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Information technology — Data centres — Practices for resource-efficient data centres

Technologies de l'information — Centres de données — Pratiques pour les centres de données économes en ressources

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Foreword

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

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Introduction

Data centres are essential to the provision of information technology (IT) services and can play an important role in the conservation of resources. However, they can also consume a considerable amount of resources if mis-managed and thus, it is critical to utilize these resources efficiently.

Resource efficiency in a data centre begins with the location (taking advantage of the external environment) and the building design to minimize energy consumption. The facilities can then implement modular extension or easily extensible space, cooling, and power according to the IT services provided and co-location situation.

Once data centres are constructed and equipped with all the necessary facilities, it is important to collect and monitor operational data. Based on the information obtained, it is possible to determine which elements utilize resources least efficiently and assess how to improve the performance.

The performance of existing facilities can be periodically measured to determine if the original design objectives for resource efficiency are being achieved and allowing performance to be improved by replacement of equipment with better resource-efficiency characteristics.

This document provides information on available options for improving resource efficiency in data centres, with particular emphasis on operational procedures.

Information technology — Data centres — Practices for resource-efficient data centres

1 Scope

This document describes generally applicable practices for improving the resource efficiency of data centres, independent of their application(s).

This document focuses on continuous improvement processes, designs and guidelines that prioritize resource efficiency. In general, the processes and practices are technology-neutral and are independent of location.

The practices for data centre resource efficiency improvement deal with various establishment and operation aspects such as data centre planning, management, cooling, power feeding, information and communications technology (ICT) and cost aspects that are not restricted by the scope of this document.

The following items are not included in the scope of this document:

— development of key performance indicators (KPIs);

— comparability between data centre performance results;

— definition of maturity model for data centres;

— social sustainability issues.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

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

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

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

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

3.1 Terms and definitions

3.1.1
availability
ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

[SOURCE: ISO/IEC 22237-1:2021, 3.1.1]

3.1.2
computer room space
area within the data centre that accommodates the data processing, data storage and telecommunication equipment that provides the primary function of the data centre

[SOURCE: ISO/IEC 22237-1:2021, 3.1.6]

3.1.3
computer room air conditioning/computer room air handling
CRAC/CRAH
equipment that provides cooling airflow volumes into a computer room as a means of environmental control

Note 1 to entry: Other abbreviations such as CCU, DFU, RACU, UFU are sometimes used.

3.1.4
data centre
structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability

Note 1 to entry: A structure can consist of multiple buildings and/or spaces with specific functions to support the primary function.

Note 2 to entry: The boundaries of the structure or space considered the data centre which includes the information and communications technology equipment and supporting environmental controls can be defined within a larger structure or building.

[SOURCE: ISO/IEC 30134-1:2016, 3.1.4]

3.1.5
direct liquid-cooled ICT equipment
ICT equipment that is cooled by direct flow of liquid into an equipment cabinet or directly to the ICT equipment chassis to provide cooling, rather than the use of moving air

3.1.6
energy efficiency
measure of the work done (as a result of design and/or operational procedures) for a given amount of energy consumed

3.1.7
hot-aisle/cold-aisle
<system> construction of cabinets and containment intended to prevent the mixing of ICT equipment intake and exhaust air within computer room space(s)

3.1.8
information and communications technology equipment
ICT equipment
information technology (IT) and network telecommunications (NT) equipment providing data storage, processing and transport services

Note 1 to entry: This represents the “critical load” of the data centre.

3.1.9
rack
open construction, typically self-supporting and floor-mounted, for housing closures and other information technology equipment

3.1.10
resilience
capacity to withstand failure in one or more of the ICT equipment or data centre infrastructures

3.1.11
set-point
desired or target value (maximum or minimum) for a physical quantity used for control

3.1.12
virtualization
creation of a virtual version of physical ICT equipment or resource to offer a more efficient use of ICT hardware

3.2 Abbreviated terms

For the purposes of this document the following abbreviated terms apply.

ASHRAE	(formerly) American Society of Heating, Refrigeration and Air conditioning Engineers
BREEAM	Building Research Establishment Environmental Assessment Method
CMDB	configuration management database
CPU	central processing unit
CRAC	computer room air conditioning
CRAH	computer room air handling
DCIM	data centre infrastructure management
F-R-F-R	front-rear-front-rear
ICT	information and communications technology
I/O	input/output
IT	information technology
LAN	local area network
LEED	leadership in energy and environmental design
MAID	massive array of inactive disks
MLPS	multiprotocol label switching
OVP	open virtual platform
PDU	power distribution unit
PUE	power usage effectiveness
RAID	redundant array of independent disks
SLA	service level agreement
UPS	uninterruptible power supply
VLAN	virtual local area network

VPN virtual private network

VXLAN virtual extensible local area network

WUE water usage effectiveness

4 Principles

4.1 General

To operate and manage a data centre with effective usage of resources, there are many things to be considered in each phase, from design to operation. Resource efficiency in the data centre can be achieved mostly in the design and building phase. In the design and building phase of a data centre, the location selection can take advantage of the external environment, by taking into consideration building that minimizes consumption, modular extension or easily extensible space, cooling, and power, according to the IT services provided and co-location situation. As there can be a variety of forms and structures depending on the purpose of the data centre, resource efficiency technology can be suitably applied in accordance with the relevant application. In addition, it is advantageous to utilize state-of-the-art IT equipment which achieves the best practice in energy efficiency as well as performance.

Once the data centre is introduced, it is quite difficult to rebuild or reengineer it. One of the effective ways to improve the resource efficiency of existing data centres is to collect and monitor operational data in facilities in order to find inefficient equipment. In addition to infrastructure facilities such as cooling and power generation and distribution, IT equipment can also be monitored. Measured data can be analysed and processed to provide statistics and insights such as predictions of the energy consumed, and key performance indicators as introduced in the ISO/IEC 30134 series (PUE, WUE, etc). The data centre operators can find out how much the efficiency of equipment is degraded. If aging facilities are failing to achieve the initially-designed efficiency and performance, they can be properly replaced.

For a data centre to achieve resource efficiency, the aspects described in 4.2 to 4.8 need to be considered.

In the design stage, it is necessary to prevent over-investments or budget shortages due to miscalculation of IT equipment capacity growth. In addition, the design can take optimal usage of resources into account during operation after the construction of a data centre. This sub-clause describes considerations for data centre design and construction in terms of building, power, cooling, and data centre infrastructure management (DCIM) for improving resource efficiency.

For data centres that are designed and constructed with resource-efficient components, continuous maintenance activities are necessary for maintaining their efficiency. During its operations, a data centre's efficiency can be degraded due to various reasons, such as equipment aging or IT trend changes. It is thus necessary to perform maintenance and enhancement activities. The following subclauses provide best practices in effective operation for the infrastructure and IT equipment of a standalone medium/large data centre in order to maintain and enhance resource efficiency through data centre operation and management. Though other data centre types can utilize different elements of the following subclauses, some data centres will not have access or control of the infrastructure described therein. Therefore, some aspects of the following subclauses will not be applicable to other types of data centres, especially those with shared facility resources.

4.2 Data centre utilization, management and planning

It is important to develop a holistic strategy and management approach to the data centre to ensure the required availability and effective delivery of economic and environmental benefits. The following aspects can be considered.

a) General policies.

Policies can be established that apply to all aspects of the data centre and its operation. See ISO/IEC TS 22237-7.

b) Resilience level and provisioning.

Two of the most significant sources of inefficiency in data centres are the over provisioning of space, power or cooling, or the facilities being run at less than full capacity. Monolithic, as opposed to modular design of facilities also represents a significant and frequently unnecessary capital expenditure. Furthermore, as the level of resilience of the data centre increases, inefficiencies due to fixed overheads increase and this is compounded by poor utilization.

c) Involvement of organizational groups.

Ineffective communication between the disciplines working in a data centre is a major driver of inefficiency and can create issues of capacity management and reliability.

4.3 Data centre ICT equipment and services

The ICT equipment creates most of the demand for power and cooling in a data centre. Any reductions in power and cooling used by, or provisioned for, the ICT equipment will have magnified effects at the utility energy supply.

The purpose of the equipment environmental specifications in this subclause is to ensure that new equipment can operate under the wider ranges of temperature and humidity, thus allowing greater flexibility in operating temperature and humidity to the operator.

The following aspects can be considered.

a) Selection and deployment of new ICT equipment.

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

b) 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 equipment.

c) Management of existing ICT equipment and services.

It is common to focus on new services and equipment being installed into the data centre but there are also substantial opportunities to achieve energy and cost reductions from within the existing service and physical estate, for example, by decommissioning hardware no longer in use or implementing energy saving policies.

d) Data management and storage.

Storage is a major growth area in both cost and energy consumption within a data centre. It is generally recognized that a significant proportion of the data stored is unnecessary, duplicated or does not require high performance access.

Some sectors have a particular issue due to very broad and non-specific data retention directives from governments or regulating bodies which can cause large volumes of data to be unnecessarily heavily protected and archived.

See Clause 5 for further information.

4.4 Data centre cooling equipment

A major part of the facility infrastructure is the cooling system.

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

The following aspects can be considered.

a) Airflow management and design.

   The objective of airflow management is to circulate only the amount of air through the data centre that is necessary to remove the heat created by the ICT equipment (i.e. no air circulates unnecessarily).

   Poor airflow management often results in attempts to compensate by reducing air supply temperatures or supplying excessive air volumes, which have an energy penalty.

   Improving airflow management will deliver more uniform ICT equipment inlet temperatures. This is a prerequisite to increasing temperature set-points and reducing airflow volumes which enable reductions in energy consumption without the risk of equipment overheating.

b) Cooling management.

   Data centre is not a static system and cooling systems can be automatically and dynamically tuned in response to fluctuations in thermal load.

c) Temperature and humidity settings.

   Operating overly restricted environmental controls (in particular, excessively cooled computer rooms) results in an energy penalty.

   Widening the set-point range for temperature and humidity can reduce energy consumption. When reviewing environmental management issues it is suggested that expert advice be sought before changing the environmental range for the facility (e.g. before set-points are changed) in order to avoid risks to operational integrity.

d) Selection of cooling system.

   The cooling system typically represents a major part of the energy consumed in the data centre in addition to the critical ICT load. This is also the area with the greatest variation in technologies.

   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.

   2) High efficiency cooling system.

      When refrigeration is used as part of the cooling system design, a high efficiency cooling system can be selected. Designs can operate efficiently at system level and employ efficient components. This demands an effective control strategy which optimizes efficient operation, without compromising reliability. Even in designs where the refrigeration is expected to run for very few hours per year, the cost savings in infrastructure electrical capacity and utility power availability or peak demand fees justify the selection of high efficiency equipment.

e) Computer room air conditioning/computer room Air handling (CRAC/CRAH) equipment.

These are major components of most cooling systems within the computer room; they are frequently unable to provide efficient operation in older facilities.

f) Reuse 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 reuse of this energy which could offer economic and environmental benefit. As ICT equipment utilization is increased through consolidation and virtualization, the exhaust temperature is likely to increase as a result, which will provide greater opportunity for waste heat to be re-used. Direct liquid-cooled ICT equipment is likely to provide new opportunities to use data centre waste heat.

Design guidelines are provided in ISO/IEC 22237-4 and operational guidelines are detailed in ISO/IEC TS 22237-7.

4.5 Data centre power equipment

Another major part of the facility infrastructure is the power conditioning and delivery system. This normally includes uninterruptible power supplies (UPS), power distribution units (PDU), cabling and can also include other equipment, e.g. backup generators and static switches.

The following aspects can be considered:

a) Selection and deployment of new power equipment.

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

b) Management of existing power equipment.

Design guidelines are provided in ISO/IEC 22237-3 and operational guidelines are detailed in ISO/IEC TS 22237-7.

4.6 Other data centre equipment

Data centre spaces contain equipment other than that of 4.3, 4.4 and 4.5. Practices can be employed to minimize energy consumption and/or improve energy efficiency of such equipment and can be optimized based on relevant building standards, such as relevant EU standards, LEED, BREEAM, etc.

Operational guidelines are detailed in ISO/IEC TS 22237-7.

4.7 Data centre building

The location and physical layout of the data centre premises is important to achieving flexibility and efficiency; see ISO/IEC TS 22237-2.

The following aspects can be considered:

a) Building physical layout.

The physical layout of the building can present fundamental constraints on the applicable technologies and achievable efficiencies (e.g. technologies such as fresh air cooling require significant space for equipment and distribution systems that might not be available in an existing building).

b) Building geographic location.

The geographic location of a data centre can impact achievable efficiency, primarily through the influence of external climate.

c) Water sources.

Data centres can potentially use a significant quantity of water to provide environmental control. The water stress of the region, the type and source of water can potentially affect data centre design and energy consumption.

Design guidelines are detailed in ISO/IEC TS 22237-2.

4.8 Data centre monitoring

The development and implementation of a monitoring and reporting strategy is key to managing the efficiency of a data centre.

The following aspects can be considered:

a) Energy consumption and environmental measurement.

Many data centres currently have little or no monitoring of energy consumption or environmental conditions; some do not have separate utility metering or billing.

The ability to measure energy use and factors impacting energy use is a prerequisite to identifying and justifying improvements. It can also be noted that measurement and reporting of a parameter can include alarms and exceptions if that parameter passes outside of the acceptable or expected operating range.

b) Energy consumption and environmental data collection and logging.

Once data on energy consumption and environmental (temperature and humidity) conditions is available through the installation of measurement devices, it can be collected and logged.

c) Energy consumption and environmental reporting:

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

d) ICT reporting:

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

See Clause 6 for further information.

4.9 Summary

Recently raised issues on the acceleration of the digital transformation with big data, cloud computing, and Internet of Things (IoT) playing an important role, have changed the design and construction of data centres. Data centre infrastructure can be designed for reliable and efficient IT services.

Data centres are complex, as it is intended for use in implementing technical innovations and organizational changes.

Data centres differ in sizes, from a small room with a rack to industrial scale sites with energy consumption of several hundred MW. Regardless of whether it is a small, medium or large company, practically every business, service organization or public institution requires a functioning information technology system. A data centre can be a stand-alone unit or be part of a distributed network of data centres. They can also be categorized according to physical size (from edge and enterprise data centres to cloud and co-location data centres to hyperscale data centres), rack density or energy consumption, for example.

Irrespective of the size of the data centre, the infrastructure covers the following areas:

— racks and housings for server, storage and network components,

— power conditioning, distribution and back-up,

— cooling and cooling transport and distribution,

— monitoring and remote management using hardware and software components,

— security and safety systems.

5 ICT equipment and services

5.1 IT system

Although IT systems vary by data centre, IT systems mostly account for at least 60 % of overall power consumption. The cooling equipment used to cool down the IT system also consumes a significant amount of power. This subclause presents guidelines for efficient management of the IT system with minimal power consumption.

5.2 Server and storage

5.2.1 IT system integration and virtualization

Reducing the amount of IT equipment has a direct effect on energy consumption. A server consumes a certain level of power even when it is in idle mode waiting for workloads. Generally, when the workload is 60 %, the power consumption increases up to 20 % to 30 % compared to its idle state. Power consumption can be significantly reduced by decreasing the number of physical IT systems through the consolidation of servers that routinely operate at low utilization levels.

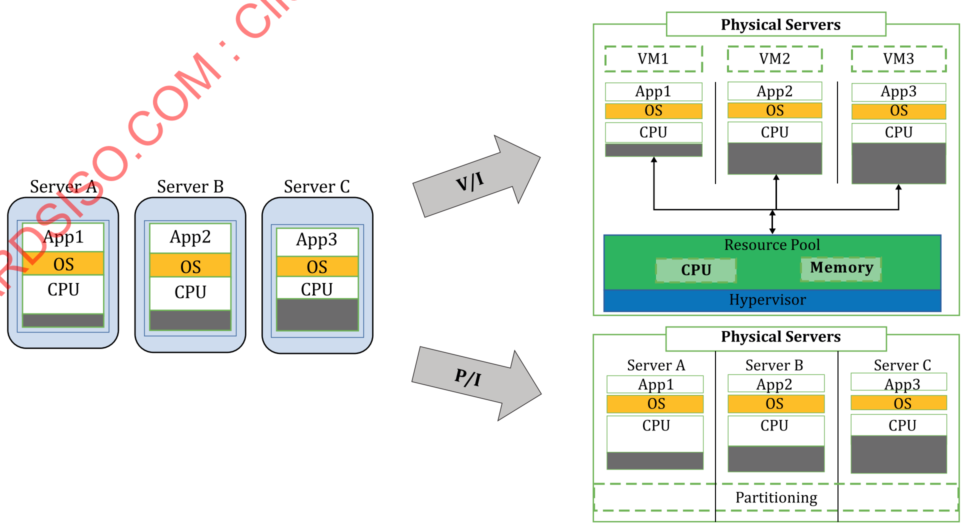

Figure 1 — Virtualization and physical consolidation

Server consolidation through virtualization can be largely divided into two categories

a) Different operating systems or versions – “virtual integration” (V/I as shown in Figure 1),

b) Same operating system or simple integration of servers – "partition-based physical integration" (P/I as shown in Figure 1).

Server consolidation and virtualization integration can be actively pursued without affecting service level agreement (SLA) contracts with customers in the data centre.

Reducing the number of systems through consolidation and virtualization integration leaves more space in the computer room and lowers power consumption since less cold air is needed.

5.2.2 Energy efficiency of the storage system

Stored data is increasing rapidly with the growth of big data and cloud services. The storage system accounts for at least 30 % of overall power consumption of IT systems and takes up 25 % of the space of the data centre. Power consumption and space of the storage system can be reduced through physical integration and data optimization based on the technologies listed below. Generally, enclosures with disk drives consume power of approximately 66 % - 75 % in the storage system, while main controller and input/output (I/O) devices consume power of approximately 25 % - 34 % in the system. In all cases, efficient use of disks is most critical.

Applicable practices to improve energy efficiency storage technologies include:

a) turning off idle disk drives via massive array of inactive disks (MAID) for long-term storage data;

b) replacement of low-capacity disk drives with high-capacity disk drives for increasing storage capacity per unit energy;

c) removal of duplicates (reduces disk capacity by 10 % - 50 % through data pattern analysis);

d) thin provisioning (enabling capacity minimization and uninterrupted expansion by virtualizing storage capacity);

e) tiering technology [integrating redundant array of independent disks (RAID) configuration of individual storage to form several RAIDs];

f) storage virtualization (increasing storage use by virtualizing different storage systems and assigning server capacities);

g) local server storage on systems which include multiple hard or solid-state disks that can be configured (at the operating system level) to power down disks not in use, increasing energy saving.

5.2.3 IT system power control

The central processing unit (CPU) performs key functions in the IT system. Depending on the workload, the CPU can release more heat and consume more power. Manufacturers are thus providing solutions that control CPU power consumption. Data centre operators can lower power consumption by applying such solutions to IT systems.

The key solution can be generally divided into two categories:

a) decreasing CPU voltage and clock frequency to pre-defined values when workload is low (usually applied after application service time when workload is low and deactivated before the start of the application service time);

b) setting a maximum power consumption for the server and preventing any use that exceeds the maximum:

— maximum power use with low frequency is set as a critical value based on long-term power use analysis,

— it is to ensure continuity of IT services when power supply becomes unstable due to earthquakes and other natural disasters.

Power control of the server can save power consumption by up to ~ 20 %, and this also leads to a decrease in the power required for server cooling. Since the aforementioned solutions directly affect CPU availability, the following points can be considered when determining applicability at certain times:

c) priority analysis of applications on the server (systems of lower priority addressed first);

NOTE This is not recommended for servers relying on processing speed (real-time ratings, online web services, etc.).

d) analysis of CPU use by month/week/day/time based on server performance analysis by;

— selecting applicable time through performance analysis of each server,

— performing simulations to check applicability during the same time for virtualized, partitioned servers.

5.2.4 Periodic preventive maintenance

When the IT system is operated for long periods, CPU or memory resources are wasted by databases and applications. Periodic rebooting is needed to clear unnecessary resources to minimize power consumption. Table 1 presents the key tasks of periodic preventive maintenance.

Table 1 — Offline periodic preventive maintenance and its expected outcome

Type of maintenance	Maintenance items	Frequency	Expected outcome
Offline periodic	System reboot (see NOTE 1)	Once/3 months	Reduced power consumption by clearing unnecessary resources (CPU, memory, paging space)
	Diagnostic (see NOTE 2)		Early detection of defects through hardware diagnosis
	System dust removal (see NOTE 3)		Enhanced cooling efficiency
	Cable rearrangement (see NOTE 4)		Enhanced cooling efficiency through improved hot-air emission

NOTE 1 System reboots are typically performed with patch or firmware upgrades and coincide with other tasks. Therefore, the system down time can be considered the additional task time in the planning stage. System down time is considered up to 4 times that for the task itself.

NOTE 2 It is necessary to ensure availability by checking electrical devices (power supply, fan, etc.) for defects through hardware diagnosis of the IT system during offline preventive maintenance.

NOTE 3 When operated for a long time, impurities in the computer room adhere to the fan and lower cooling efficiency.

NOTE 4 Improper arrangement of cables at the back of racks prevents hot air from being released to hot aisles, thereby causing an increase in system temperature. This also contributes to increased power consumption of the fan.

Figure 2 shows efficient installation of cables in racks.

SOURCE Reference [2], reproduced with the permission of the authors.

Figure 2 — Cases of efficient installation of cables in racks

5.2.5 Management of idle equipment

The IT system usually remains in the computer room even when IT services become idle. A significant amount of power is consumed even when the system is in the idle state. Power consumption is also involved in cooling equipment. As such, idle equipment requires periodic and continuous management as summarized in Table 2.

Table 2 — Management of idle equipment

No.	Items	Description	Source
1	IT equipment and service audit	Audit of IT equipment services and hardware use	Configuration management database (CMDB) and data centre infrastructure management (DCIM)
2	System shutdown	Shutdown of idle equipment that cannot be taken out	
3	Return of idle equipment	Space acquisition by taking out idle equipment and installation of blank panels	
4	Switching off distribution board	Blocking of distribution boards connected to removed systems	
5	Cooling equipment control	Control of cooling equipment to adjust for changes in heating arising from equipment shutdown and removal	

5.2.6 IT system arrangement

The following can be considered for system arrangement to maintain an optimal cooling environment in the computer room:

a) classifying the system arrangement in the computer room into server zone, storage zone, and network zone;

b) when installing IT systems, those with the same type of airflow can be grouped together (in most cases, the airflow of systems installed on racks is from front to rear and front to top);

c) placing equipment that releases more heat in areas with efficient cooling (intensive cooling devices can be installed if necessary);

d) installing racks at least 1 800 mm from the exhaust vents of computer room air conditioning (CRAC) equipment (see Figure 3);

e) providing hot-aisles and cold-aisles to maximize cooling efficiency;

f) for an IT system with a front-rear-front-rear (F-R-F-R) arrangement as shown in Figure 4, it is necessary to install a separate device to prevent mixing of cold air and hot air.

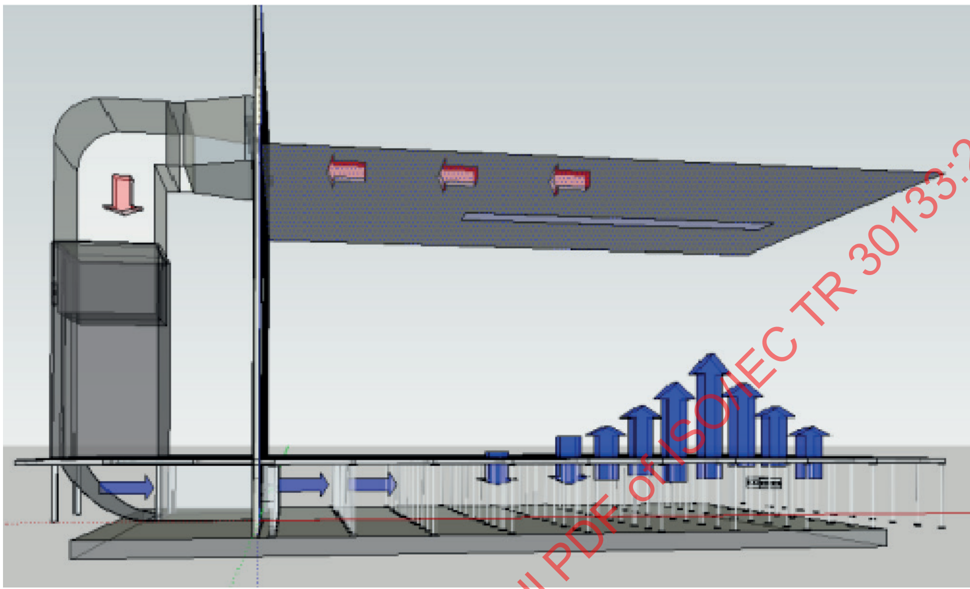

Figure 3 — Cold-air volume around CRAC equipment

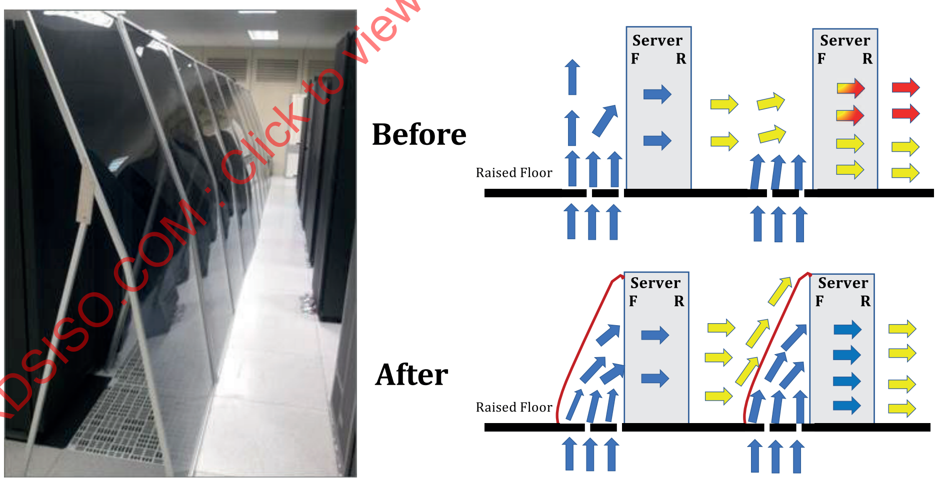

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Figure 4 — Energy efficiency in F-R-F-R arrangement

5.3 Network equipment

5.3.1 Network virtualization

Similarly to server and storage virtualization, virtualization of network equipment can improve energy efficiency, save space, and reduce operating costs as summarized in Table 3. With the recent increase in server virtualization and cloud services, network virtualization has become increasingly important.

A network is overlaid on an existing physical network as shown in the schematic of Figure 5 and includes:

a) a decrease in Layer 2 switches by employing Open vSwitch (OVS) and other virtual switches during server virtualization;

b) the application of virtual extensible local area network (VXLAN) technology to integrate network equipment during expansion of the L2 network and increase in demand for virtual LAN, (VLAN);

c) equipment integration through the conversion of the existing router to a virtual router (e.g. used in the multiprotocol label switching (MPLS) virtual private network (VPN) environment),

d) conversion to virtual network equipment that provides an integrated Layer 2/3 function (e.g. open virtual platform, OVP).

Table 3 — Expected outcome through network virtualization

Expected outcome	Details
Reduced cost	Decrease in power consumption and space taken up in data centre
Increased availability	Loop prevention and fast convergence function Increase in equipment availability through device clustering
Improved security	Improved security through network separation of different applications in the same virtual device/network
Enhanced operation efficiency	Decrease in equipment requiring monitoring

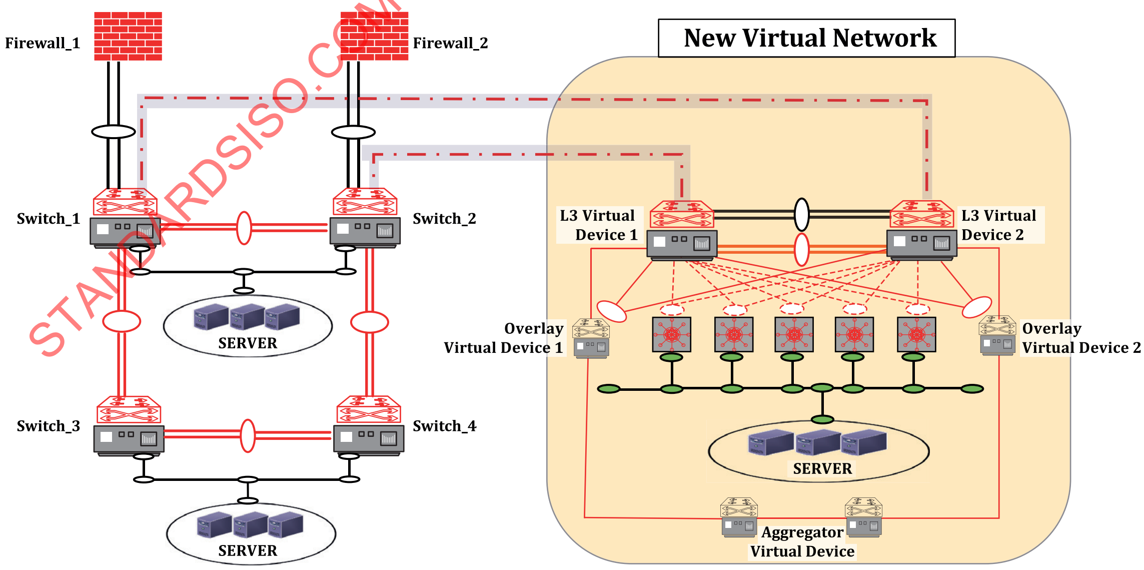

Figure 5 — Example of network virtualization