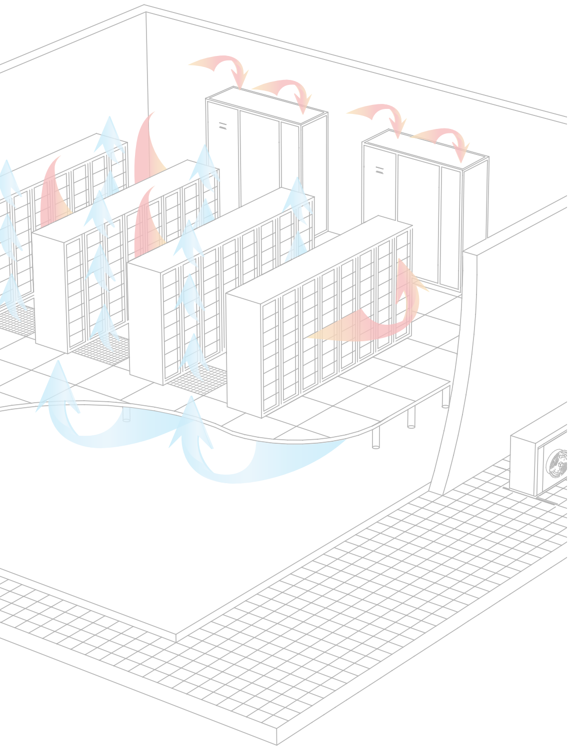
TECHNICAL FOCUS

PRECISION AIR CONDITIONING: THE AERMEC SOLUTION FOR DATA CENTERS



AERMEC TECHNOLOGY APPLIED TO DATA CENTERS

This document offers an overview on Aermec solutions for the air conditioning of server rooms.
Cooling represents a significant part of the total consumption of a EDP (Electronic Data Processing), but the current cooling systems are often inefficient, because of the inadequate sizing of the system.
Sizing and properly conducting the air conditioning system can therefore lead to significant energy and cost savings.

Technical Sales Support Department

SUMMARY

The“Technical Focus” series is intended to offer an example for information only of the possible advantages in the use of innovative Aermec solutions.
As the data and results presented in the publication refer to specific buildings and situations, then these can vary significantly depending on the applications and intended use. For these reasons the calculations and considerations made in this document cannot be considered an alternative to the design by a professional engineer.

Aermec reserves the right to carry out at any moment any modification deemed necessary for the improvement of the product with any modification of published data.

DATA CENTERS: TERMINOLOGY

RACK
shelf structure which hosts hardware components (server, switch and router).

CRAC
(Computer Room Air Conditioning)
Modular units for the control of ambient conditions, specifically designed to maintain a constant air temperature and humidity in the room, which usually contains data processing equipment.

IT
Information Technology
Set of systems and equipments for data processing and communication.

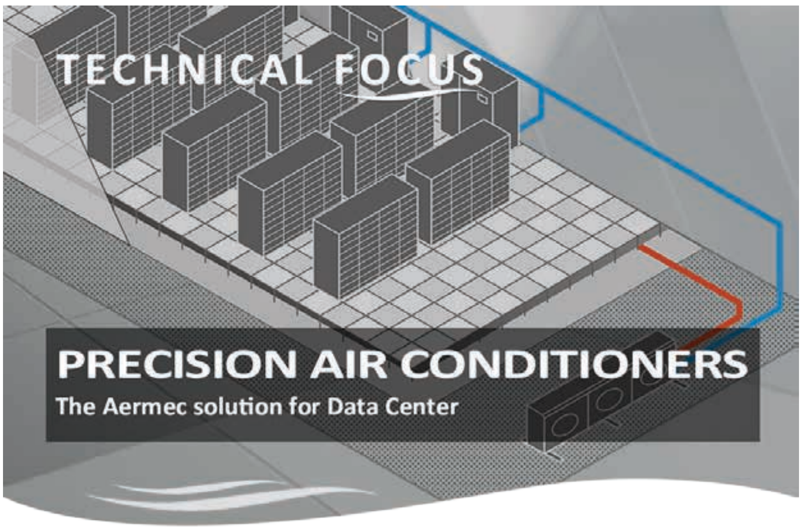
Data Center or EDP
Building that has as its primary function to contain high-performance server and sensitive electronic equipment.

Server
Component or subsystem computer processing.
It provides at logical and physical level any kind of service to other-components, which request them through the network.

PAC
(Precision Air Conditioners).

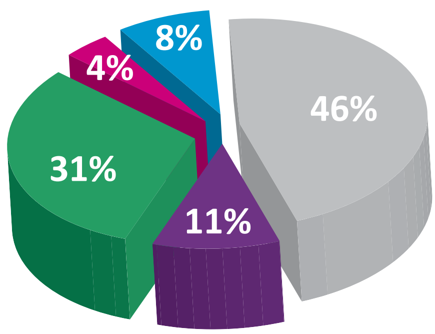
INTRODUCTION

Data processing centres and technological environments in general represent critical applications, because they require complete reliability, safety and efficiency.
What distinguishes the Data Centers are especially energy consumptions, often toghether with the high densities of installed thermal powers (the power density of Data Center can be expressed floor unitary surface or for rack unit).
Another feature is that they must ensure the continuity of operation during the entire year without interruption.
It is the energy efficiency of units and systems which today focuses mainly on the demand of developers and designers, and to which Aermec want to answer with new and more advanced solutions.



Chapter 1
FEATURES OF DATA CENTERS

Data Centers represent a high-density-building -typology with high power density: a Data Center requires an average of 10-15 times more energy than a standard office building, reaching sometimes 40 times. In addition, the field of “Information and Comunication Technology (ICT)” is one of the main causes of growth of energy consumptions in Europe. The density of the servers is in fact growing, and consequently is rapidly increasing power demand of air conditioning systems dedicated to them.
To the cooling of a server room is destined a significant portion of the total energy consumption of the Data Center, for this reason sizing and properly conduct the air conditioning system can lead to considerable energy savings.



Distribution of energy consumptions in a Data Center

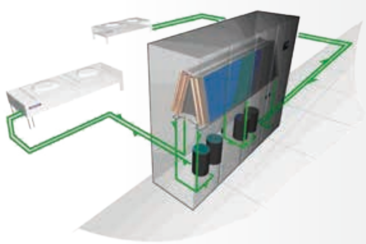
PUE

Power Usage Effectiveness

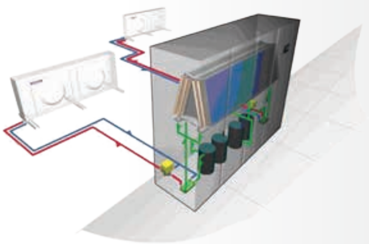
$$PUE = \frac{\text{Total power Data Centers}}{\text{IT devices power}}$$

Just as there is a parameter that defines the chiller or heat pump efficiency, which is the EER or the COP, even for server rooms has been defined as a quantity that evaluates the energy efficiency. This parameter is the "PUE", defined as the relationship between the total electric power consumption of the Data Center and the energy used by the IT equipment. The more this value is close to the unit, the more the Data Center is efficient.
To this day, the great part of the Data Centers PUE has values of around 2; it is therefore evident that there is a significant margin for improvement, with an important contribution, which can arrive directly from the cooling system.
The always growing interest in the air conditioning systems of the servers, is in fact highlighting the inefficiency of the traditional approach to the cooling of server rooms, which, if improved, offers a great opportunity of energy savings (the second right after the load reduction of the IT equipment).

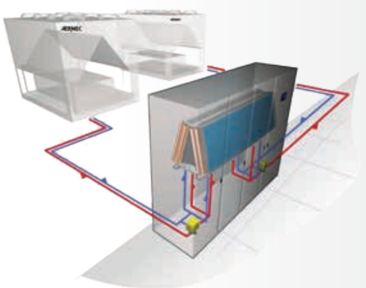
Chapter 2
PRECISION AIR CONDITIONERS



Configuration with air-cooled direct expansion with double refrigerant circuit.



Configuration direct expansion water-cooled with double refrigerant circuit.



Configuration with chilled water.

The server rooms have to be cooled with proper "precision air conditioners", often indicated with the acronyms:

– CRAC (Computer Room Air Conditioning)
– PAC (Precision Air Conditioning)

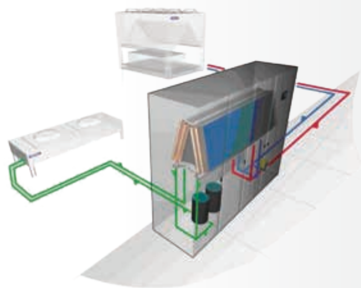
These systems differ from the traditional air conditioners for residential sector, for the rigid control of the temperature and humidity conditions, which is necessary to secure the good functioning of servers.

The more used systems for server's cooling are air cooled. The air can be distributed to electronic equipments in several ways: through grilles on the raised floor, from above or localized systems placed between racks.

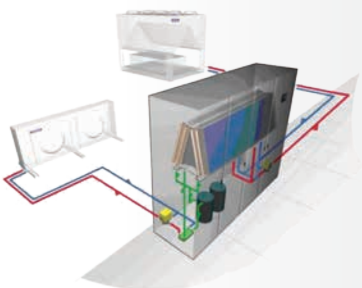
Precision air conditioners can be:

- **with Direct expansion:** they have inside one or more air-cooled or water-cooled refrigerant circuits. A feature of the evaporation coils is to be dimensioned to treat mainly sensitive loads. The water-cooled units are connected to dry coolers installed externally, in which a glycol solution circulates. The water-cooled unit offers the possibility to take advantage of the free-cooling: depending on the temperature that the glycol solution reaches in the dry cooler, it can go to cool the fluid in condensation, or go directly to feed appropriate water coils placed inside the unit as an alternative to those in direct expansion.

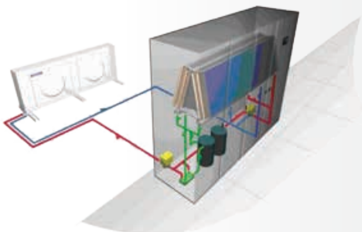
- **with Chilled water:** in this case the unit is not equipped in the refrigerant circuit, it presents internally one or more cooled-water coils, with water produced by means of an external chiller.



Configuration "dual-cool": air-cooled direct expansion and chilled water.



Configuration "dual-cool": water-cooled and chilled water direct expansion.



Configuration with water cooled direct expansion with free-cooling option.

The units for Data Center must be equipped with all necessary components to ensure complete thermo-hygrometric treatment of the air, in accordance with requirements that vary depending on the installation: in addition to the cooling of the room, it may be required the re-heating (made with electric coil, with water coil, or for units with direct expansion, it can be achieved by exploiting the hot gas cooling), the humidification (typically immersed electrode) and degrees of filtration efficiency of the air more or less high.
It is, in some aspects, of real air handling units for specific environments, high-density loads and thermal factors next to one.

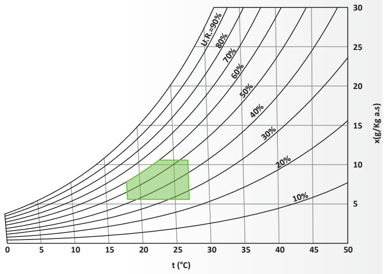
In Data Centers it is necessary to ensure adequate redundancy of cooling systems, to avoid affecting the normal operation of the server room in the event of failure of an air conditioner.
Redundancy can be achieved by equipping the units with independent refrigerant circuits, in which one acts as replacement to the other. In very large systems it is possible to install more units than necessary in order to keep some as reserve units.
Antother solution may be to employ units called “dual-cool”, that is with double refrigerant circuits and double coolant. In this case the units is equipped with two separate refrigerant circuits, one with direct expansion and the other with chilled water, so that if the chiller that feeds the water coil no longer operates, intervenes the internal refrigerant circuit to ensure always proper cooling.

Temperature and humidity conditions in the Data Center

The temperature and humidity conditions to be maintained in a Data Center are fixed by ASHRAE in the document “thermal guidelines for data processing environments” of 2011.

In this document are identified as “recommended” the following conditions:

- Temperature between 18°C and 27°C
- Specific humidity between 5,6 and 10,6 g/Kg with a maximum limit in terms of relative humidity of 60%.



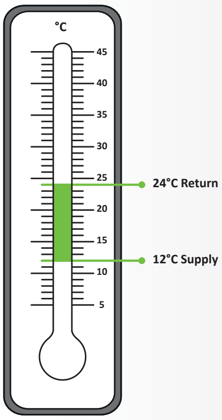
The humidity content, in server rooms, is very important. Too high humidity values can lead to mistakes of tape bearing, excessive wear and corrosion. These risks increase exponentially when the relative humidity exceeds 55%. On the other hand, too low values of relative humidity (below 30%), increase the risk of electrostatic discharge which can damage components and have an adverse effect on the operation of the unit.

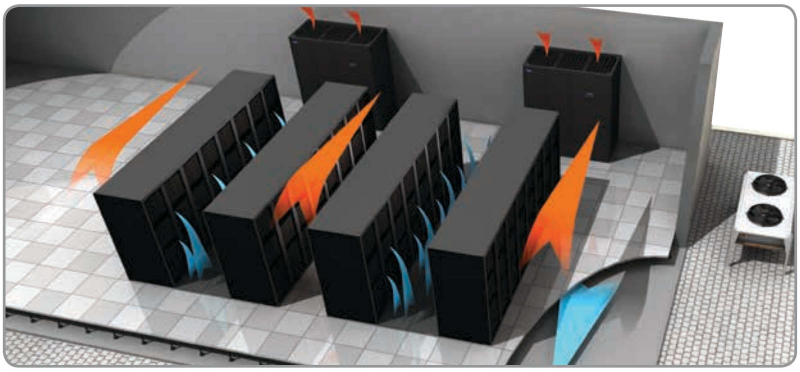
Chapter 3
SYSTEM SOLUTIONS

Improving the efficiency of the air conditioning is one of the main roads to take to the significant reduction in consumption of Data Centers. In this regard, one of the strategies to increase the efficiency of the air conditioning system is to optimize the air flows. There are several solutions, the most widely expected to distinguish inside the room of hot and cold aisles. This solution leverages the design feature of the servers, that draw cold air from the front and expell it behind. Placing them one in front of the other in rows, are created cold aisles from which servers aspire the air, and hot aisles in which the air is expelled. Compared to the traditional approach, which aims to maintain constant the average conditions of the room, the one based on hot/cold aisles allows to take into account the actual needs of the servers ensuring their proper cooling.
A general principle in the design of a Data Center is therefore to separate the flows, avoiding to mix supply and return.
From the point of view of the application, the system solutions can be different depending on the powers involved in the server room.

LOW DENSITY

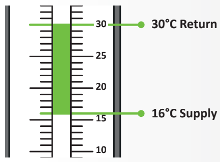
With low density applications are intended the ones in which the power density of servers is less of 5kW per rack.
In this range of powers the tendency is to make open aisles: cold air is fed from the air conditioning in the raised floor and through specific grilles, it reaches the server that aspire and reject it in the hot aisle, which returns to the conditioning unit placed around the perimeter of the room.
This is only an example of application of the concept of “open aisle”, the solutions can be various depending on the needs and spaces that the server rooms offers. For this reason, air conditioning units are available with different configuration of precision, such as the flow can be from the bottom (down flow) or from above (up flow).
The solution of open aisles ensures a a good separation between the air flows, although it is not absolute. In applications where power requirements are contained, it proves to be a good solution, because it is not expensive, quick to realize and flexible (The layout is easily modifiable in case of future expansion of the server room).
This solution, however, requires to produce air at rather low temperature: the air outlet temperature is tipically 12°C.

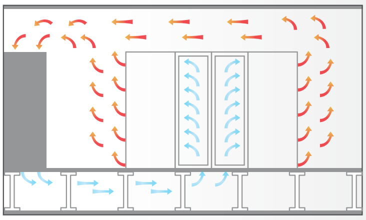




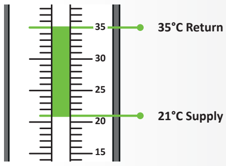
MEDIUM-HIGH DENSITY

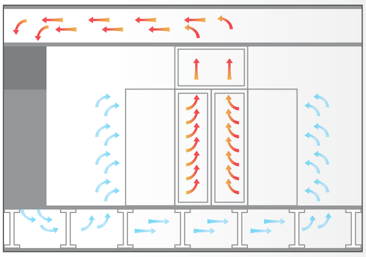
Cold aisle:
it is closed at the top and laterally clearly separating the supply flow from that of recovery





Hot aisle:
The hot aisle is ducted so confining the heat output from the server.

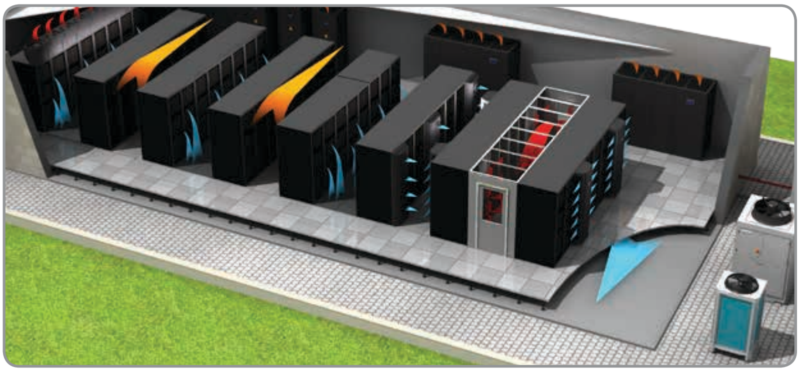




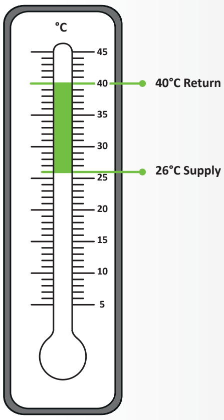
With increasing density of servers, a solution to open aisles may not be sufficient to ensure proper cooling of the rack. In these applications, in fact increases the risk of mixing between the two streams, that can be avoided by closing aisles and confining the air flows.
We identify two possible solutions:

- **Compartmentalization of cold aisle:** the cold aisle is closed at the top and the side, going to separate the flow of supply air from the one of recovery;
- **Compartmentalization of hot aisle:** the hot aisle is ducted so confining the heat output from the server.

Both solutions involve a clear separation between the flows of hot and cold air. The confinement of the flows allows to increase the temperature of cold air to be sent to the server, because the risk of mixing is practically not existing. In these applications, in fact, meets the higher supply air temperatures, ranging from 16°C to 21°C. The increase of the supply temperature has as a result of the increase of the efficiency of air conditioning equipment: if with direct expansion increases the evaporation temperature, if they are water cooled units, this means the use of water at higher temperature, in any case it improves the efficiency of the system.
A second aspect, not less important, is linked to dehumidification: when in the server rooms the latent contribution of external loads is low, a low temperature of coil means a dehumidification not always necessary. Consequently there is a subsequent dehumidification to keep moisture in the room at the desired levels. The containment of hot and cold aisles is therefore an excellent solution, because it allows to operate at a higher temperature of the coil, reducing or eliminating the phenomena of uncontrolled dehumidification.



Hot Aisle Containment HT



The solution with hot aisle normally includes the supply of air at 21°C and the return at 35°C. A solution with higher working temperatures (27 / 40°C) can lead to an increase in efficiency of the system. The ASHRAE, in fact, in its guidelines for data center design (ASHRAE TC 9.9 – Thermal Guidelines for Data Processing Enviroments) sets a maximum limit for the supply temperature of 27°C and 40°C for the return.
Aermec therefore proposes, in order to achieve greater energy savings, the solution "Hot Aisle Containment HT (High Temperature)", created by keeping the architecture and file-based containment of hot aisles, but raising working temperatures.

Chapter 4
AERMEC FOR DATA CENTERS

The solution named by Aermec "Hot Aisle Containment HT" includes the use of water-cooled precision air conditioning units, installed in server rooms with hot aisle confined configuration. It is expected, in this case, to work at a temperature of supply air 27°C, higher than about 20 °C to the traditional applications. The increase of supply air temperature, however it requires special precautions: it is important, in this case, to work in constant air flow with the values that should be carefully evaluated, in particular need to identify what is the minimum flow required to the server to avoid the formation of hot-spots.
In view of this, the highest temperatures of water have the advantage of increasing the efficiency of the chiller, and secondly to increase the hours in which it is possible to use the free-cooling.
In this regard Aermec optimizes the free-cooling technology, creating a "free-cooling modulating": even when the external conditions guarantee a minimum coverage of the thermal load (ie, when the outside temperature is slightly lower than the temperature of water), the free-cooling modulating system permits to optimize the free external source, according to increasing percentages in proportion to the difference of temperature between the outlet water from the PAC units and the external environment, to cancel the contribution of mechanical cooling maximizing so the efficiency of the system. The combination of a technology like this, with the solution "Hot Aisle Containment HT" can then lead to huge energy benefits.
In order to demonstrate the energy benefits, that the increase of water supply and free-cooling temperature can bring, we present herewith the numerical simulations.

Aermec defines:

pPUE
Partial Power Usage Effectiveness

$$PPUE = \frac{\text{IT devices power + Air conditioning systems}}{\text{IT devices power}}$$

Chapter 5
CASE STUDIES

It was considered a Data Center with a request of cooling capacity of 80kW. This demand is met by two units of water-cooled precision air conditioning units, able to provide, operating conditions, at least 40kW of cooling capacity. Each of the two PAC units is powered by a water-glycol mixture (20% of ethylene glycol) cooled by an air to water chiller, with a nominal power of 80kW (determined with external air of 35°C, produced water 7°C, Dt 5°C). The choice of dividing the required power in two parts and sizing both the chiller for the total load, is primarily related to reliability reasons: in case of malfunction of a chiller, the other is able of conditioning automomously the entire server room. The data center's load is constant, 24 hours a day , 7 days a week. The total power required by the room, throughout the year, for its cooling, is then equal to 700,8MWh (80kW x 8670h/year).

OPERATING CONDITIONS

A and C solutions:
Supply temperature 24°C
Ambient relative humidity 45%
Water inlet temp. PAC= 15°C
Water outlet temp. PAC= 20°C

B and D solutions:
Supply temperature 27°C
Ambient relative humidity 40%
Water inlet temp. PAC= 18°C
Water outlet temp. PAC= 23°C

The solutions for conditioning, which have been analyzed, are the following:

A Water supply temperature of conditioning unit 15°C (ΔT=5°C)

B Water supply temperature of conditioning unit 18°C (ΔT=5°C)

C Water supply temperature of conditioning unit 15°C (ΔT=5°C) produced with chiller with free-cooling option.

D **W**ater supply temperature of conditioning unit 18°C (ΔT=5°C) produced with chiller with free-cooling option.

The simulations have been executed for three different places: Milan, London and Cape Town.
The results shown in the following pages highlight how the rise in temperature of the produced water does indeed involve a reduction of consumptions: to change from 15°C to 18°C of produced water implies a reduction in electricity consumption during the year of about 2%, in all the three analyzed cases. This percentage is not too high, but significant, if one thinks that it was achieved simply by modifying the working set of the chiller.
More significant, however, are the advantages to be gained by exploiting the free-cooling. In this case the obtained energy savings varies depending on the incidence of the free-cooling for each place: where the temperatures are more rigid, the intervention of the free-cooling will be more frequent and therefore the savings achieved will be more important.

CASE STUDY 1: MILAN

Legend

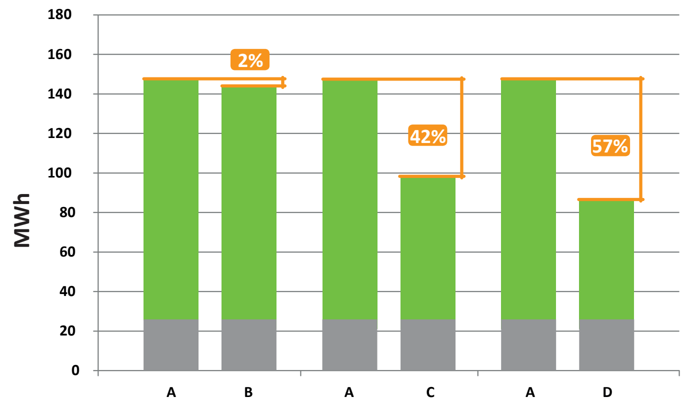
A Produced water T 15°C (Δt= 5°C)

B Water T 18°C (Δt= 5°C)

C Produced water temperature 15°C (Δt= 5°C) with free-cooling option

D Produced water temperature 18°C (Δt= 5°C) with free-cooling option

Results of simulations

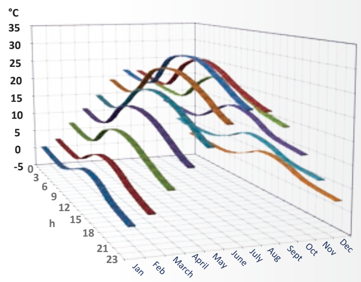


Electricity consumption:

chiller + pumps

PAC

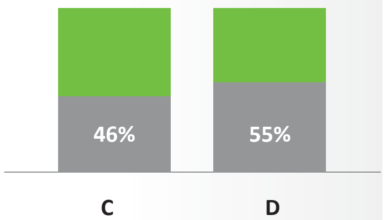
Climatic profile of Milan



	CASE	A	B	C	D
Required cooling energy from the Data Center	MWh	700,8	700,8	700,8	700,8
Electric power absorbed by chillers	MWh	132,7	129,7	85,91	74,99
Electric power absorbed by PAC	MWh	26,30	26,30	26,30	26,30
EER (chiller + PAC)	W/W	4,41	4,49	6,25	6,92
pPUE	-	1,52	1,51	1,36	1,33

For the calculation of pPUE have been considered the absorbed powers from rack unit, from chillers (with circulation pumps included) and from Precision Air Conditioners.

Percentage of free-cooling mode operation on annual basis



mechanical cooling

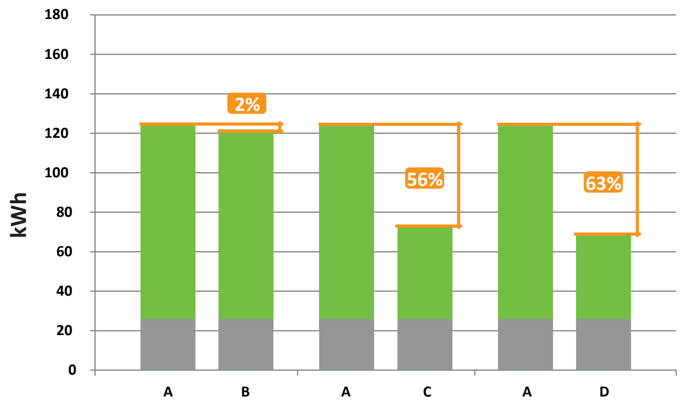
free-cooling

CASE STUDY 2: LONDON

Legend

- **A** Produced water T 15°C (Δt= 5°C)
- **B** Water T 18°C (Δt= 5°C)
- **C** Produced water T 15°C (Δt= 5°C) with free-cooling option
- **D** Produced water T 18°C (Δt= 5°C) With free-cooling option

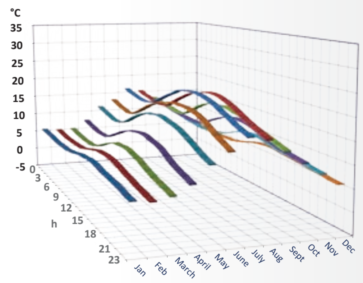
Results of simulations



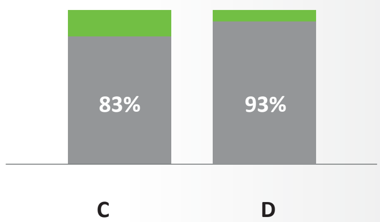
Electricity consumption:

- chiller + pumps
- PAC

Climatic profile of London



Percentage of free-cooling mode operation on annual basis



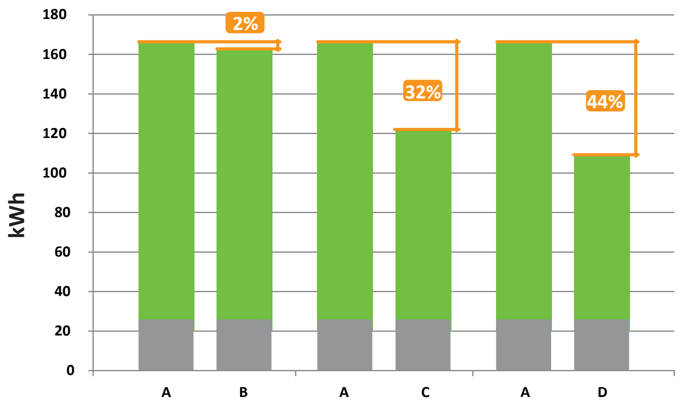
- mechanical cooling
- free-cooling

	CASE	A	B	C	D
Cooling energy required from the Data Center	MWh	700,8	700,8	700,8	700,8
Electric power absorbed by chillers	MWh	117,6	114,9	65,96	61,95
Electric power absorbed by PAC	MWh	26,30	26,30	26,30	26,30
EER (chiller + PAC)	W/W	4,87	4,97	7,60	7,94
pPUE	-	1,47	1,46	1,30	1,29

For the calculation of pPUE have been considered the absorbed powers from rack unit, from chillers (with circulation pumps included) and from Precision Air Conditioners.

CASE STUDY 3: CAPE TOWN

Results of simulations



Electricity consumption:

- chiller + pumps
- PAC

Legend

A Produced water T 15°C (Δt= 5°C)

B Water T 18°C (Δt= 5°C)

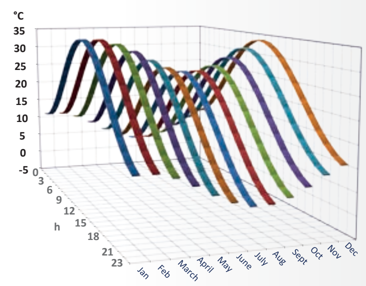
C Produced water T 15°C (Δt= 5°C) with free-cooling option

D Produced water T 18°C (Δt= 5°C) with free-cooling option

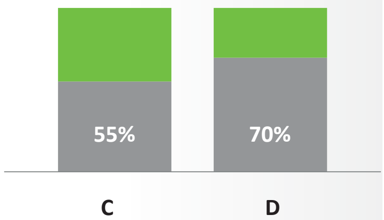
	CASE	A	B	C	D
Cooling energy required from the data center	MWh	700,8	700,8	700,8	700,8
Electric power absorbed by chillers	MWh	159,6	156,0	115,01	102,61
Electric power absorbed by PAC	MWh	26,30	26,30	26,30	26,30
EER (chiller + PAC)	W/W	3,77	3,84	4,96	5,44
pPUE	-	1,60	1,59	1,46	1,42

For the calculation of pPUE have been considered the absorbed powers from rack unit, from chillers (with circulation pumps included) and from Precision Air Conditioners.

Climatic profile of Cape Town



Percentage of free-cooling mode operation on annual basis



- mechanical cooling
- free-cooling

From these results it is evident that the higher operating temperatures (27/40°C compared to 24/35°C) permit to achieve significant energy savings, without compromising the proper functioning of the server, as long as you put adequate attention to the system aspect, confining the air flows and calculating accurately the involved flows.

Aermec S.p.A. via Roma 996 - 37040 Bevilacqua (VR) Italy
T. +39 0442 633111 F. +39 0442 93577
sales@aermec.com
www.aermec.com