FREECOOLING, EVAPORATIVE AND ADIABATIC COOLING TECHNOLOGIES IN DATA CENTER

Applications in Diverse Climates
within Europe, Middle East and Africa

Freecooling, Evaporative and Adiabatic Cooling Technologies in Data Center Applications

Just a few years ago, the standard working temperature of a data center white space was approximately 22 °C. Today, it is quite normal to have data centers running between 24-27 °C in front of the servers, as confirmed by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), who expanded its data center operating temperature guidelines. The data center environment is getting hotter and data center management has evolved accordingly to incorporate more power and higher temperatures.

Data center designs, in accordance with ASHRAE guidelines, have thus accepted to move to the upper limit of the recommended envelope, and in some cases, even to the allowable ranges (A1-A4), allowing data center managers and manufacturers to be creative with cooling solutions. One of the most efficient solutions that have recently been introduced is adiabatic and evaporative cooling: an ancient technique brought into the 21st century.

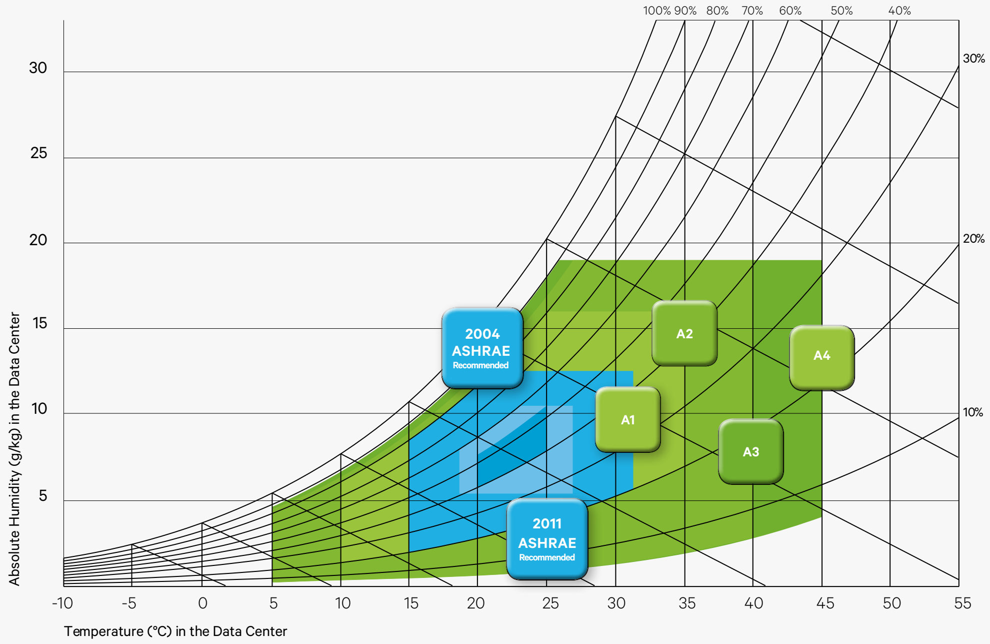


Figure 1. *ASHRAE guidelines*

Using Freecooling Technology in Europe, Middle East and Africa (EMEA)

The traditional cooling approach considers open aisle architectures with return air temperatures to cooling units between 22-26°C and supply air temperatures to the data center between 10-14°C to be considered standard. With the use of intelligent air distribution management to the servers, data center designers and facility managers can increase chilled water temperatures from the standard 7-12°C, to 20-26°C. As a result of the Vertiv™ SmartAisle™ cold aisle containment solution, the servers' exact cooling and airflow needs are met, thus investing only necessary kilowatts in targeted cooling.

The Vertiv SmartAisle solution increases space efficiency and provides uniform and predictable temperature to all IT equipment, directly controlling cold aisle temperature and humidity.

Combined with the right chiller, such as the Liebert® HPC freecooling chiller or the Liebert AFC adiabatic freecooling chiller, the benefits are even greater:

- Higher capacity at smaller footprint
- Significant energy savings as a result of the freecooling usage for a significant number of hours per year
- Low noise operation.

In this paper, we will investigate the impact of using freecooling technologies with and without adiabatic and evaporative technologies in major EMEA cities.

Introducing Adiabatic and Evaporative Cooling Technologies

How Adiabatic and Evaporative Cooling Works

By using an ancient process with a heritage that can be traced back to the Roman Empire, adiabatic/evaporative cooling is a process of reducing air temperature as a result of water evaporation in the air. Over 2,000 years ago, the system was used to lower the temperature in a hot room by spraying water into the air or on the floor, which has a cooling effect on the area as the water evaporates.

Today, adiabatic/evaporative cooling uses the principles of the ancient system with the benefit of 21st century technology within the category of thermal management units.

The Benefits of Adiabatic Cooling Applied to Freecooling Chillers

The ancient adiabatic cooling principle can be used today to significantly reduce data center energy bills. One of the most interesting possible applications is the enhancement of a freecooling chiller's efficiency, obtained by humidifying ambient air going into the heat rejection coils (both the condensing and freecooling ones). The ambient air is humidified and cooled down, without incurring in any additional energy cost, by passing through wet pads.

Air is thus delivered at a lower temperature to the freecooling and the condensing coils, thus achieving respectively a higher freecooling capacity and a more efficient compressor operation.

With a chiller operating at full load, the following annual energy savings can be expected when adopting this system:

- Compared to a freecooling chiller, a saving of 25-35%
- Compared to a standard air-cooled chiller, a saving of 60-65%.

In cases of systems with redundancy and part load conditions, the energy savings can be even higher.

The adiabatic freecooling chiller thus offers new levels of efficiency, allowing data center managers to reduce overheads.

Liebert® AFC - The First Integrated Adiabatic Freecooling Chiller in the Market

As a result of these smart applications, new generation data centers will be able to provide unparalleled benefits in terms of cost saving, reliability and cooling availability.

A freecooling chiller with an integrated adiabatic system design in one single unit is, in fact, able to guarantee 100% cooling even in the worst environmental conditions of ambient temperatures peaks. This also holds true in the case of water shortages, where back-up compressors will provide full capacity whenever needed. Another significant advantage of such unit is its ability to retrofit existing thermal management systems or existing chilled water type designs, without the need to re-design the entire cooling infrastructure. It is important to note that the Liebert® AFC reaches its peak performance when operated in conjunction with floor mount units such as Liebert PCW and Vertiv™ SmartAisle™ containment, thus granting superior freecooling and energy savings.

So far, cutting-edge data centers have been preferably located in cold climatic areas, in order to leverage the cold ambient air, thus increasing the use of freecooling and consequently improving annual efficiency. For example, the best mechanical power usage effectiveness (pPUE) value that can be achieved by a highly efficient freecooling system in Northern Europe (i.e. a chilled water system in Oslo, working between 20°-15°C water temperatures) is in the range of 1.11-1.15.

In **warm countries**, such as the Mediterranean area, the use of freecooling is traditionally very limited and compressors cover most of the cooling load, in terms of hours per year. For this reason, data center managers conventionally conceived freecooling systems as being less attractive compared to a standard air-cooled chiller system; the latter achieving pPUE values of 1.2-1.3.

The recent trend, however, has seen freecooling become increasingly convenient, as a result of an increase in chilled water temperatures alongside the increase in data center air temperatures.

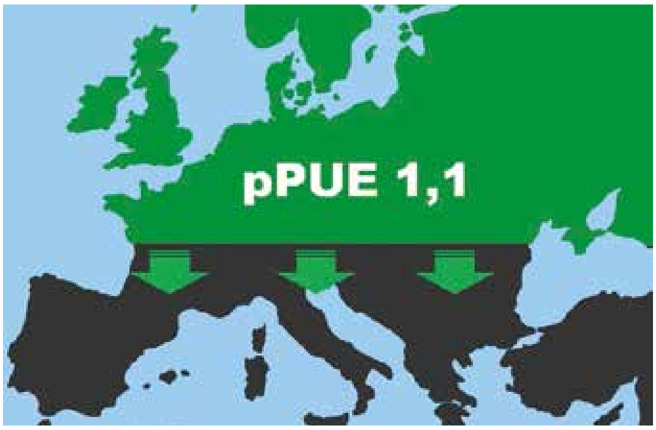


***Figure 2.** Adiabatic cooling allows for pPUE values as low as 1.1 even in southern EMEA countries.*

***Figure 3.** Liebert® AFC adiabatic pads*

An adiabatic wet pad system is able to decrease the temperature of the air entering the freecooling coils of 5-10°C (depending upon weather conditions), thus allowing freecooling to operate at even higher ambient temperatures.

This system, moreover, delivers even greater benefits to the data centers working at partial loads; as a result of a considerable adiabatic freecooling capacity which covers the load almost all year round.

The compressors' cooling back-up is called on duty only in case of simultaneous peaks both in data center loads and external ambient temperatures: but this happens only for a very limited amount of hours per year.

If we consider two different European cities, such as London and Madrid, as shown in ***Figure 4***, it is clear that, **at full data center load**, Liebert® AFC can run in hybrid mode (adiabatic freecooling plus backup compressors) at almost 100% of the time. Even more impressive is that even in cities such as Dubai, which register a higher average ambient temperature, the hybrid mode is active for 50% of the time.

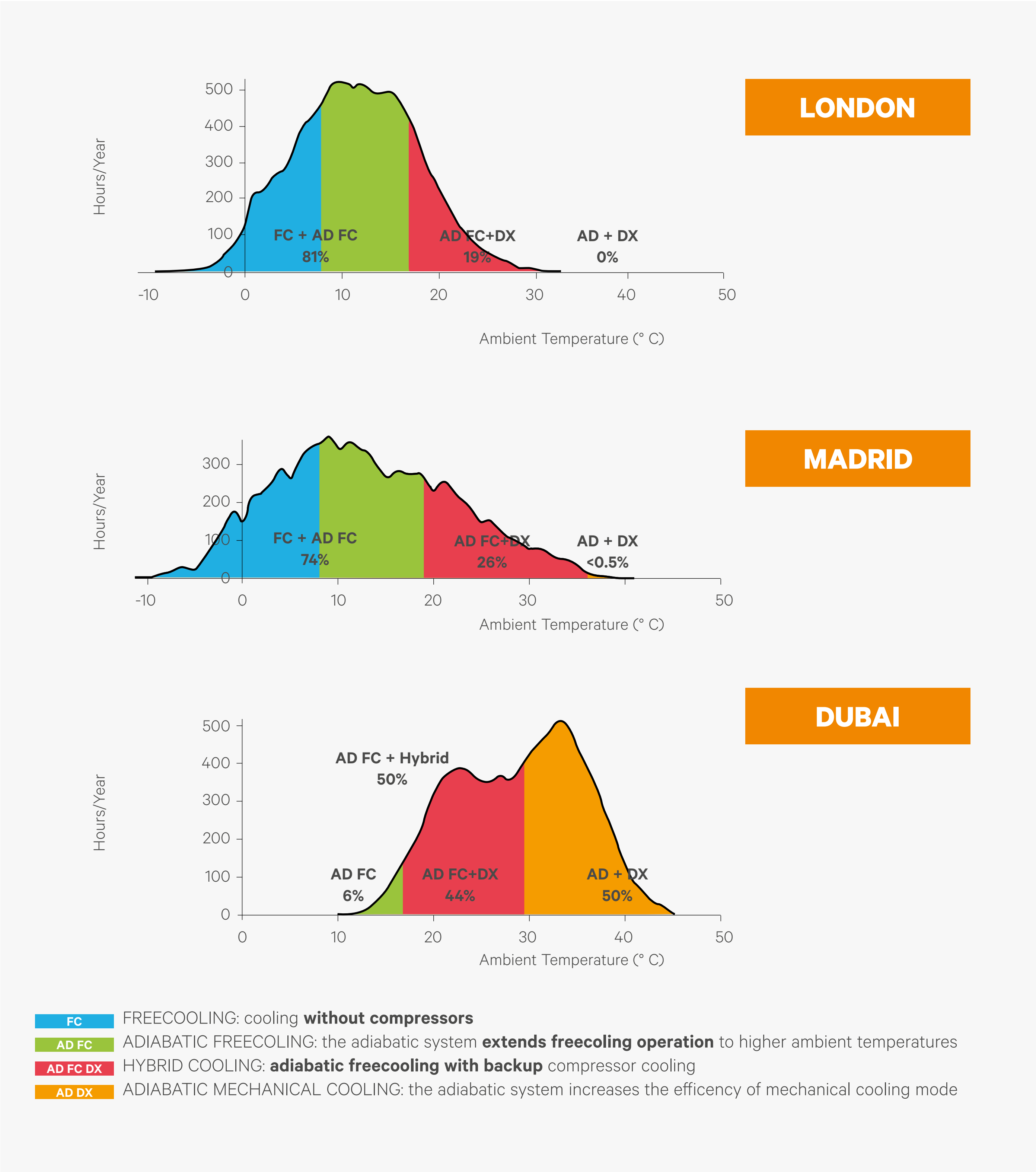


Figure 4. *Liebert AFC annual operating modes in London, Madrid, Dubai, 1 MW Tier 4 data center at full load (chillers at 50% load) – Adiabatic ON for ambient temperatures >8°C*

The benefits are significant also when we examine the mechanical power usage effectiveness obtained using our Liebert® AFC solution. If we consider a legacy solution, including a standard chilled water floor mount unit and an air-cooled chiller (units with efficiency at standard market levels), the pPUE obtained is of **1.21 in London and 1.31 in Dubai**. If we consider the same data center requirements, but with Liebert PCW and Liebert AFC (working with designed chilled water temperatures of 26-20°C and a data center air supply of 22°C) the pPUE obtained is of **1.06 in London and 1.18 in Dubai**, which are both significantly lower values compared to those obtained with the legacy solution.

In these units, in fact, the water consumption has a very low impact in terms of costs when compared to the energy savings achieved.

This is possible as a result of an optimized design and advanced control logic specifically conceived for this new product. The electronic control predictively calculates the balance between water and energy costs and implements the combination which optimizes operating costs.

CITY	AIR-COOLED CHILLER CW 12-7 °C	STEP 1 FREECOOLING CHILLER CW 15-10 °C	STEP 2 FREECOOLING CHILLER CW 26-20 °C	STEP 3 ADIABATIC FREECOOLING CHILLER CW 26-20 °C
London	pPUE 1.21	pPUE 1.17	pPUE 1.09	pPUE 1.06
Madrid	pPUE 1.22	pPUE 1.18	pPUE 1.12	pPUE 1.07
Dubai	pPUE 1.31	pPUE 1.32	pPUE 1.24	pPUE 1.18

Figure 5. pPUE *values in different cities. These values consider a chilled water system composed of CRACs, pumps and different chiller technologies.*

The Benefits of Evaporative Cooling Applied to Indirect Evaporative Freecooling Units

The Liebert® EFC is Vertiv's indirect evaporative freecooling unit which acts as a complementary unit to the Liebert AFC adiabatic freecooling chiller. Both use the adiabatic/evaporative cooling technology, but the former also includes indirect air-to-air heat exchange.

The Liebert EFC is capable of reducing air temperatures by leveraging the evaporative cooling principle through the evaporation of pressurized water which cools the surrounding air. The highly efficient evaporative system sprays water inside the unit, as well as onto the heat exchanger to enable cooling even at high ambient air temperatures, without the need for mechanical cooling.

The evaporative principle uses air to absorb water that is sprayed at high pressure. Water evaporation thus removes heat from the air and cools the outside air temperature. Outside air consequently transitions from dry bulb temperature to wet bulb temperature (***Figure 6*** shows the transition from 35°C to 20°C). The use of evaporative cooling allows freecooling operation to be maximized and compressor-related cooling to be reduced to a minimum, thus optimizing operating costs even further.

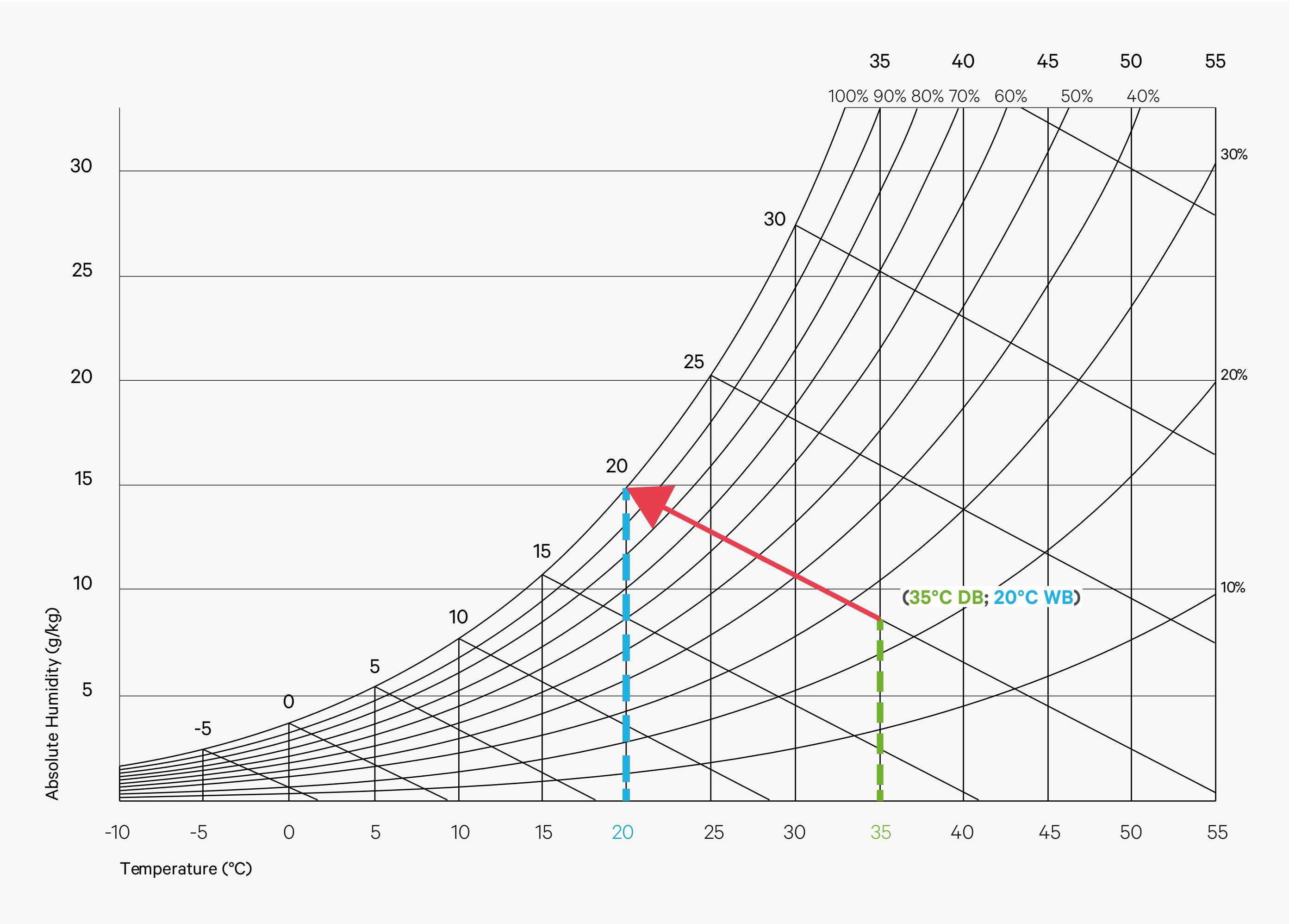


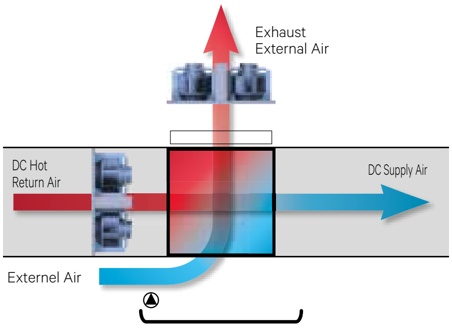
Figure 6. *The Psychrometric Chart*

In order to optimize the overall system efficiency, the Liebert® EFC unit has been designed to automatically change its operating mode according to the external environment. When the external air is cold enough to allow for freecooling, the unit works in dry operation mode (winter operation mode).

Higher ambient temperatures and external humidity determine unit capacity and performance as the evaporative effect is directly associated to the external air capacity in order to absorb water.

When the unit operates in environments with a higher temperature and lower relative humidity (summer operating mode), Liebert EFC works in evaporative mode. In climates featuring high levels of humidity, the unit may require the integration of a Direct Expansion (DX) system or the installation of a Chilled Water (CW) coil (DX/CW operation mode).

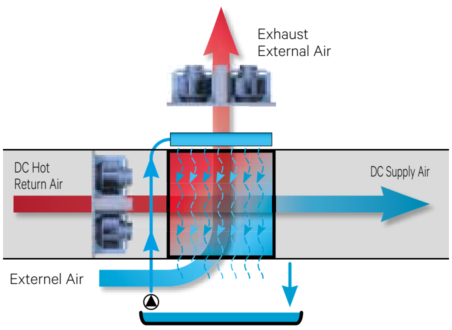
Winter



Dry Operation

Air-to-Air Heat Exchange Without Spraying Water

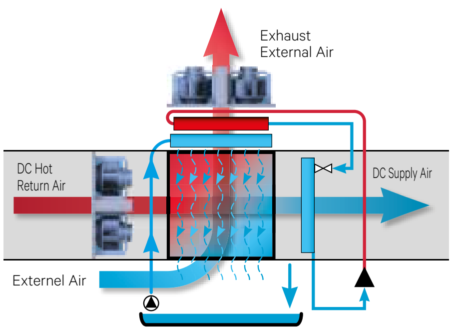
Summer



Wet Operation

Air-to-Air Heat Exchange Via the Spraying of Water to the External Air Side

Optional



DX/CW Integration

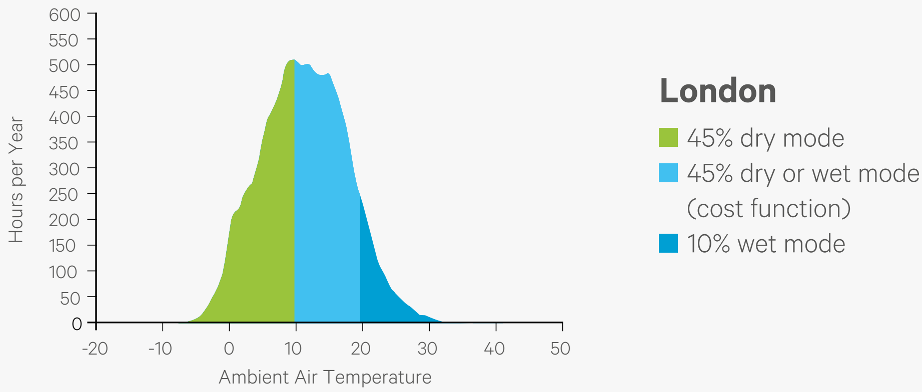
External Air Is too Hot to Achieve 100% Cooling with Adiabatic, the DX Module Is thus Integrated to Cover the Missing Capacity

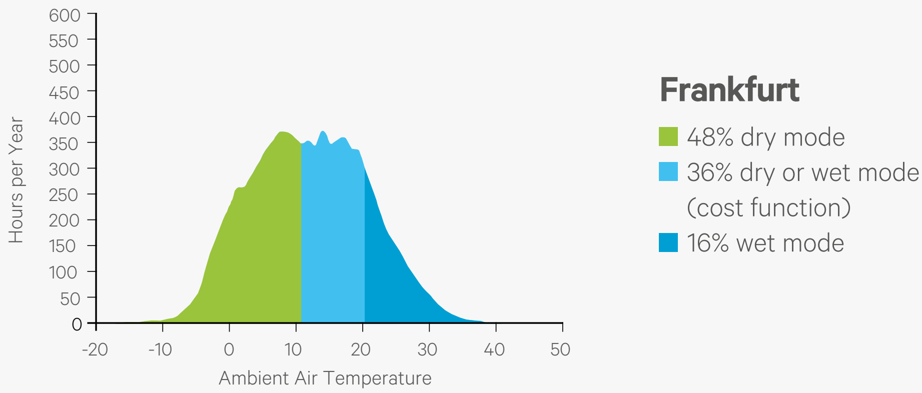
Figure 7. *Liebert EFC operating modes*

While respecting ASHRAE guidelines, the Liebert® EFC unit can be installed not only in colder climates, where the unit takes advantage of the dry operating mode, but also in hotter ones (as shown in Figure 8 for Istanbul), where DX operation is reduced to a minimum and used only during extreme temperature peaks that occur throughout the year. This results in a significant reduction in electrical consumption, even at full load (reaching the highest possible savings at partial loads).

The cost function, which is the software logic embedded in the control, optimizes running costs (water and electricity), and, according to the external dry bulb and heat load, selects the most convenient working mode (i.e. dry vs. wet). With the same logic, the cost function will also optimize the use of the optional DX mode.

ASSUMPTIONS: DATA CENTER 36°C ⟶ 24° C
100% IT LOAD (N REDUNDANCY OPERATION)





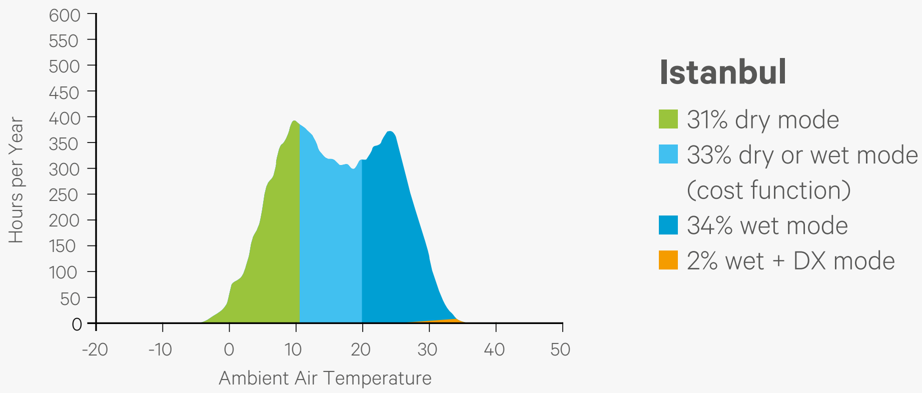


Figure 8. *Liebert EFC operating modes in different cities*

One of Liebert® EFC's key differentiators is its state-of-the-art Vertiv™ ICOM™ Control which guarantees water management and energy optimization both at unit and teamwork level. The user-friendly Vertiv ICOM Control collects information from different units' key parameters and operating modes (dry, wet and DX/CW) while taking into account water and electricity costs. This allows the control to predictively calculate and implement the combination which optimizes operating costs.

Liebert EFC also offers a constant control of data center air via its integrated control logic, ensuring dew point temperature is lower than heat exchanger surface temperature, thus avoiding unnecessary dehumidification which often occurs during extreme winter operation (i.e. temperatures <-20°C). This occurs when the unit's unnecessary internal dehumidification can cause it to exceed ASHRAE recommended minimum humidity levels.

The Vertiv SmartAisle™ control logic, moreover, optimizes internal air volumes and temperatures according to specific server needs and allows Liebert EFC to exactly match the servers' airflow needs, ensuring that not even a single watt is wasted in moving or cooling unnecessary air.

As a result of these state-of-the-art technologies, both in terms of servers and in thermal management technologies, top efficient data centers today can also be built in warmer climates, thus contributing and leading the way to a significant reduction in global energy consumption.

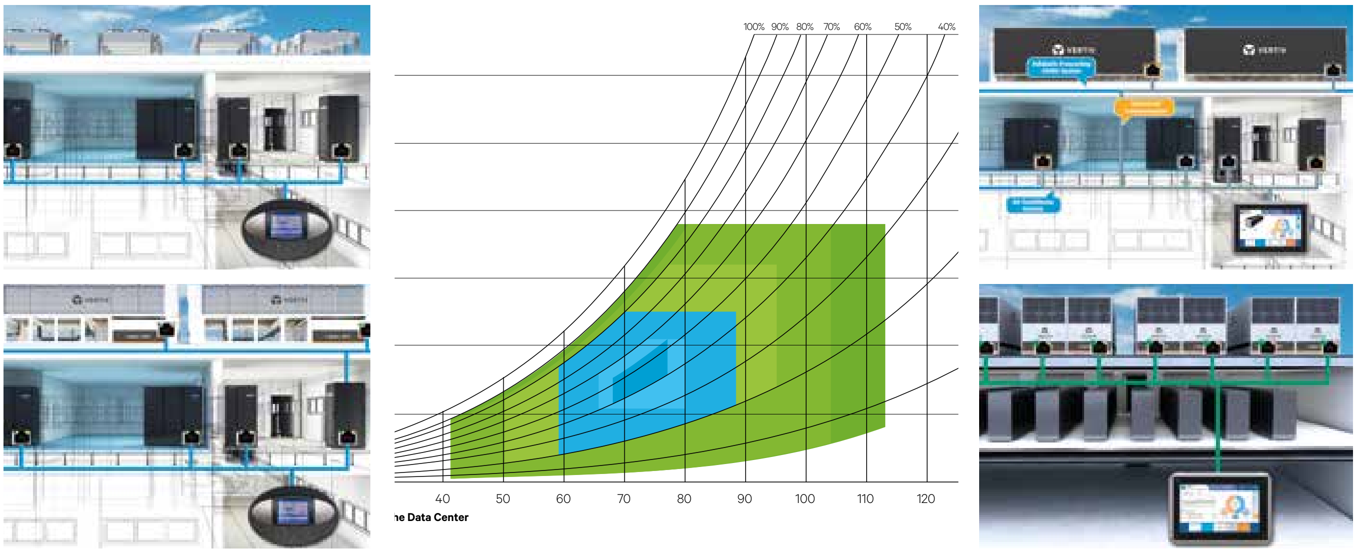
The Thermal Management Product Portfolio

With the introduction of the Liebert® AFC adiabatic freecooling chiller and the Liebert EFC indirect evaporative cooling unit, Vertiv™ can offer the solution that better meets any data center need (i.e. maximized availability, reduced total cost of ownership, higher efficiency, lower installation costs, unit modularity or outdoor space limit) independently of the application:

- **Direct expansion systems:** from floor-mount to in the row units able to operate at high return air temperatures suitable for the increased temperatures within which the IT equipment works
- **Chilled water systems:** highly efficient chilled water floor mount units and freecooling chillers that maximize freecooling operation all year round
- **Adiabatic chilled water systems:** combining adiabatic, freecooling and mechanical cooling technologies in a single unit
- **Indirect evaporative freecooling:** indirect air-to-air heat exchange and evaporative cooling technologies in one footprint.

DIRECT EXPANSION

ADIABATIC CHILLED WATER



CHILLED WATER

EVAPORATIVE

Utmost Efficiency at the Data Center System Level with the Vertiv ICOM™ Control

The last remarkable aspect of Vertiv's Thermal Management solutions lie in the innovative Vertiv ICOM Control which exploits the function of a single unit operation as well as multiple units working together (the teamwork mode). This feature is extremely important in order to maximize energy efficiency within a data center environment. In addition to the teamwork mode available in any Thermal Management unit, on Liebert AFC and Liebert EFC, the Vertiv ICOM Control also exploits the management of energy and water by collecting information from the different units' key parameters and operating modes while taking into account water and electricity costs.

The control predictively calculates and then implements the combination which optimizes operating costs.

When considering the entire data center scenario, including indoor and outdoor units, the Vertiv ICOM Control becomes the key driver in terms of delivered efficiency at the data center system level.

The software logic, embedded in the control, ensures the perfect coordination of the whole system, thus leading to superior energy savings at the entire data center level.

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