Ventilation and Cooling Requirements for ICT rooms

Best Practice Document

Produced by UNINETT led working group
on physical infrastructure
(No UFS 108)

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January 2013

Document No: GN3-NA3-T4-UFS108
Version / date: January 2013
Original language: Norwegian
Original title: "UFS 108: Krav til ventilasjon og kjøling av IKT rom"
Original version / date: Revision 4 of January 2013 (updates version 3 of December 2009)
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UNINETT bears responsibility for the content of this document. The work has been carried out by a UNINETT led working group on physical infrastructure as part of a joint-venture project within the HE sector in Norway.

This translated version is based on the fourth revision of the Norwegian counterpart approved by the Norwegian HE sector on January 2013 after an open consultation period of four weeks.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 238875, relating to the project 'Multi-Gigabit European Research and Education Network and Associated Services (GN3)'.

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Executive Summary

This document provides specification of the Norwegian HE sector's recommended ventilation and cooling requirements for ICT rooms.

In general terms, the document recommends the installation of satisfactory ventilation and cooling systems. Inadequate cooling may have consequences for computer systems' uptime and accessibility, which in turn will affect an institution's productive capacity.

When installing a ventilation system, it is important to ensure that it is isolated as much as possible from other ventilation systems, and that in the event of fire it is able to prevent the spread of smoke and fumes to ICT rooms. ICT rooms must be pressurised and incoming air must be filtered. Air humidity must be regulated in compliance with requirements pertaining to the equipment being used in the room. The ventilation of battery rooms must be carried out in compliance with prevailing standards.

The design and installation of cooling systems must focus on energy conservation, i.e., the application of systems that require little energy in order to produce cooling and, if possible, that recycle surplus heat. In larger installations, compressor-based systems are recommended which will often also facilitate the use of free cooling during winter. This means that the compressors are only in operation when the outdoor temperature is so high that the temperature of the cooling medium does not provide adequate cooling.

The construction of "green" ICT rooms may entitle the institution to an investment subsidy from a public sector body such as Enova.

The ideal room temperature is determined based on what is currently defined as "best practice". Work is currently being carried out in the international arena to reduce the energy consumption of ICT rooms. This may result in an increase in ideal room temperature threshold values. In essential ICT rooms, the emphasis should be on redundancy to ensure that any faults that arise do not result in a shutdown of operations. For installations that have large per rack cooling capacity requirements, water-cooled racks should be evaluated. This document illustrates various examples of air flow regulation. It recommends systems that maximise air flow regulation, thus providing optimal exploitation of the supplied cooling output.

A BMS (Building Management System) must be established to regulate operation of the ventilation and cooling systems, and to monitor room temperature and humidity. The BMS must have an interface to the ICT operations management system and the campus's IT department should be advised of the BMS alarm notifications by way of, for example, SNMP, e-mail or SMS.

Introduction

This document provides specification of the Norwegian HE sector's recommended ventilation and cooling requirements for ICT rooms, and is a revision of version 2 of the document (dated 2 July 2008). A revision log will be found in Chapter 6.

The target group comprises IT managers and IT operations personnel in the HE sector. The aim of this document is to raise the quality of ventilation and cooling systems in ICT rooms within the HE sector. Furthermore, it is intended that the recommendations in this document will form the basis of expansion, renovation and new building projects, and that they will be applied in everyday work contexts.

1 General information

In connection with the construction of new buildings and major renovation projects it is important to make an assessment of current and possible future ventilation and cooling requirements. Experience has shown that the demands on cooling requirements in the future continue to rise. This is due to the introduction of new systems, increased equipment density, more powerful processors and an increasing number of systems/components that require connection to the computer network. The demands on uptime and accessibility are also on the increase and, in many institutions, normal production will be shut down if faults or defects arise that affect cooling capacity. For example, the introduction of IP telephony has entailed that the prevailing temperature and humidity for edge switch performance may be crucial to an institution's ability to notify of incidents relating to the safety of its personnel.

Experience has shown that building-related costs resulting from increases in ventilation and cooling capacities in buildings in normal operation may be very high. For this reason it is recommended that during new construction and renovation projects, measures be taken which will make provision for future capacity expansion without incurring major building-related work and costs.

General recommendations:

1. Set aside space in ICT rooms for new room cooling units.
2. Set aside outdoor areas (roofs, etc) for new heat exchangers/ice water cooling systems.
3. Install additional/redundant pipes so that capacity can be increased simply by connecting up ice water/room cooling units.
4. Fit all existing pipes with additional/spare connection points to enable the connection of new room/ice water cooling units.
5. Ensure that ice water production for ICT rooms is independent of production for the remainder of the building, and that the temperature of the ice water is suited to the needs of the computer room, since too high temperature will reduce the cooling effect of the room coolers.

2 Ventilation

This document makes the following recommendations regarding the installation of ventilation systems in ICT rooms:

1. Ventilation systems for essential ICT rooms should be separate from those used in the remainder of the building in question. The reason for this is to prevent the spread of smoke and fumes into the rooms in the event of fire. Ventilation systems that serve ICT rooms must be operative 24 hours a day. If a fire prevention system based on a hypoxic air venting system is adopted (ref. UFS 104 “Fire Protection Requirements for ICT Rooms”), the ventilation system must be adapted to the needs of such a system.

2. All rooms must be pressurised in order to prevent the incursion of dust and dirt.

3. The risk of static electricity in an ICT room can be reduced by regulating the air humidity. Normally, air humidity should be in the range between 40 and 55% RH (relative humidity). At a room temperature of 23ºC, the humidity should not be allowed to drop below 30%. However, the installation of an air humidifying system could be expensive. Many types of equipment will be able to function without such a system, although this will be contingent on local conditions. Before a decision is taken regarding the installation of an air humidifying system, any equipment requirements, supplier guarantees etc., must be evaluated and used as the basis for decision-making/design of the system. It is common that rooms used for backup functions will require a humidification system. Humidity can be generated by means of steam or water atomiser systems. Water atomiser systems are favourable in terms of energy consumption. Dehumidification must be carried out automatically and condensed water removed and disposed of via a drain. In order to avoid the need to install a humidifying system, it is important not to supply too great a volume of external air that requires air conditioning.

4. In general, all ICT rooms must be equipped with one or several thermometers/hygrometers. It must be possible to transfer measurements to the BMS and the ICT operations management system (NAV). Measurements must be taken after the respective computer equipment components have been put into operation. Measurement instruments are installed 1.5 metres above the computer room floor, and at every 3 - 6 m in the cold zone between equipment racks, or close to the equipment component’s air intake.

5. Incoming air must be cleaned to remove dust, smoke and other contaminants.

6. Air returning to the cooling units must be decontaminated prior to re-cooling. This is to prevent the cooling system from circulating dust and dirt around the ICT room.

7. Battery and UPS rooms must be equipped with suction systems for explosive gases such as hydrogen and oxygen. Suction inlets must be located on the floors and ceilings. Air removed by suction must be discharged to the atmosphere outside the building in compliance with NEK EN Standard 50272-2:2001: “Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries”. Suction commences as soon as gas is detected, or during charging. Batteries that may release gases during charging should be located in a separate room.

3 Cooling

This document makes the following recommendations regarding the installation of cooling systems in ICT rooms:

1. All ICT rooms used for housing active equipment components must be equipped with a cooling system. It is recommended that surplus heat is recycled as an integral part of the institution's general heating system. Note that in cases of building renovation and the construction of "green computer rooms", it may be possible to obtain subsidies from public sector bodies such as Enova. For smaller ICT rooms in particular, but also for larger rooms for which it is possible to obtain adequate volumes of air, the cooling system can be based on the utilisation of external air. However, in such cases it must be practicable to extract the air volumes necessary during the warmer summer months. Moreover, the circulation of air around the room must be sufficient to prevent the development of hot spots during both summer and winter. Care must be taken to ensure adequate filtering of both external and re-circulated air. Space in the room must be set aside to permit circulation of the required air volume.

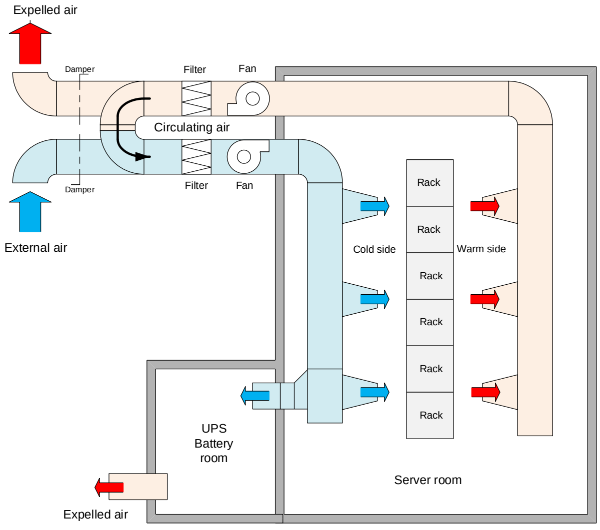


Figure 1. The principle of air-based free cooling

Note that Figure 1 illustrates the principle of air-based free cooling, but without any supplementary cooling system that may be necessary if the external air temperature becomes too high (on hot days) to provide adequate cooling.

2. The ideal temperature in an ICT room is between 20 and 25°C. 25°C is regarded as a temperature alarm threshold value. The operative room temperature should aim for 20°C. In the event of system malfunction this provides a buffer of 5°C, and thus time to repair any faults. Temperature measurements must be transmitted to the BMS and the ICT management system (e.g. NAV), which will activate an alarm in the event that the threshold value is exceeded. An external alarm can be transmitted via SMS (GSM) and/or e-mail.

   The ideal room temperature for valve regulated UPS batteries is 20°C. In the event of temperatures outside the 15 - 25°C range, the charging voltage should be adjusted. The lifetime of a battery is halved for each 10°C increase in temperature (based on a reference temperature of 20°C). The normal lifetime for batteries operating at 20°C is between 10 and 15 years. At a room temperature of 30°C the lifetime will be reduced to between 5 and 7 years.

   Due to cost considerations linked to power supplies and cooling, it is apparent that manufacturers are currently producing equipment that can tolerate higher temperatures than previously. It is too early to decide whether this trend will influence the designated ideal room temperature for ICT rooms, but the development should be monitored. For disk stations in particular, such a development would tend to indicate higher operative temperatures (35ºC). This increases the potential of external air as the basis of cooling systems. However, at such high temperatures response times in the event of malfunction of the cooling system will be shorter. Such a development emphasises the need for a separate battery room.

3. The maximum permitted temperature fluctuation is 5°C per hour.

4. Essential ICT rooms must be equipped with redundant cooling systems (ice water cooling units, room cooling units, pipes). This means that if a malfunction occurs in one or several of the cooling units, the remaining cooling systems will become operative in order to maintain the correct room temperature. Under normal circumstances, backup cooling units can be switched off since a major cooling overcapacity will be detrimental to the operation of the cooling units in question. Regulation of the various redundant cooling units must be carried out automatically using the BMS. The BMS will ensure that the connection and disconnection of the various redundant cooling systems is such that equal running times/loads are achieved.

5. Important room cooling units can be designed to use the municipal water supply in the event of failure of the ice water supply. The municipal water supply shall not be used as the principal source for cooling, but only to ensure redundancy.

6. The power supply for the cooling units shall be provided by the main ICT room panel. In the event of a power cut, standby power will preferably be supplied by a diesel generator. For particularly important equipment, it may be necessary to obtain power from the UPS, e.g., for circulation pumps supplying water to racks fitted with a water cooling system.

7. When calculating an ICT room's cooling capacity, the heat generated by the equipment should match the supplied effect. Moreover, an allowance of 20 – 30% spare capacity should be built in to take future expansions into account. If major expansions are anticipated, floor space for new cooling unit(s) should be set aside, and pipes/pipe connection points built in, so that the installation of new ice water and room cooling units is primed and can be implemented without major reconstruction work.

8. Ceiling/roof-mounted cooling units must be equipped with drip trays in order to prevent any condensation from coming into contact with and damaging equipment.

9. All pipes in ICT rooms must be insulated in order to prevent the formation of condensation.

10. Humidity sensors must be installed close to all cooling units (below the raised floor, in drip trays, etc.). When activated, an alert will be transmitted to the BMS and a monitoring system such as the NAV.

11. This report recommends the following general scaling parameters:
    a. 2 kW per m² for rooms containing an assortment of equipment types such as combinations of old and new components, servers, disks, network-related equipment, open and closed racks, etc.
    b. 4-5 kW per m^2 for rooms used exclusively for housing servers (7.5 kW per rack)
    c. 10-15 kW per rack for heavy-duty computation clusters
    d. Telecommunications rooms: 1 kW basic cooling + 5 W per switchport.
12. The BMS must be constructed with in-built redundancy or a manual control option.

13. Plans must be drawn up for the regulation of air flow in ICT rooms (ref. the figures in Section 5). In order to achieve optimal system performance, air flow should be controlled proactively by means of channels/pipe systems. In situations involving a raised computer room floor, all components installed beneath the floor, such as pipes, cable racks, etc., must be designed in such a way as not to obstruct the flow of cooled air.

Note that when designing server parks, heavy-duty computation clusters etc., the supplier's cooling system requirements must form the basis of the design concept. For example, heavy-duty computation clusters consisting of 40 1U machines might have a cooling requirement of 10-15 kW per rack. Moreover, there currently exist installations that require 25 kW of cooling per rack.

For outputs of the order of approx. 5 kW per rack and greater, dedicated water-based cooling systems should be assessed as a supplement to standard air-based cooling. The following are examples of water-based cooling systems (ref. the figures in Section 6):
1. Cooling baffles installed in rack doors which cool incoming air from the ICT room. Heated air is released untreated into the ICT room. The ratio between local water-based cooling and the ICT room's standard cooling system could be approx. 50/50.
2. Racks installed with a local cooling unit by which warm expelled air is cooled locally without the emission/release of heat into the ICT room. This will also result in less radiant heat emitted into the ICT room. Systems are available offering up to 40 kW of cooling per rack.

The use of water-based cooling in the racks may result in lower running costs (more cost-effective cooling). The reason for this is that traditional ice-water systems are based on the production of ice water using compressors in which the ice water will be at a temperature of between 8 and 12°C. Systems based on the use of cooling baffles/local cooling units are commonly able to exploit higher water temperatures, typically approx. 18°C. Under Norwegian climatic conditions, and in the majority of cases, it will be possible to produce water at approx. 18°C using only simple heat exchangers and circulation pumps. Supplementary cooling by means of compressors will only be necessary on the warmest days.

In certain circumstances, it may be desirable to employ an air-based free cooling system, by which computer equipment is cooled by means of virtually untreated external air. Such an approach will be beneficial, most particularly in terms of energy conservation. Moreover, such systems may be appropriate for short periods in the event of malfunction of the standard system. If air-based free cooling is to be used it is important to make sure that that environmental factors in the ICT rooms in question such as temperature variations, air humidity, dust, and such like are regulated, and that the rooms are airtight for fire extinguishing purposes, etc. In order to handle the capacity requirements on hot days, free cooling by means of heat exchangers and compressor-generated supplementary cooling systems are preferred.

The majority of institutions have a varied array of equipment with a combined cooling requirement of approx. 2 kW per m^2. Basing essential supplementary cooling on the use of water-cooled racks represents one strategy for addressing the possible future installation of high heat output racks on the same floor space. If the rooms in question are installed in advance with a pipe system for water distribution, and the necessary outdoor space set aside, it will be possible to carry out an expansion of this type relatively easily.

In recent years, we have observed an increase in the number of edge switches powered by PoE. The current PoE standard (IEEE 802.3 af/at) can support equipment delivering up to 5 W / 25 W. There are also equipment manufacturers which can supply PoE systems delivering up to 50 W per port. It is reasonable to suppose that PoE will result in an overall increase in the amount of equipment such as telephones, AP, cameras, timers, etc., all of which can/must be powered via the horizontal distribution network, and which in turn will result in increased cooling requirements in rooms where edge switches terminate.

4 Air circulation in server rooms

A system enabling the circulation of cooled air must be adapted to the equipment installed at the various institutions in question. Equipment layout will range from open racks with shelving for individual items of equipment, to compact server racks (containing blade servers or sliding rail-mounted 1 U servers). It is important that air is circulated in such a way as to avoid the development of so-called “hot spots”.

The following alternatives, either exclusively or in combination, may be considered:

1. The use of open racks without any special requirements in terms of cooled air circulation. This system assumes a configuration consisting of traditional free-standing servers/equipment installed on shelves in racks.

2. The use of closed racks where cooled air circulation is facilitated via the raised computer room floor, i.e., input/output at the base/top of the racks, respectively. This system assumes that the equipment in the racks facilitates the satisfactory flow of air in a vertical direction.

3. There is a trend towards the closer packing of equipment within racks, i.e., the use of blade servers (chassis-based servers) and/or deep 1 U servers. In general, the aforementioned servers utilise the entire depth of the rack, which makes vertical air flow problematic. In such cases it will be necessary to employ racks with ventilation apertures in their front and back door panels, combined with a ventilation system which circulates cooled air via a conduit mounted below the ceiling and/or the computer room floor leading to the front of the racks and which incorporates suction to remove warm air from behind the racks. If several rows of racks are required, they must be arranged such that front door panels face opposite one another, and the same for back door panels. The reason for this is to avoid the warm air expelled from a rack in one row being used to “cool” racks in the adjacent row. A configuration involving placing front door panels opposite back door panels should be avoided. It may also be appropriate to lay out the racks and rows in such a way as to prevent warm air from being circulated into the room’s aisle areas, towards other equipment, etc.

4. An alternative to controlling the air circulation as illustrated in Figure 5.10 is to build server racks in the form of cubes as shown in the figure, but with cooling units located between the racks. One can then choose to locate the air intake side of the racks adjacent to a cold zone or the warm side. The effect of the cooling units can be increased by making optimal use of the temperature difference between the cold and warm sides. This arrangement takes less space because the enclosure of the warm or cold zone is used instead of a duct system. Because the air only moves horizontally, the height of the raised floor may also be reduced if desired.

5 Examples of air flow regulation in ICT rooms

The following figures illustrate the different principles behind the regulation of air flow in large ICT rooms (server rooms). The exception is Figure 5.9, which shows a system adapted to an equipment room (ER) and telecommunications room (TR). Note that all numerical values given in the figures should be regarded as guides, and must be viewed in the context of the design of the room and the type and layout of equipment installed. The figures do not show redundant cooling systems, which are nevertheless a requirement.

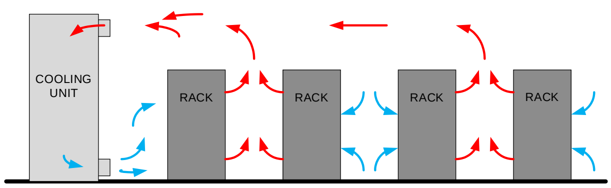
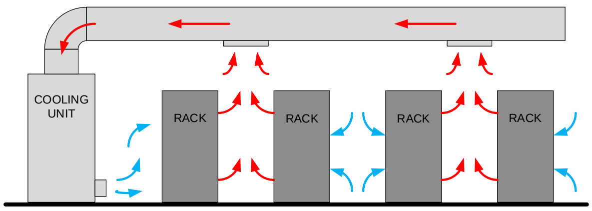
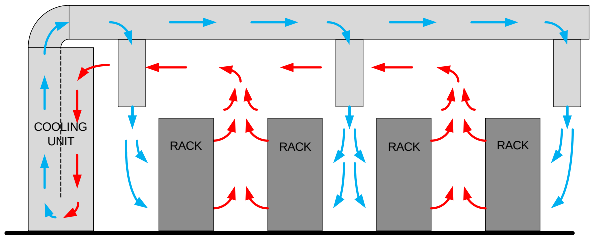
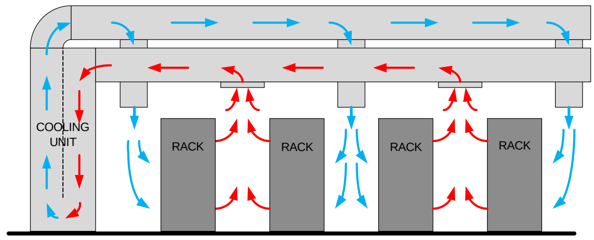
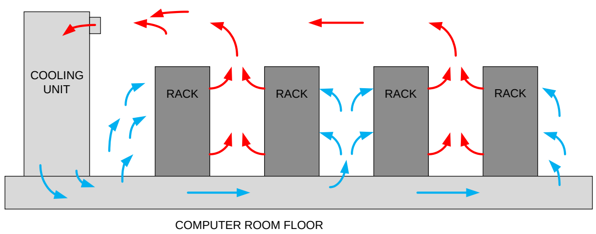
Figure 5.1. Unregulated input/output air in a room without a raised computer room floor. Not recommended for total cooling requirements greater than 40 kW; should be restricted to a maximum of 8-10 racks. Inexpensive, easy to install. **The system is widely used in the HE sector and is recommended for smaller installations/institutions.**	
Figure 5.2. Partially regulated output air in a room without a raised computer room floor. Maximum cooling capacity of 3 kW per rack. Inexpensive, easy to install.	

Figure 5.3. Partially regulated input air in a room without a raised computer room floor. Maximum cooling capacity of 3 kW per rack. Inexpensive, easy to install.	
Figure 5.4. Partially regulated input/output air in a room without a raised computer room floor. Maximum cooling capacity of 5 kW per rack. This system provides high efficiency and provides excellent air circulation. For rooms of “standard” ceiling heights, it may be virtually impossible to construct cable racks (for telecom, power, patching, etc.), and lighting (hanging light fittings). If cable racks are to provide standard routing, the ceiling height must be identical to that required in cases when a raised computer room floor is constructed. This system is not recommended since rooms with a raised floor are preferred.	
Figure 5.5. Partially regulated input air in a room with a raised computer room floor. Maximum cooling capacity of 3 kW per rack. **This system is widely used in the HE sector and is recommended in situations where the system shown in Figure 1 is unsuitable.**	

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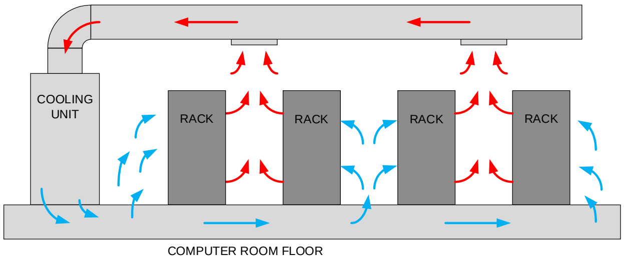
<td>Figure 5.6. Partially regulated input/output air in a room with a raised computer room floor.

Maximum cooling capacity of 5 kW per rack. Good and effective system.</td>
<td>
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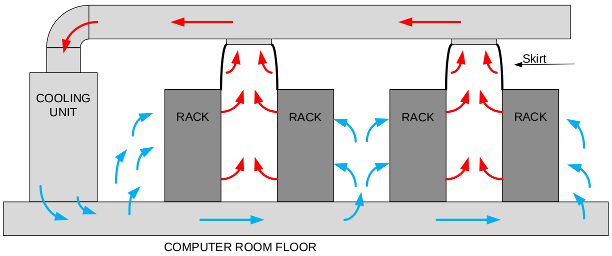
<td>Figure 5.7. Partially regulated input/output air in a room with a raised computer room floor.

The system is similar to that shown in Figure 5.6, but is supplemented by the use of skirts that guide the flow of output air. Maximum cooling capacity will be somewhat greater than 5kW per rack. Good and effective system.</td>
<td>
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<td>Figure 5.8: Fully regulated input/output air.

May be utilised for racks with a 15 kW cooling requirement. The system presupposes that air can flow through the equipment installed in the racks (aided by fans in the racks). Good and effective system.

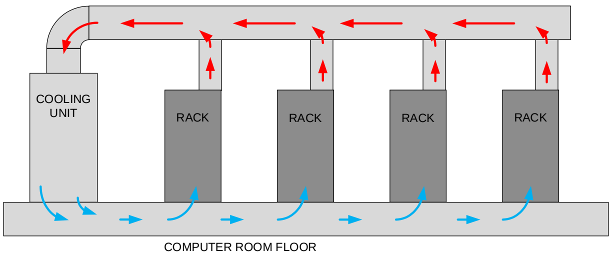
For cooling requirements on this scale, a dedicated rack water cooling system should be considered, e.g., water cooling of the rack door panels. Moreover, for cooling requirements on this scale, the equipment supplier's recommendations must form the basis for the system selection.</td>
<td>
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Figure 5.9: Unregulated input/output air in main equipment rooms (ER) and telecommunications rooms (TR).

Normally, ceiling-mounted systems would be expected to deliver a maximum cooling capacity of approx. 5 kW.

This system is recommended for both ERs and TRs.

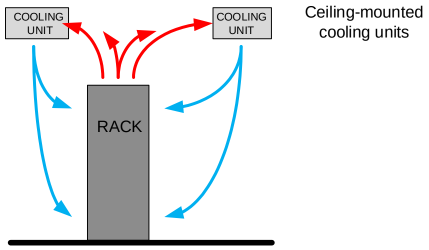


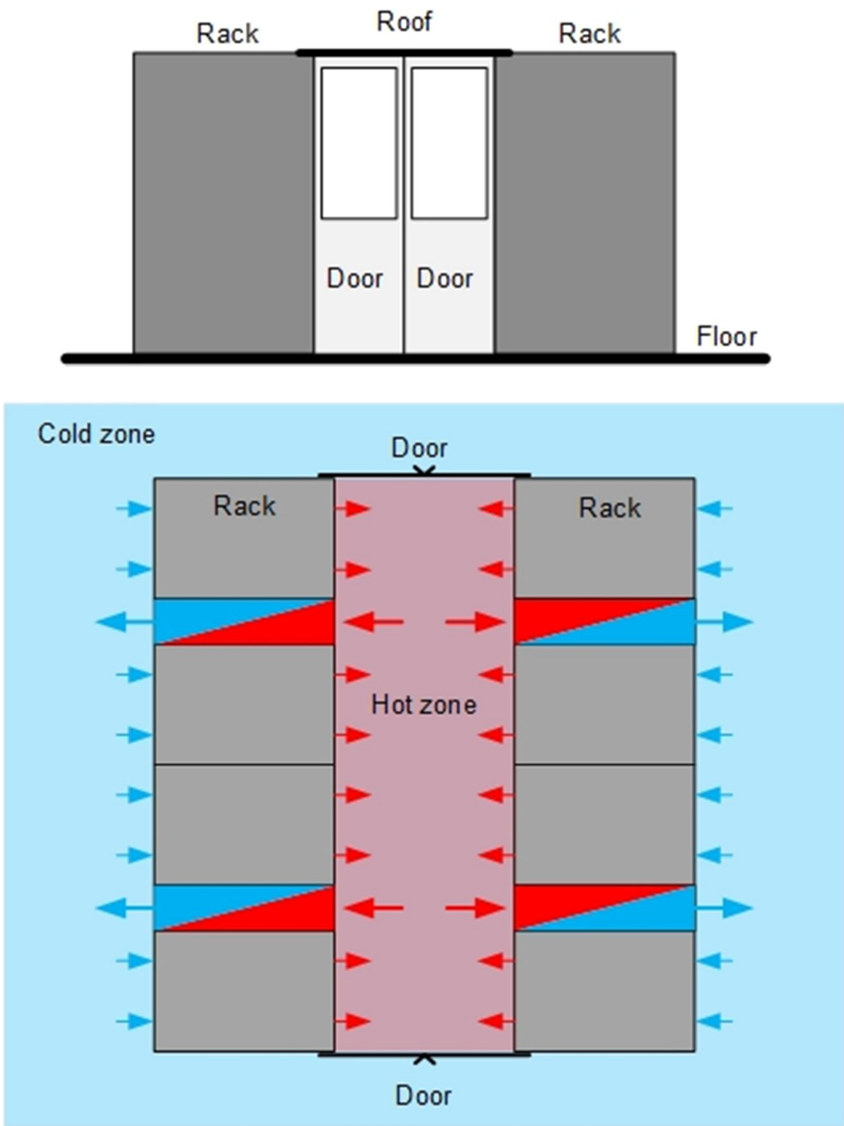
Figure 5.10. System based on cooling racks and a chamber for collecting warm air.

The chamber is created by arranging racks in a warm/cold rack layout and fitting doors and ceilings which prevent warm air from encroaching into the cold zone.

This arrangement can be used for racks with a high cooling requirement, e.g. blade servers. Cooling racks are available with a width of 300 mm and cooling capacity of up to 60 kW. The number of cooling racks in a layout depends on the cooling requirements of the equipment.

This arrangement should be considered as an alternative especially in cases where limited ceiling height means there is no room for a traditional raised floor.

It is also an effective arrangement in HPC environments as well as other server rooms with high heat generation per rack.



6 Examples of direct cooling systems installed in equipment racks

The following figures illustrate some examples of local rack cooling systems.

Figure 6.1. Local rack cooling by means of door-mounted cooling baffles.

This approach assumes that air is first extracted from the ICT room and then cooled within the door panel before being utilised to cool the equipment. Warm air is emitted into the ICT room.

This system can be installed as a free-standing unit in an existing ICT room containing systems with high cooling requirements. In this way, the need to upgrade existing cooling systems is avoided.

This approach is utilised for NTNU’s heavy-duty computing system, supplied by IBM.

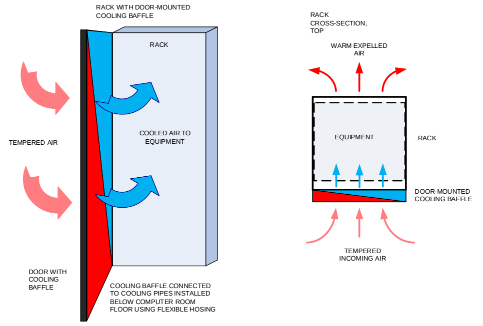
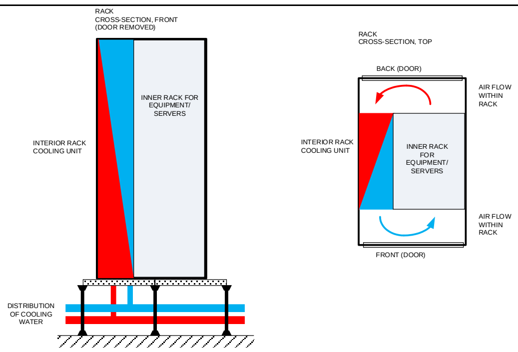
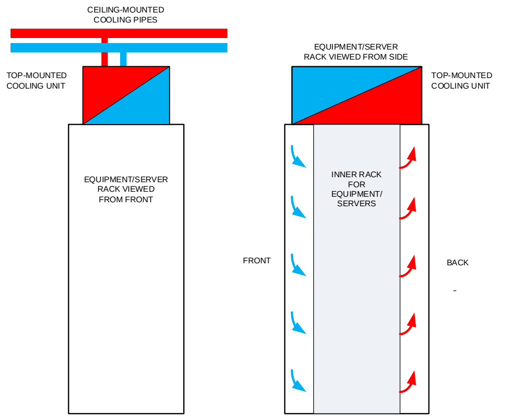


Figure 6.2. Local rack cooling by means of a cooling unit integrated into the rack.

The approach entails that all cooling takes place locally within the rack. There is no need to extract air from the ICT room. The system releases very little heat into the ICT room, such that the ICT room’s overall cooling requirement remains relatively low.



This approach is utilised for UiT's heavy-duty computing system (Stallo), in which each rack has a cooling capacity of approx. 30 kW. Supplied by HP.	
Figure 6.3. Local rack cooling by means of a top-mounted cooling unit. The approach entails that all cooling takes place locally within the rack. Cold/warm air enters/leaves the equipment via the front/back panels, respectively. As in the system illustrated in Figure 6.2, this system releases relatively little heat into the surrounding ICT room.	

7 Energy use

In recent years the focus on energy use in ICT rooms has increased, with the introduction of such concepts as Power Usage Effectiveness (PUE). Put simply, PUE is calculated as the total energy use in a computer centre divided by the energy use in the ICT equipment.

$$Power\ Usage\ Effectiveness\ (PUE) = Total\ Facility\ Power \frac{\square}{\square}\ IT\ Equipment\ Power$$

A low PUE value indicates an efficient use of energy and can be documented dynamically by means of continuous measurement in all the equipment associated with an ICT room. This type of measurement regime will provide a basis for environmental accounting.

In connection with new installations and renovation, solutions should be sought which provide the lowest possible PUE – with a value as close as possible to 1.

References

Standards from the Norwegian Electrotechnical Committee (www.standard.no)

1. NEK EN 50272 “Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries”

Telecommunications Industry Association

1. TIA-942 Telecommunication Infrastructure Standard for Data Centers

2. The Green Grid, 2007, “The Green Grid Data Center Power Efficiency Metrics: PUE and DCiE”, Technical Committee White Paper.

Revisions

This version includes the following amendments to version 3, published on 22 December 2009.

1. General adjustment/revision of text based on experience reported by the sector.

2. Chapter 5, Figure 5.10, showing a cooling system based on cooling racks and chambers for collecting warm air.

3. New Chapter 6 “Energy use”

Glossary

Enova	A Norwegian public sector enterprise established to promote the environmentally sound restructuring of energy production and consumption in Norway.
Free cooling	A cooling system in which the use of cold outdoor air (usually during winter) completely or partially replaces compressor operation, i.e. cooling by heat exchange with air or water. In ice water systems, free cooling is used to cool the ice water itself.
GSM	Global System for Mobile Communications. The ETSI standard for mobile communications
ER	Equipment Room
IEEE	Institute of Electrical and Electronics Engineers
IP telephony	A telephone system that utilises the internet protocol
TR	Telecommunications Room
NAV	Network Administration Visualized, an ICT management system developed by the HE sector
NEK EN	The Norwegian Electrotechnical Committee, European Norm
NTNU	Norwegian University of Science and Technology
PoE	Power over Ethernet – IEEE 802.3af/at
BMS	Building Management System. A system designed to control and monitor a building's technical infrastructure (e.g., electrical, water, heating, sanitation systems, etc.)
SMS	Short Message Service
U	Basic rack height unit. 1U is equivalent to 1.75 inches or 44.45 mm
The HE sector	The Norwegian higher education sector
UiT	University of Tromsø
UPS	Uninterrupted Power Supply