate seasons, and in winter (during which outdoor air temperature is low), outdoor air is introduced directly to the air conditioner to reduce the amount of cooling required by the cooling coils, and water chilling unit energy consumption for generating chilled water is greatly reduced. Furthermore, the same amount of air is exhausted from the hot aisle as is introduced from outside.



dP – Deep pressure
H – Humidity
T – Temperature

Figure B.3 – Outline of an outdoor air cooling system

B.1.2.2 Control system and operating status

Figure B.4 shows the operation control method and trends in the status of the air with outdoor air cooling. During the intermediate period, and winter, low-temperature air (2) is introduced into the air conditioner, mixed (3) with return air (1) in the room, and air cooled and humidified by a cooling coil and an evaporative humidifier and supplied to the room (4). When the temperature of the humidified air is lower than that of the supplied air, an electric heater is used to heat the air to the specified temperature (5) to prevent condensation.

Large amounts of ICT equipment are commonly installed in the room, and temperature and humidity are strictly controlled to prevent faults in, and deterioration of, equipment. With this method, the amount of outdoor air introduced is controlled to ensure that the low-temperature air supplied to the room is of the specified humidity. Furthermore, to ensure that the supplied air reaches the specified temperature, an electric heater is employed as necessary to heat the air before being supplied to the air conditioner. When temperature and humidity conditions are such that energy conservation through the introduction of outdoor air is not possible, the outdoor air intake duct is closed according to the measured outdoor air enthalpy value, and operation is the same as for conventional air conditioning. Furthermore, in order to introduce the large volumes of outdoor air required, the volume of air passed through the exhaust fan is controlled to ensure that air pressure in the room reaches the specified value.

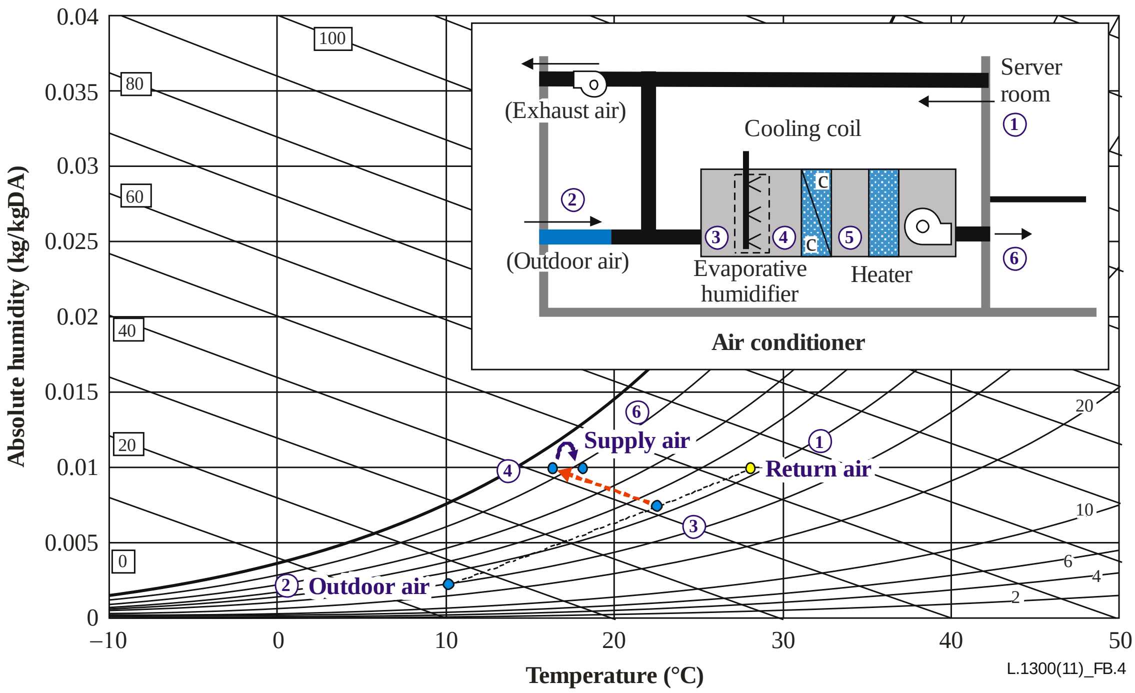


Figure B.4 – Air status in an outdoor air evaporative cooling system

B.1.2.3 Caution

With outdoor cooling, the status of the outdoor air is measured to determine whether or not outdoor air can be introduced, and control the operation mode. The operation mode changes frequently with changes in the status of the outdoor air, with the possibility of a deterioration in the ability to control the indoor environment. The control system is designed to minimize these frequent changes in the operation mode, and thus achieve stable environmental control. Furthermore, in regions where outdoor air temperature is low, low-temperature air and hot air are mixed and supplied to the room, and a design to prevent temperature irregularities and reduced temperatures is necessary.

With this method, low-temperature external air is introduced directly for cooling, thus reducing heat source power, however blower power is increased by installation of indoor discharge fans and increased ventilation resistance of outdoor air intake ducts. In order to determine the energy conservation within the entire system, it is important to introduce an operation control system able to determine the difference between the reductions in heat source power and blower power.

B.1.3 Evaporative cooling system

B.1.3.1 Air conditioning system outline

Figure B.5 shows the configuration of the evaporative cooling system. As with a conventional system, evaporative cooling employs floor supply air conditioners to supply cold air to the room. Furthermore, the equipment is made up of an evaporative cooling unit comprising an evaporative cooler to cool return air passed from the room to the air conditioner with outdoor cold air, and an indirect sensible heat exchanger, an outdoor air fan passing outdoor air through the evaporative cooling unit, and a circulation fan passing air through the evaporative cooling unit.

A large number of server devices are installed in server racks on the raised floor in the room, arranged in a regular pattern alternately facing the cold aisle (towards which the server device air inlets are directed) and the hot aisle (towards which the exhausts are directed). The high-temperature interior air discharged from the hot aisle into the space at the top of the room is drawn in from the top of the floor supply air conditioners, dehumidified and cooled to specifications using the cooling coils in the air conditioner, and supplied to the under-floor chamber. Part of the air circulated in the air conditioner from the hot aisle is introduced to the evaporative cooling unit. Similarly, outdoor air is introduced into the evaporative cooling unit, and outdoor air humidified in the evaporative cooler, and the resulting cooled air and return air exchange heat indirectly so that humidity remains unchanged while the temperature is reduced. Thus, the interior return air cooled with the latent heat of evaporation of water is mixed with interior return air circulated directly in the air conditioner, dehumidified and cooled to the specified temperature using chilled water in the cooling coils in the air conditioner, and supplied to the under-floor chamber.

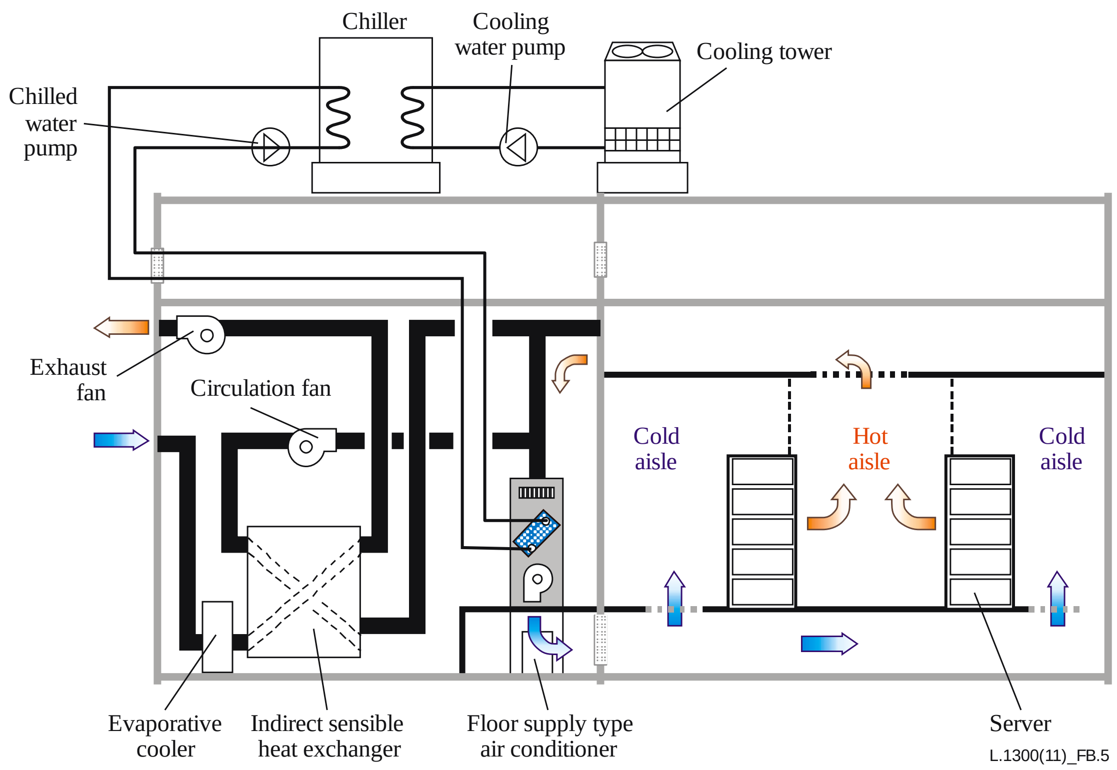


Figure B.5 – Outline of an evaporative cooling system

B.1.3.2 Control system and operating status

Figure B.6 shows the trend in the status of the air with this method. With the evaporative cooling method, the intermediate period and winter low-temperature outdoor air (5) is humidified with the evaporative cooler in the evaporative cooling unit, cooled further (6), heat exchanged indirectly with the interior return air (1) in the sensible heat exchanger, and the interior return air cooled (2). The cooled interior return air (2) is mixed (3) with the circulated interior return air, cooled (4) to the required temperature with the cooling coils in the air conditioner, and supplied to the room. Here, depending on the outdoor air conditions, the interior return air shall be dehumidified at the heat exchanger because of the low temperature of outdoor air. In this case, the evaporative humidifier is controlled by following measured outdoor air conditions. Also, under outdoor air conditions of temperature and humidity in which the cooling effect is reduced and energy conservation cannot be expected, the exhaust fan and circulation fan are halted and ducts are switched to prevent the waste of electric power.

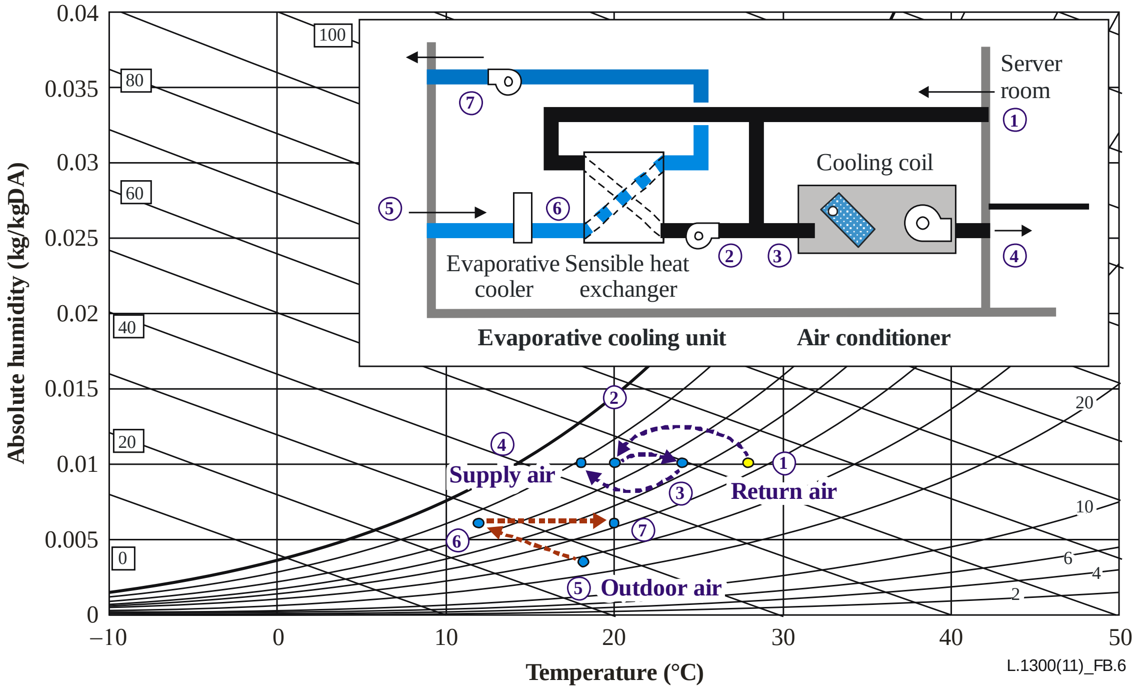


Figure B.6 – Air status in an evaporative cooling system

B.1.3.3 Caution

With the evaporative cooling method, the low-temperature outdoor air is humidified in the evaporative cooler to further cool its temperature. However, under conditions in which the outdoor air wet-bulb temperature is 0°C or lower, water used to humidify the air in the evaporative cooler may freeze. To prevent such freezing, control is implemented to prevent humidification, and air is passed through the equipment, in response to outdoor air conditions. Similarly, in the sensible heat exchanger, when the temperature of the outdoor air is low, it is possible that return air may be dehumidified in the sensible heat exchanger, and a method of control must be implemented to prevent dehumidification.

The evaporative cooling method uses cooling by the outdoor air to reduce the power required by the chilling unit. However, fan power required to pass outdoor air or return air through the evaporative cooling unit is increased. In order to determine the energy conservation within the entire system, it is important to introduce an operation control system able to determine the difference between the reductions in chilling system and distribution power, such as fans etc.

B.1.4 Spot cooling with a conventional air conditioning system

B.1.4.1 Air conditioning system outline

Figure B.7 shows the configuration of the spot cooling system used for natural circulation of the refrigerant. The combined spot cooling method and typical air conditioning method, and the spot cooling method alone, are possible for cooling. However, a system was configured using only the spot cooling method.

A large number of server racks incorporating server devices are installed on the free access floor in the room, and are arranged alternately facing the cold aisle (towards which the server rack air inlets are directed) and the hot aisle (towards which the exhausts are directed).

With the spot cooling method, a spot cooling unit cooling the air in the hot aisle and circulating it in the cold aisle, and a water-cooled condenser using chilled water to condense refrigerant gas evaporated with the spot cooling units, are installed. Suspended spot cooling units employing natural circulation of refrigerant are installed in the space between the server rack and the ceiling. These units draw in the high-temperature return air discharged from the hot aisle into the space above the room, cool the return air in the room to the specified temperature by evaporating the refrigerant in the cooling coils in the cooling units, and supply it to the cold aisle. The refrigerant evaporated in the cooling coils is circulated naturally using the liquid gas density difference and circulates through the water-cooled condenser naturally to transport heat to the exterior.

With this method, the spot cooling units cool the air locally, and are thus effective in preventing hot spots. Furthermore, by locally handling the entire amount of heat generated in the room, the blowers supplying large volumes of air to the entire room, as with the typical air conditioning method, are substituted by a small fan for localized air circulation, and a large reduction in heat transport power is possible.

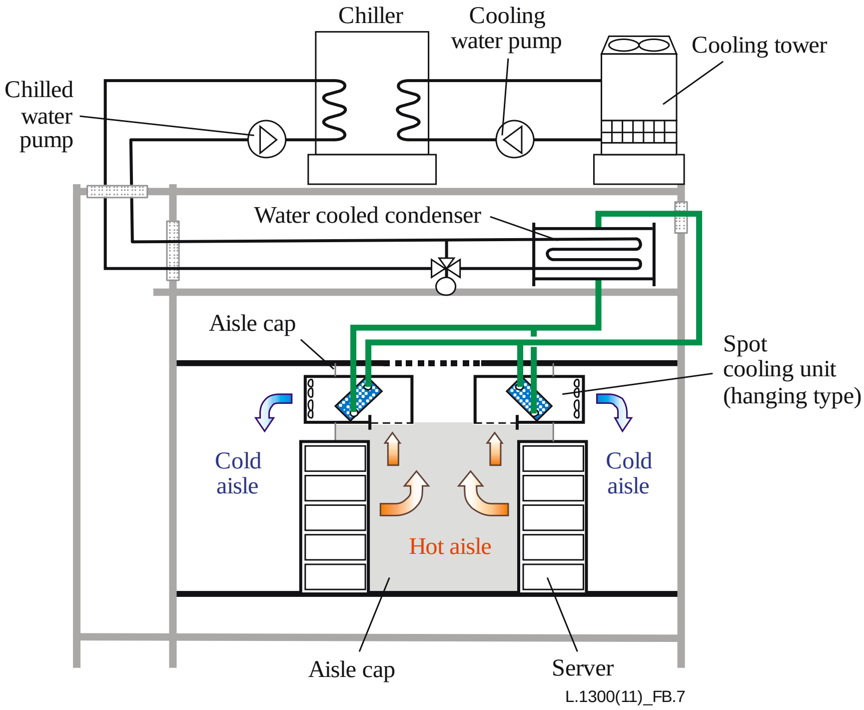


Figure B.7 – Outline of a spot cooling system

Figure B.8 shows an outline of the natural refrigerant circulation method. The high-temperature exhaust from the server rack is passed through the cooling coils by a small fan in the spot cooling unit. The refrigerant in the cooling coils absorbs heat from the high-temperature exhaust air and evaporates the refrigerant. The density of the gas is reduced, and it therefore circulates through the water-cooled condenser installed above the coils. In the water-cooled condenser, the refrigerant is condensed to a liquid by the chilled water, and falls under gravity and thus circulates through the cooling coils. This natural circulation of the refrigerant permits heat transport without motive power.

Heat generated in the server rack is transported to the exterior by the air and refrigerant. With this method, the refrigerant is transported without motive power using natural circulation, and the air is circulated locally, so that heat transport is possible with very low blower power. This permits a large reduction in heat transport power in comparison to the typical air conditioning method.

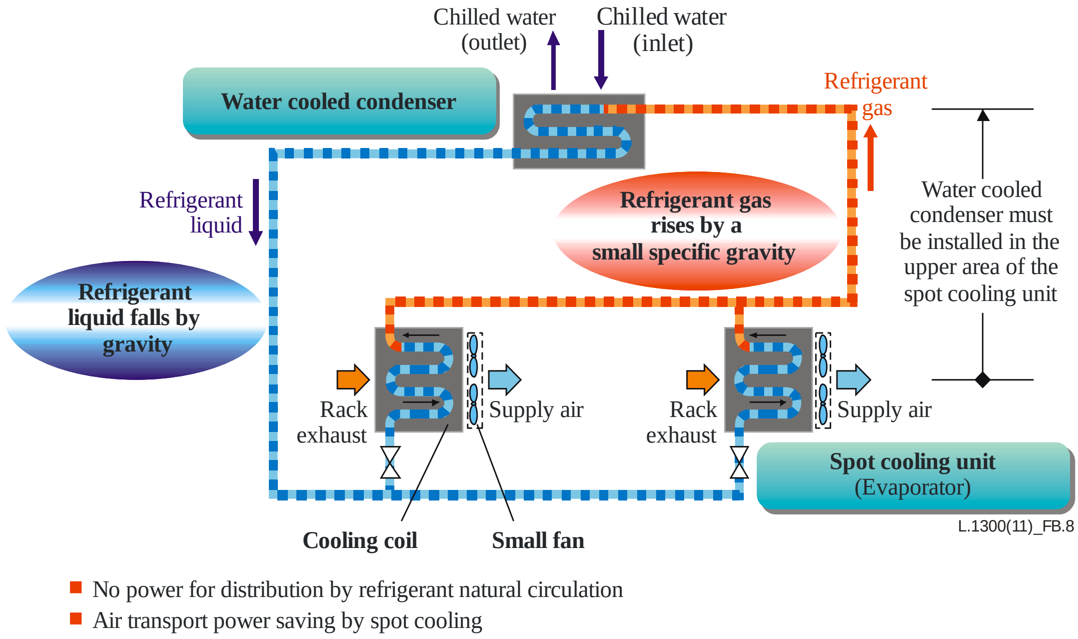


Figure B.8 – Principle of a refrigerant natural circulation system

B.1.4.2 Control system and operating status

With the spot cooling method, the refrigerant evaporated in the cooling units is condensed in the water-cooled condensers, and the flow of chilled water through the water-cooled condensers is controlled to maintain the refrigerant at the specified temperature. Furthermore, the high-temperature air in the hot aisle is drawn in, and the flow of refrigerant controlled to ensure that the cooling unit outlet air reaches the specified temperature.

B.1.4.3 Caution

This method involves a system in which multiple spot cooling units are installed at the top of the server racks, and differs from conventional air conditioning supplying chilled air to the room from the floor. Since the cooling unit layout affects the thermal environment, it is important to have an appropriate layout plan for the server rack arrangement and load distribution at the planning stage. The exhaust air from the server racks is introduced efficiently to the cooling units, thus improving the thermal environment, and highly efficient operation with improved cooling performance of the cooling unit is possible. Methods of preventing air dispersion in the hot aisle are therefore effective.

B.2 Selection of cooling systems suited to data centre specifications

When selecting air conditioning systems for data centres, improved efficiency of ICT equipment, and progress in cloud computing, require high levels of space efficiency to permit the installation of large amounts of ICT equipment in a limited space. Furthermore, from the point of view of preventing global warming and controlling running costs, high levels of energy conservation are required to increase air conditioning energy efficiency, and control energy consumption. The factors and effective air conditioning methods to ensure space efficiency and energy efficiency of the various air conditioning methods were therefore investigated.

B.2.1 Data centre power density and cooling methods with high space efficiency

Energy conservation is naturally a matter of importance in the construction of urban data centres. However, space efficiency in terms of the maximum number of server racks able to be installed is also important. With conventional air conditioning, outdoor air cooling, and evaporative cooling systems, air conditioning equipment is installed in the room to circulate air heated by the ICT equipment throughout the entire room. With these methods, increased power density of a data centre requires higher cooling performance and larger dimensions to the air conditioning equipment, with consequently greater floor area required for installation of air conditioning equipment. Here, power density indicates energy consumption of ICT equipment per unit floor area of data centre. On the other hand, with the spot cooling method using natural circulation of the refrigerant, spot cooling units are suspended from the ceiling above the server racks. Use of this space eliminates the need for floor area to accommodate a conventional floor supply air conditioning unit, and ensures that it is possible to accommodate an increased number of cooling units when power density increases, and thus allows a major reduction in the carbon footprint of cooling equipment. Furthermore, with conventional methods, cold air is supplied throughout the floor chamber, and increased floor chamber height is therefore required for cold air supply. With this method, under-floor chambers are not required, and floor height can be reduced.

B.2.2 Outdoor air conditions and high energy-efficiency cooling methods

Energy consumption of air conditioning systems is comprised of power consumed by water chilling units employed in the production of chilled water required to cool air, and power consumed by heat transport equipment such as fans and pumps used to transport heat inside and outside the room.

Outdoor air cooling systems and evaporative cooling systems are able to make effective use of low-temperature outdoor air, and permit a reduction in heat source power. However, the ventilation resistance of evaporative cooling units, air transport ducts, and under-floor chambers is considerable, and blower power is therefore increased. In cold regions, when outdoor air wet-bulb temperature is low, chilling system energy consumption is therefore considerably reduced, ensuring the most energy-efficient air conditioning method.

On the other hand, the spot cooling method employs the natural circulation of the refrigerant, and interior cooling is therefore possible by localized air circulation, so that blower power required for air circulation is greatly reduced in comparison with the typical air conditioning and outdoor air cooling, evaporative cooling methods. Furthermore, the spot cooling method employs the natural circulation of refrigerant, permitting heat transport without motive power, so that heat transport power can be greatly reduced in comparison with the typical air conditioning method. With this method, energy-efficiency is improved through reduced transport power, even outside cold regions, thus ensuring the most energy-efficient air conditioning method in temperate regions.

Based on this comparison, for the construction of data centres with a high power density, located in a temperate region, space efficiency of suspended spot cooling units employing the spot cooling method with natural circulation of refrigerant is highest, air conditioning efficiency is high, and spot cooling is therefore the most appropriate air conditioning method for high-power density data centres.

B.2.3 Further efficiency improvements

In addition to the large reduction in transport power through use of this spot cooling method, it is also effective to consider the reduction in heat source power (which accounts for a large proportion of cooling system energy), when determining the efficiency of a cooling system. In cold areas, heat source power can be reduced through effective use of low-temperature exterior air to produce chilled water with the free-clean method, and with large, high-efficiency refrigeration units.

Appropriate control of a cooling system for the amount of heat generated is effective in reducing its power consumption. Methods to control the operation of air conditioners in conjunction with the power information for ICT devices, and methods of controlling optimized operation of the entire cooling system while monitoring the energy consumption of the entire system, are effective.

Annex C

Practical solutions for correcting airflow direction for equipment

(This annex forms an integral part of this Recommendation.)

In the case where the airflow can be in different directions for equipment mounted in a rack/cabinet, it is necessary to install a plate or duct to achieve an efficient solution. This annex provides two requirements for this duct/plate installation and design.

C.1 Requirements for correcting airflow direction for equipment

C.1.1 Design

The shape of the plate or duct should be designed so as not to decrease the intake and exhaust capacity of the equipment once it is installed.

C.1.2 Description in the installation manual of the equipment

A description should be added to the installation manual of such equipment so that practical solutions can be easily implemented.

Annex D

Minimum data set for controlling data centre equipment for energy saving management in data centres

(This annex forms an integral part of this Recommendation.)

Table D.1 below, lists the minimum data set necessary for evaluating energy efficiency and for controlling data centre equipment in order to save power in data centres. The rationale for this minimum data set is described in [b-ITU-T DC-MDS]. "G" and "S" in the "Data flow direction" column respectively represent data that should be obtained from the equipment and data that should be set according to the equipment.

Table D.1 – Minimum data set controlling data centre equipment for energy saving management in data centres

Type of equipment		Data set	Data flow direction
ICT equipment		Input power	G
		Inlet temperature	G
		Power state (shutdown, sleep, active)	G
		Power state (shutdown, activate)	S
Facility equipment	Cooling equipment	Input power	G
		Inlet temperature of indoor unit	G
		Outside temperature	G
		On-off state	G/S
		Amount of refrigerant supplied from an indoor unit to ICT equipment	G/S(1)
		Temperature of refrigerant supplied from an indoor unit to ICT equipment	G/S(1)
	Power equipment (UPS, rectifier, PDU)	Output power	G
		Input power	G

(1) If data cannot be obtained from the equipment, data can be estimated by using alternative data which can be obtained from the equipment and static data of the equipment. An example of estimation is shown in [b-ITU-T DC-MDS].

Annex E

Verification experiments related to increase of efficiency of air-conditioning and control technologies at a data centre

(This annex forms an integral part of this Recommendation.)

E.1 Overview

As ICT devices such as servers are integrated into high-density data centres, energy consumption per unit floor space is high, and large amounts of energy are needed for air-conditioning to cool these devices. The power consumption of ICT devices and the power consumption of air-conditioning equipment are closely related to each other, and to reduce the power consumption in the entire data centre, optimum control of ICT devices and air-conditioning equipment as a linked system is effective. Major reductions of power consumption can be realized by combining ICT load consolidation control, which optimizes ICT device operating states in conjunction with computational load (workload), with ICT linked air-conditioning control, which controls air-conditioning in coordination with the operating state of the ICT devices. In addition, by applying these controls to multiple data centres, total power consumption can be decreased by remote load distribution, which allocates the workload in appropriate ratios.

The basic line of thought of ICT load consolidation control, ICT linked air-conditioning control, and remote load distribution is to build a model that represents power consumption of the whole data centre and to decide control parameters of the model to minimize the total power consumption. Construction of a model related to energy consumption in a data centre is described in clause E.2, a control method that minimizes energy consumption on the basis of the model is described in clause E.3, and a control system that executes minimization of energy consumption is described in clause E.4.

E.2 Data centre energy model

E.2.1 Construction of a model of the whole data centre

Diversified equipment such as servers, network switches, storage devices, air-conditioning equipment, power supply devices and lighting fixtures are used in a data centre and are closely related to each other. By constructing a model of electric power characteristics and energy flow of each one of these devices, it becomes possible to visualize, manage and optimally control the state of energy consumption in the data centre. Figure E.1 shows an example of energy flow in a typical data centre.

Furthermore, the energy consumption in a data centre is also related to external conditions such as workload and open air temperature. Figure E.2 shows typical external conditions.

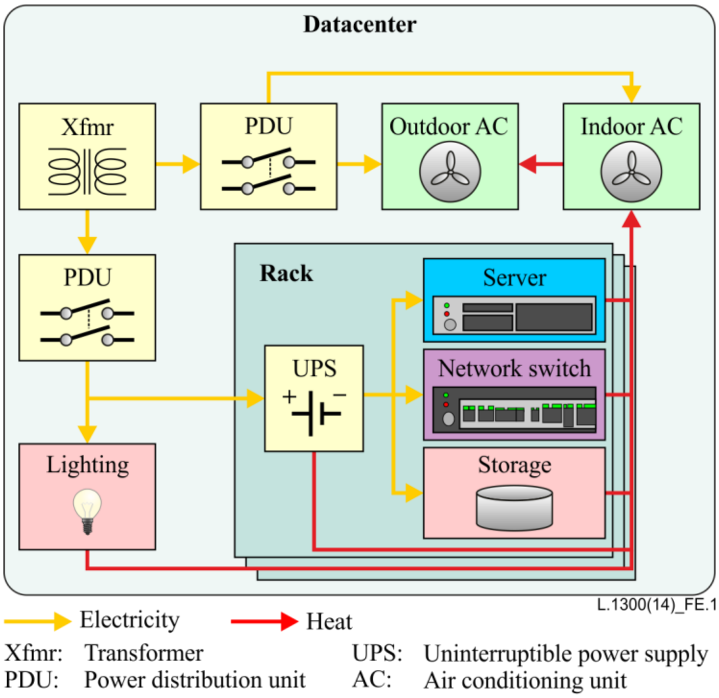


Figure E.1 – Example of energy flow of data centre

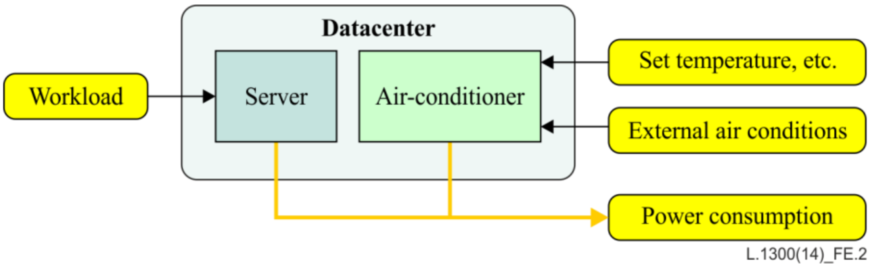


Figure E.2 – Example of external conditions related to power consumption

E.2.2 Construction of a server model

A power consumption model of a server is composed of the cooling fan portion and the system board portion (including CPU, memory, hard disk drive (HDD) and PSU). Other than the cooling fan, the power consumption of each one of these portions depends on the interior server temperature and workload as shown in Figure E.3. The power consumption characteristics of the system board can be estimated from data of the Standard Performance Evaluation Corporation (SPEC). Figure E.4 shows typical power consumption characteristics of a system board. The power consumption of the fan, on the other hand, is determined by the fan speed, which can be estimated from the product specification. The fan speed is controlled by the temperature inside the server and inlet air temperature as shown in Figure E.5.

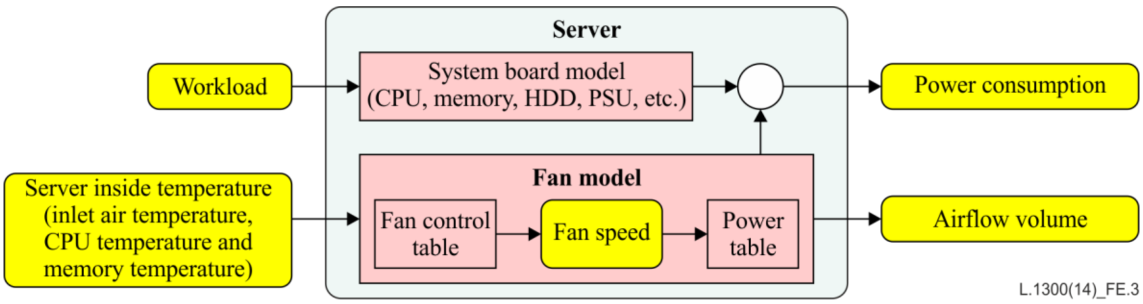
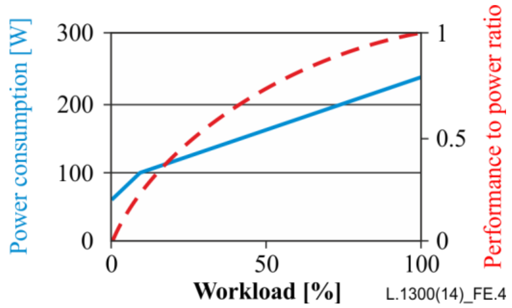


Figure E.3 – Example of server model



(Blue line: Power consumption; Red dotted line: Performance to power ratio (100% workload is expressed as 1))

Figure E.4 – Example of power consumption characteristic of system board

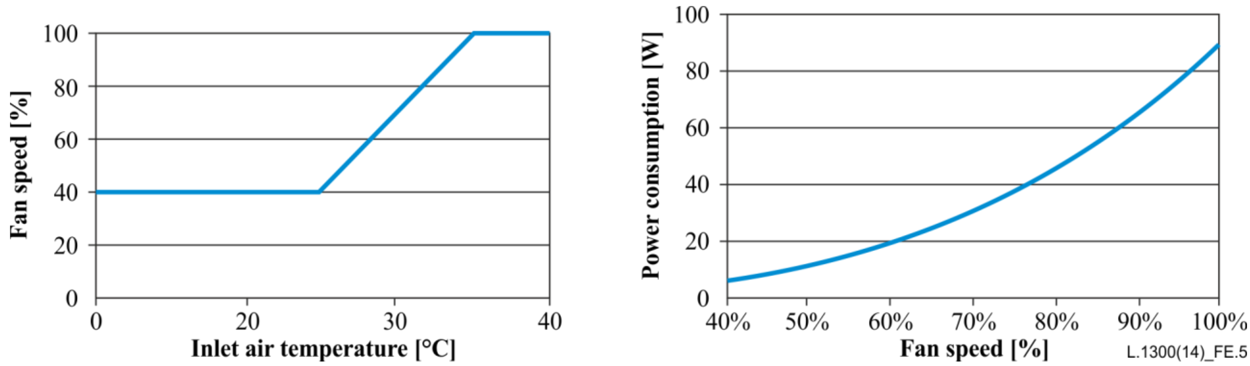


Figure E.5 – Example of fan characteristics

(Left: Fan control table; Right: Power table (Maximum fan speed is expressed as 100%))

E.2.3 Construction of an air-conditioner model

It is considered that the electric energy consumed by ICT devices is entirely converted into heat, and that the heat generated out of ICT devices is entirely cooled with an air-conditioner. For the power consumption of an air-conditioner related to cooling, a model can be constructed as shown in Figure E.6. The power consumption characteristics of an air-conditioner largely vary by the composition and type of the air-conditioner. But typical power consumption characteristics of an air-conditioner outdoor unit that is composed of a fan, heat exchanger and compressor are shown in Figure E.7 as estimated from the product specification.

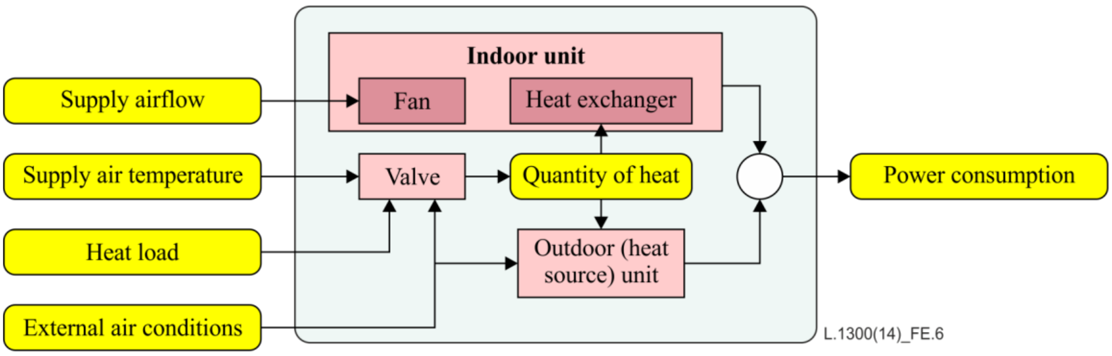


Figure E.6 – Example of air-conditioner model

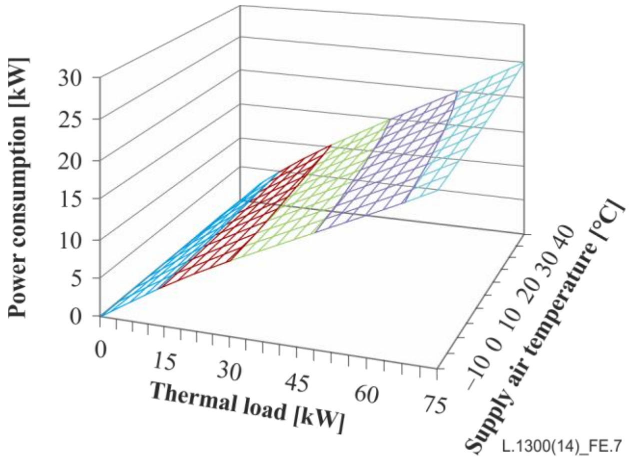


Figure E.7 – Example of relation between thermal load (cooling calorific value), open air temperature and air-conditioner power consumption

E.2.4 Construction of a power supply system model

With power supply system devices such as PDUs, UPSs and power cables, the power loss varies by the magnitude of the electric power, and therefore, a model of this relation can be constructed (see Figure E.8). The power consumption of the whole data centre can be calculated by integrating the power losses in power supply systems for the various power paths in the data centre, after calculating the power consumption of ICT devices and air-conditioning equipment.

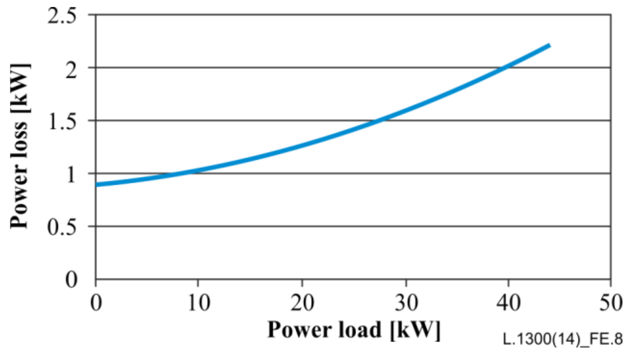


Figure E.8 – Example of UPS's power loss model

E.3 Control method to minimize energy consumption

The workload in a data centre varies with the time of day and with the season. Calculation of resource distribution and energy used for air conditioning on a daily and seasonal basis is necessary for effectively reducing overall power consumption.

By using an energy model, it becomes possible to obtain the operating state of ICT devices and air-conditioning equipment for minimizing the energy consumption in the whole data centre against the workload.

E.3.1 Minimization of energy consumption by ICT devices

Higher server workload results in better server energy efficiency from the power consumption characteristics of servers as shown in Figure E.4. While the workload is low, wasteful power consumption can be eliminated by concentrating the workload to partial servers to increase the workload per server and by turning off the power for the servers, to which no workload is allocated.

W_s is the sum of the system board power consumption of all servers. The calculation to minimize W_s can be formulated as follows:

minimize $W_s = \sum M_{si}(x_{si})$

subject to $\sum x_{si} = x_{DC}$

Where; M_{si} and x_{si} represent system board power consumption characteristics and workload respectively of the i-th server. Furthermore, x_{DC} represents the gross workload input to the data centre. Regarding power consumption characteristics M_{si} of the system board, the server power is turned off and the power consumption is reduced to zero.

As a point to consider, in case the cooling efficiency varies by the server location, it will be better if the load is concentrated to servers located in positions where they can be cooled with small amounts of energy. This minimization is optimized by using sensing data such as temperature or thermo-fluid simulation.

E.3.2 Minimization of air-conditioner energy consumption

With a conventional air-conditioner, it is usual that the air-conditioner is run in the state where the air-conditioner supply temperature and airflow, which are needed for the server's maximum heat value and maximum fan airflow, are set and fixed. On the contrary, for a data centre, the air-conditioner supply temperature and airflow are set to permit cooling with minimum energy as matched with heat value W_s that corresponds to the workload.

Figure E.9 shows the relation between elements related to the energy consumption of an air-conditioner and servers. Where the air-conditioner power consumption is expressed as W_c and the server fan power consumption is expressed as W_f, calculation for minimization of the total power consumption related to the air-conditioner is as follows:

minimize $W_c + W_f$

where $W_c = M_c(T_c, Q_c, W_{sf}, T_e)$

$W_f = \sum M_{fi}(x_{si})$

$W_{sf} = W_s + W_f$

Where; M_c represents air-conditioner power consumption characteristics, which is a function of supply temperature T_c, supply airflow Q_c, thermal load W_{sf} and open air temperature T_e. Furthermore, M_{fi} and T_{si} represent fan power consumption characteristics and inlet air temperature respectively of the i-th server.

As a point to consider, where the room is divided into a cold aisle and a hot aisle by a containment measure, reverse flow will occur unless the air-conditioner airflow is larger than the server airflow, and the air-conditioner airflow is restricted. Furthermore, air-conditioner supply temperature T_c and server inlet air temperature T_{si} are similar.

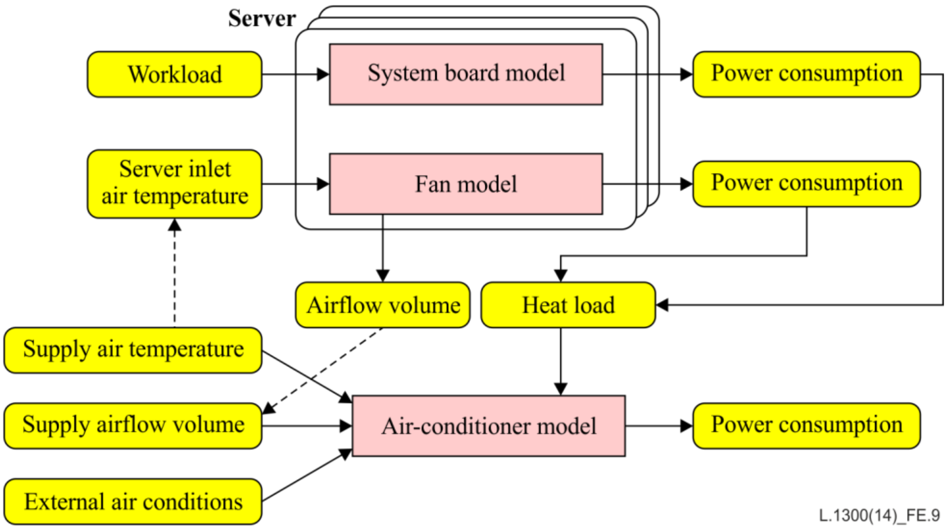


Figure E.9 – Example of power consumption characteristics related to an air-conditioner and servers

E.3.3 Minimization of energy consumption between multiple data centres

If the workload can be distributed to multiple data centres, then it is possible to minimize the total data centre power consumption by optimizing the workload distribution to data centres.

The calculation for minimizing W_A, the total power consumption by all data centres against workload x_A is as follows:

minimize $W_A = \sum M_{DCi}\,(x_{DCi}, T_{ei})$

subject to $\sum x_{DCi} = x_A$

Where; M_{DCi}, x_{DCi} and T_{ei} represent power consumption characteristics, workload and open air conditions respectively of the i-th data centre. Open air conditions are particularly of large influence when an air-conditioning system using open air is used as the air-conditioner. The optimum distribution ratio to the workload can be determined based on what was described above.

E.4 Control system configuration

An example of a control system configuration for automatically keeping the state of minimum energy against variation of workload and open air temperature is shown in Figure E.10.

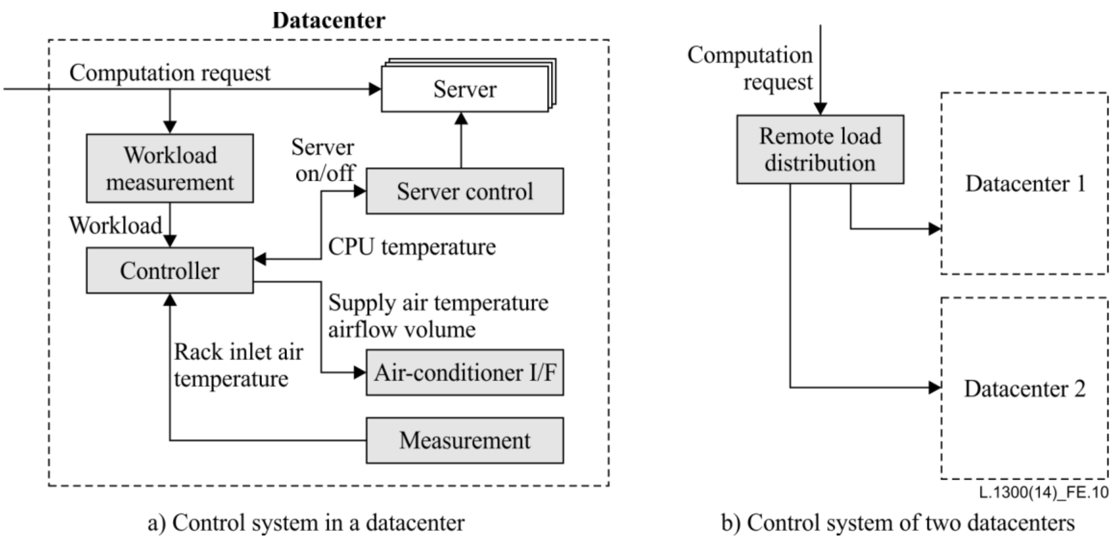


Figure E.10 – Example of control system configuration

E.4.1 Controller unit

This unit executes management of the data centre model and energy minimizing calculation. Two controls are available. One is load consolidation control that executes ICT device energy minimizing calculation, and the other is ICT linked air-conditioning control that executes the air-conditioning equipment energy minimizing calculation.

E.4.1.1 Load consolidation control

Upon input of the present workload, the workload allocated to each server by the energy minimizing calculation described in clause E.3.1 is calculated. To a server with no (zero) workload, a power off command is sent, and for allocating workload to a server that has been powered off, a power on command is sent.

E.4.1.2 ICT linked air-conditioning control

Upon input of the server operating state, temperature information and so forth, the air-conditioner supply temperature and airflow are calculated by the energy minimizing calculation described in clause E.3.2, and they are output to the air-conditioner. As a result of the energy minimizing calculation, the energy consumption of ICT devices is minimized. Server on/off commands and commands to control the air-conditioner are sent.

E.4.2 Workload measurement unit

This unit measures in real time, the value of the workload requested of the data centre. It is recommended that measurement is taken with a device that centrally controls the traffic in the data centre such as a network server.

E.4.3 Server control unit

This unit controls the workload to servers that are controlled from the control calculation unit as well as issues server power On/Off control. Server virtualization techniques are used as the method to control workload consolidation. This unit will output the server's operating states, such as CPU temperature, to the control calculation unit.

E.4.4 Air-conditioner I/F

An interface (I/F) that permits changes in the air conditioner temperature setting and other parameters from a remote location. The air-conditioner set temperature and airflow are input from the control calculation unit by the use of this interface.

E.4.5 Measurement unit (sensor)

This unit measures the rack inlet air temperature and open air temperature by sensors, collects and controls these measured values for a fixed period. It sends the measured values to the control calculation unit in correspondence to a request from the control calculation unit.

E.4.6 Remote load distribution

Upon input of the total workload to data centres, the workload for each data centre is allocated on the basis of results of the energy minimizing calculation described in clause E.3.3.

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