THERMAL MANAGEMENT

TECHNOLOGIES, BASICS OF PSYCHROMETRIC INTRODUCING ADIABATIC AND EVAPORATIVE COOLING SOLUTIONS

VERTIV™

VERTIV.

CORPORATE FACT SHEET

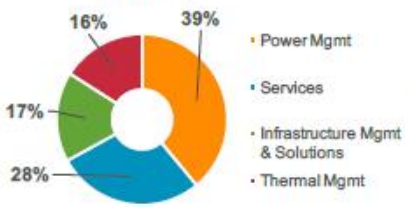
Empowering Vital Applications For a Digital World

WHO WE ARE

Vertiv designs, builds and services critical infrastructure that enables vital applications for data centers, communication networks and commercial and industrial facilities. We support today's growing mobile and cloud computing markets with a portfolio of power, thermal and infrastructure management solutions.

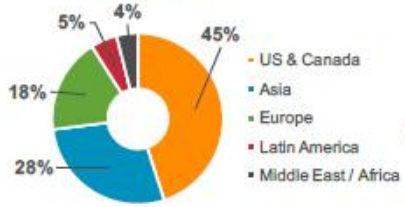
We offer unsurpassed global scale and broad expertise, built from our heritage as Emerson Network Power. And now as Vertiv, we match industry leadership with the focus and spirit of a startup.

Offering



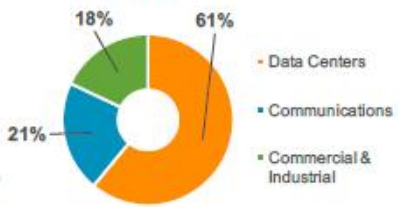
Broad range of power, thermal and infrastructure management portfolio

Geography



Global, well-established footprint and supply-chain network

End Market



Serve vital applications in data centers, communication networks and commercial/industrial environments

KEY FACTS

STATUS
Privately held

REVENUE
USD 4.4 billion (fiscal 2016, as Emerson Network Power)

HEADQUARTERS
Global: Columbus, Ohio, USA
Regional: China, India, Philippines, United Kingdom

LEADERSHIP
Rob Johnson, CEO

EMPLOYEES
~20,000 worldwide

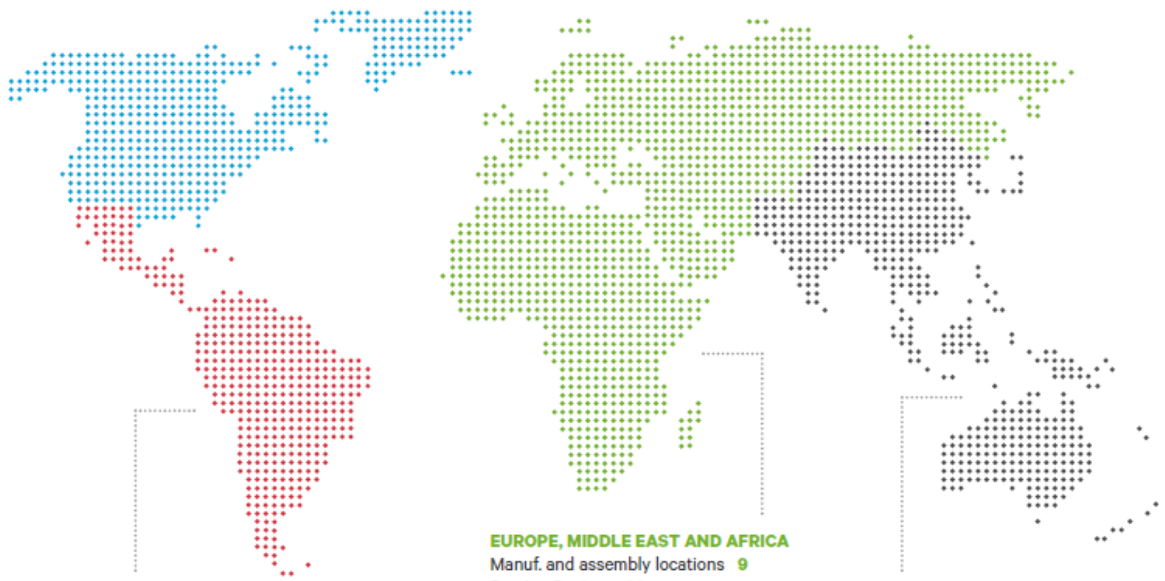
MAJOR CUSTOMERS
America Movil, AT&T, China Mobile, Ericsson, Facebook, Microsoft, Reliance, Verizon

OUR VISION

We seek to help our customers create a world where critical technologies always work

OUR GLOBAL PRESENCE

Meeting Our Customer Wherever They Are



US AND CANADA
Manuf. and assembly locations 13
Service Centers 80+
Service Field Engineers 965+
Technical Support/Response 145+
Customer Experience Centers/Labs 5

GLOBAL PRESENCE
Manuf. and assembly locations 28
Service Centers 255+
Service Field Engineers 3,135+
Technical Support/Response 415+
Customer Experience Centers/Labs 14

LATIN AMERICA
Manuf. and assembly locations 1
Service Centers 15+
Service Field Engineers 535+
Technical Support/Response 100+
Customer Experience Centers/Labs 2

EUROPE, MIDDLE EAST AND AFRICA
Manuf. and assembly locations 9
Service Centers 60+
Service Field Engineers 535+
Technical Support/Response 100+
Customer Experience Centers/Labs 4

ASIA PACIFIC
Manuf. and assembly locations 5
Service Centers 95+
Service Field Engineers 945+
Technical Support/Response 75+
Customer Experience Centers/Labs 3

OUR FLAGSHIP BRANDS

ASCO® Our global critical power switching, control and management solutions, engineered to the most demanding specifications, ensure power, reliability, compliance and efficiency.

Chloride® Our global industrial power solutions meet the most demanding technical specifications and provide safe, reliable power – no matter the challenge.

Liebert® Our global power and thermal management solutions are some of the world's most efficient and reliable power and cooling technologies.

NetSure™ Our global, intelligently engineered power systems deliver high availability, energy efficiency and scalability for converged networks.

Trellis™ Our industry leading software gives customers an integrated view of operations across IT and facilities resources, enabling better decisions that save time and money.

Thermal Management

VERTIV.

DATACENTER REQUIREMENTS SUMMARY

OPEX

UPTIME

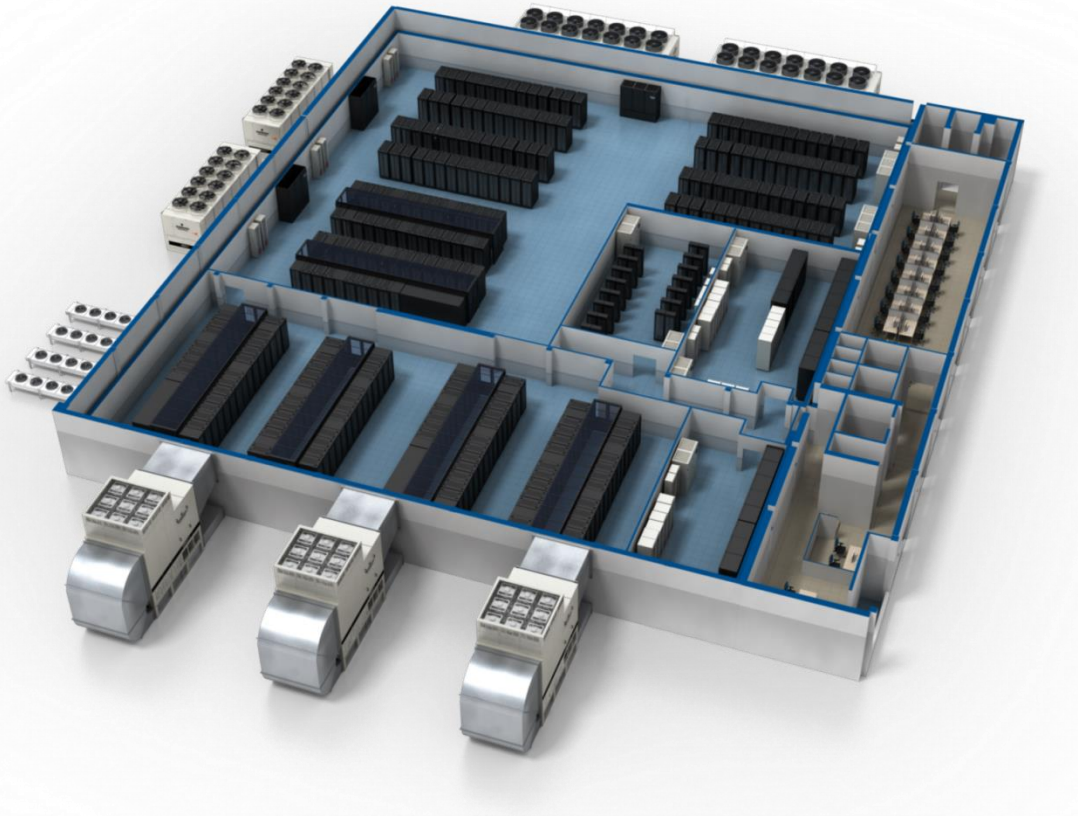
Data Centers Trends

- Cloud Computing
- Virtualization
- Latent Power of “Big Data”
- Exponential Use of Mobile Devices
- Network

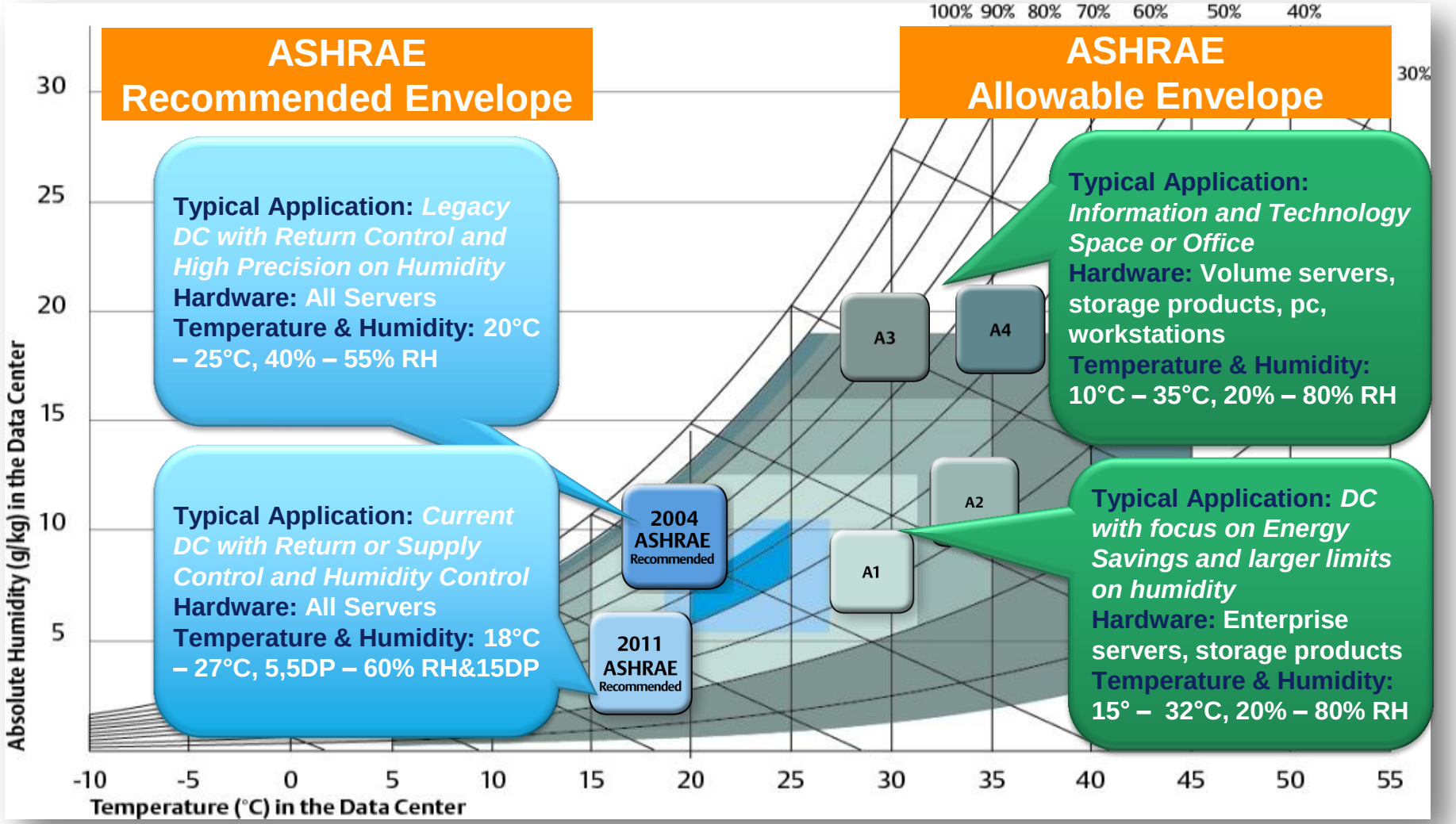
THE DATA CENTER WORLD

- Over the last few years, the **data center ecosystem** has become mission-critical in supporting major innovation trends.

- This has consequently driven an **increase in operating temperatures** within which IT infrastructure functions, defined by **ASHRAE** recommended and allowable temperature and humidity envelopes.

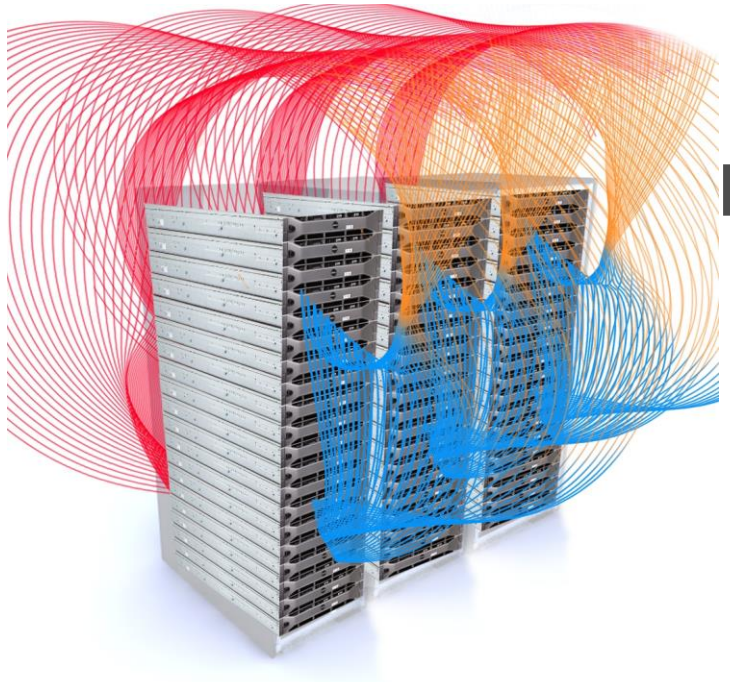


DATA CENTER OPERATING THRESHOLDS



BACK TO THE BASICS: IF AIRFLOW IS NOT ENOUGH…

Hot Aisle

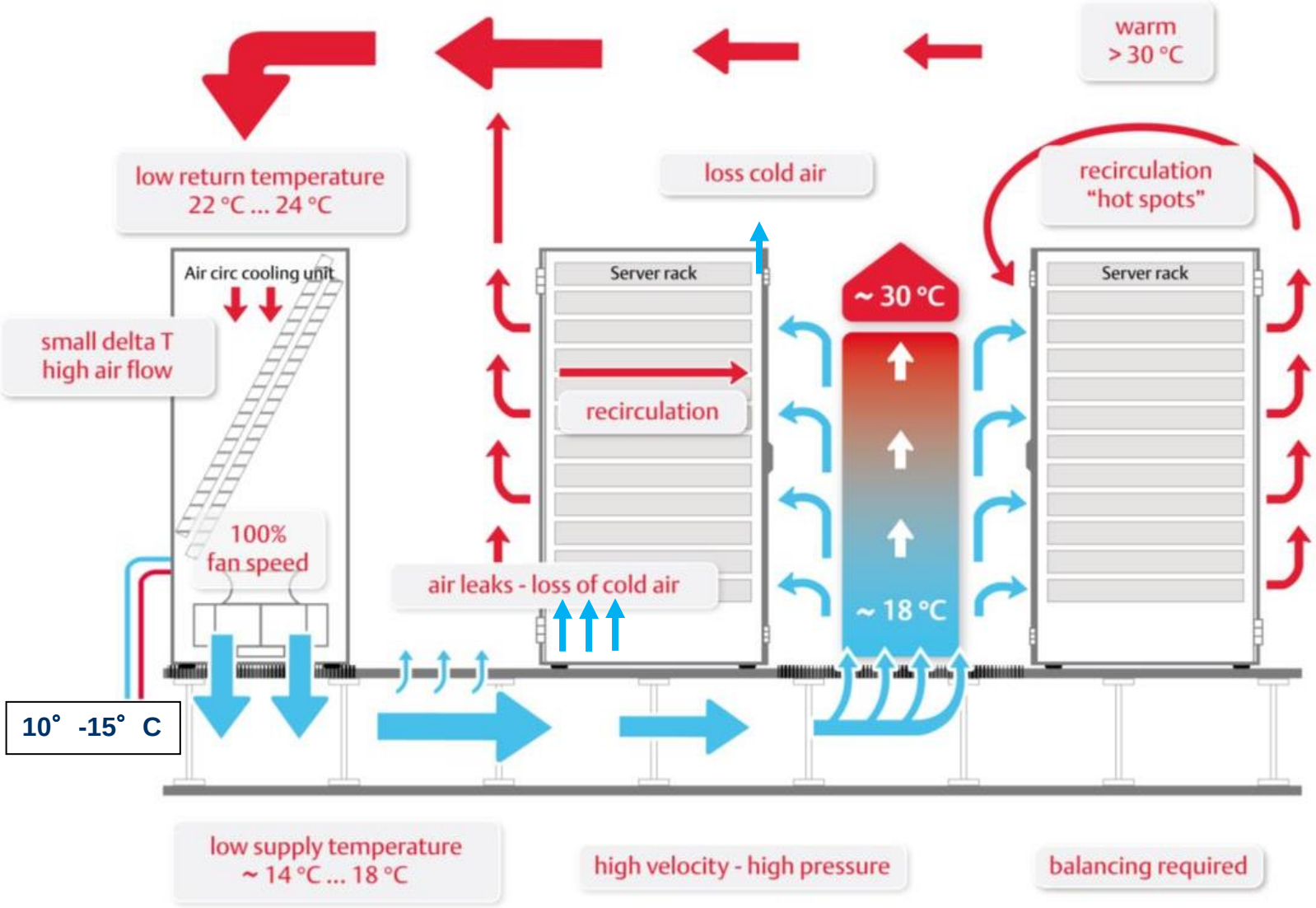


Recirculation

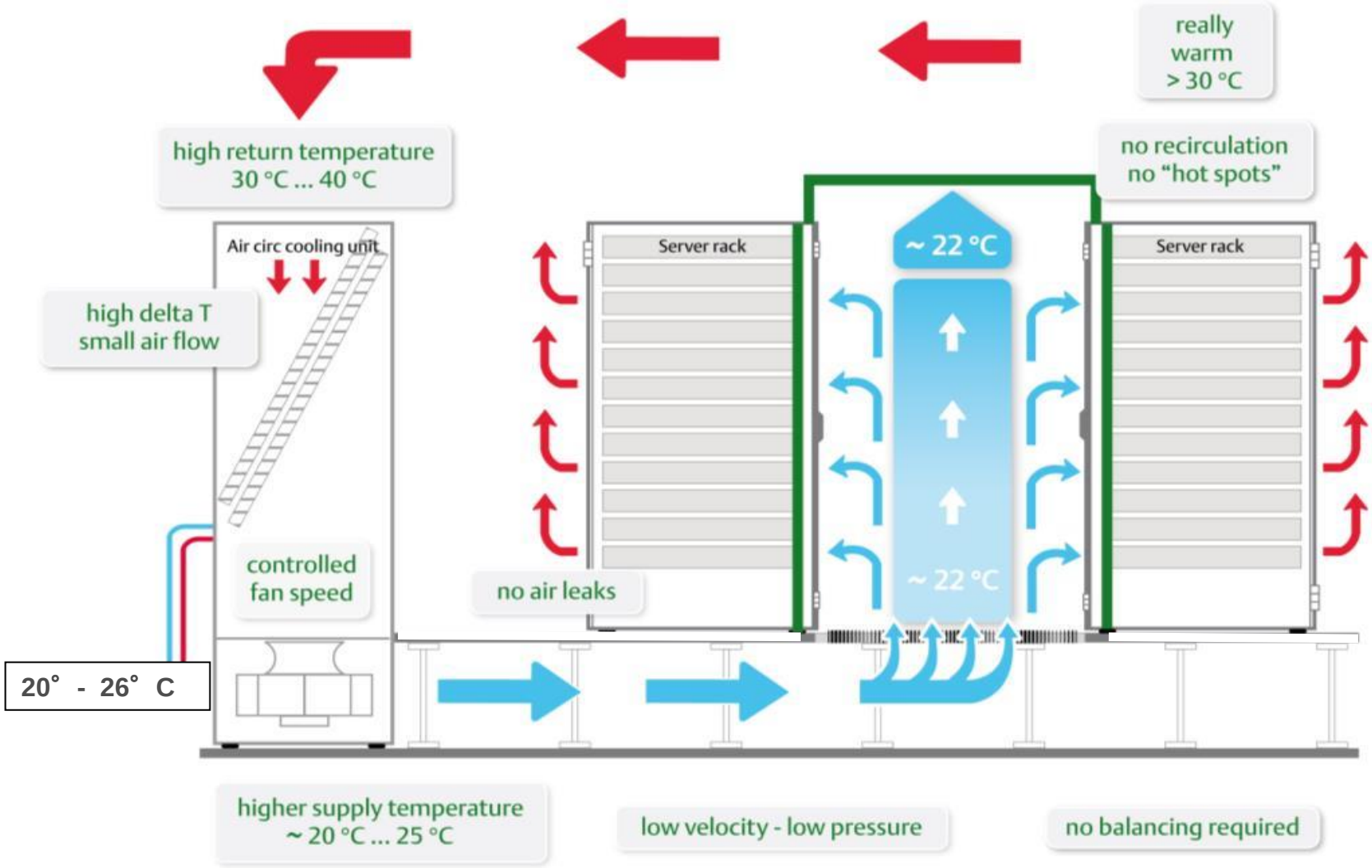
Cold Aisle

- **If we break while accelerating a car won't work properly..**
  - Breaks will be overheating
  - Fuel consumption increase
  - Lifetime compromised
  - …..
- **The same is happening in a Datacenteris**
  - *Air path are not pre-determined: air goes wherever it want: the lowest effort is the one it follow!*
  - *Energy consumption will be increasing*
  - *Server overheating is expected*
  - *Lifetime compromised*
  - *…*

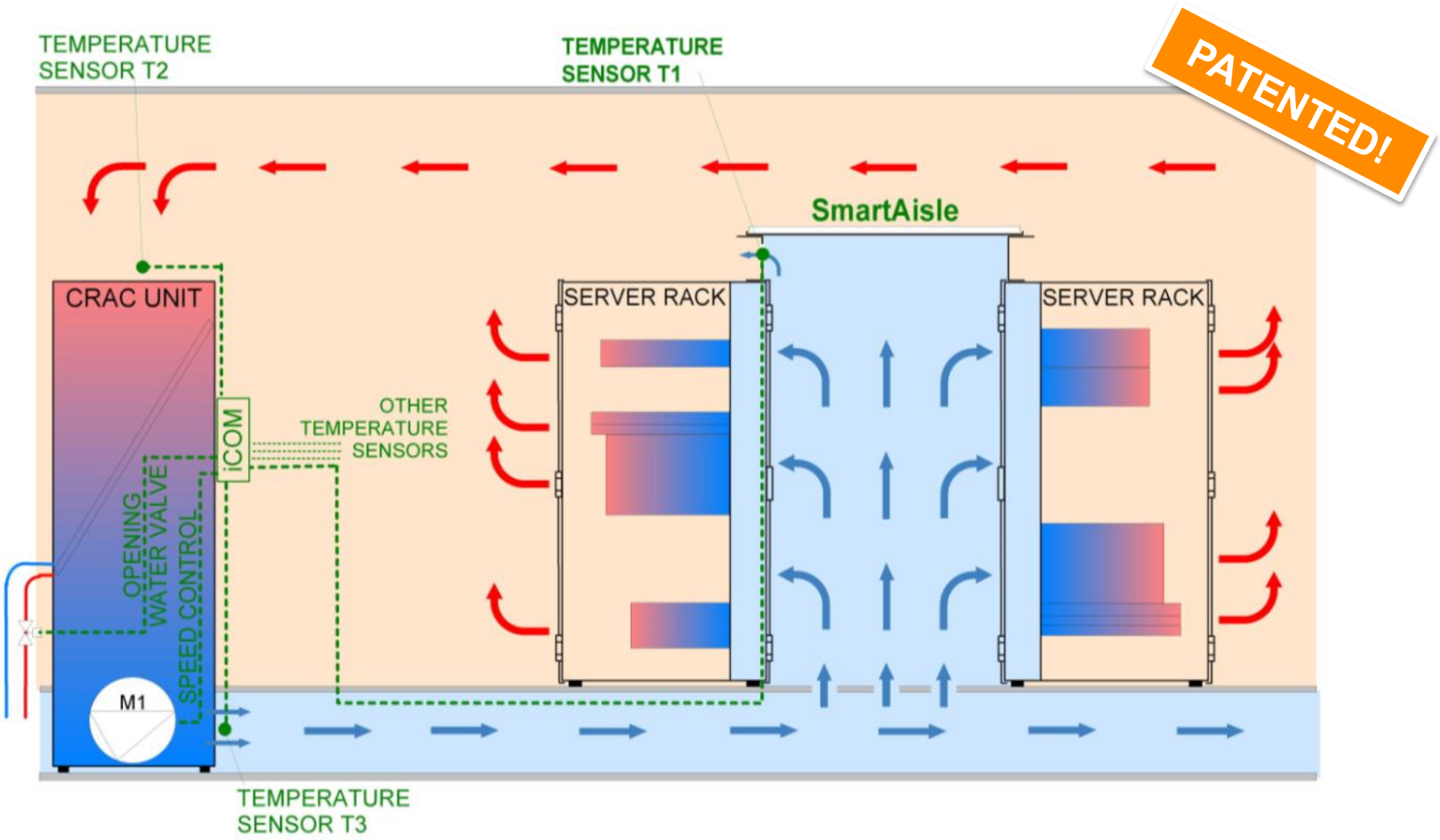
LACK OF “AIR PATH MANAGEMENT”



SIMPLICITY WINS: HOT-COLD SEPARATION



BEING SIMPLE AND BEING SMART...AISLE™



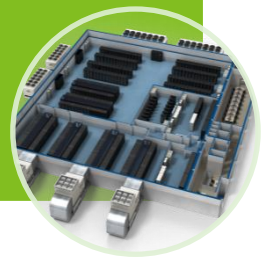
DATACENTER REQUIREMENTS & TECHNOLOGIES AVAILABLE

- **Temperature Control**
- **Humidity Control**
- **Air Filtration**
- Air Contamination
- Target Efficiency
- Availability (Risk)
- Servers'
- Replacement Cycle

Data Center Requirements

- **Conventional:**
  - **Direct Expansion**
  - **Chilled Water**
- **Air-to-Air Evaporative**
  - **Indirect Evaporative**
- **Freecooling water based**
  - **One control loop sys**

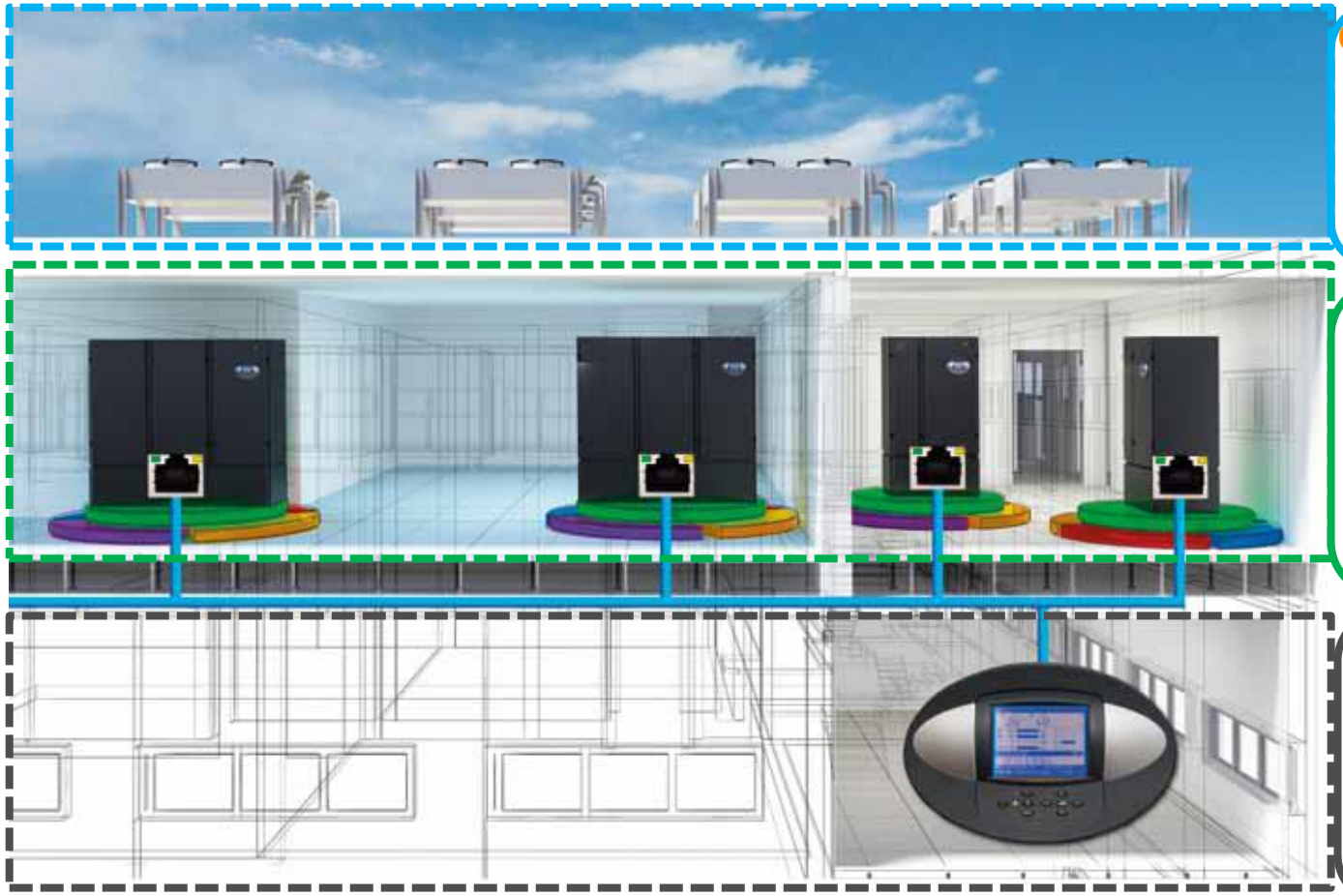
Thermal Management Technologies



- White Space
- **Outdoor Space Limit**
- **Building Type (Multi-storey/Warehouse)**
- **Location:**
  - *Noise Issues*
  - *Air Quality*
  - *T and H Profile*

Building & Location Constraints

DIRECT EXPANSION SOLUTION



Outdoor Condensers:

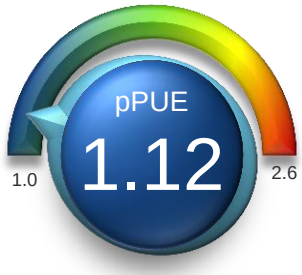
- Reduced refrigerant charge, with micro-channel coils
- Intelligent communication with floor-mount units

Direct Expansion Floor-Mount:

- Designed to suit 38°C of return temperature
- Includes the economizer to provide direct or indirect freecooling for the data center

Control of airflow and temperature in front of the servers:

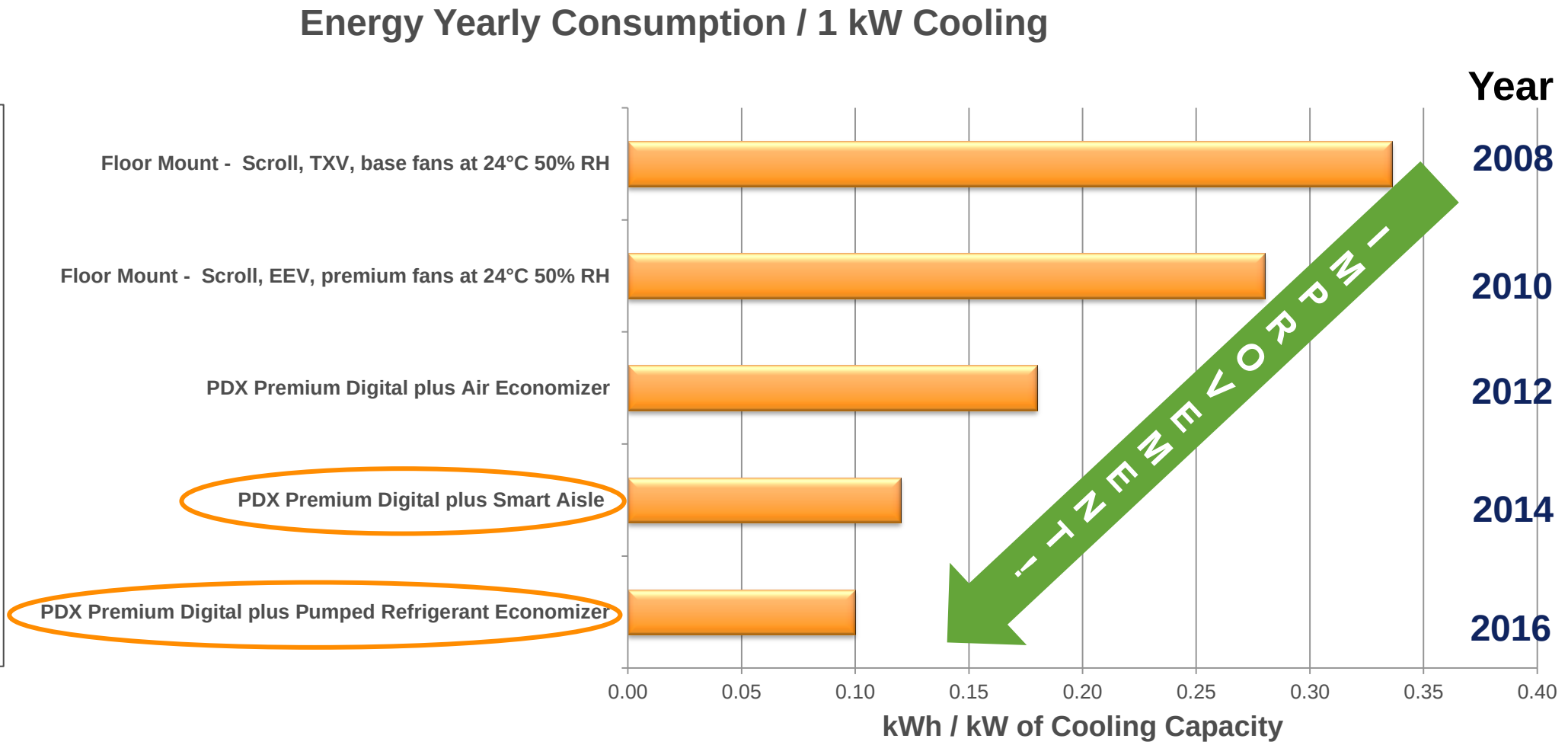
- Always provides the right quantity of air at the right temperature



ENERGY CONSUMPTION OF DIFFERENT DX SYSTEMS

Market and Customer Requirements:

The Data Center Technology trend anticipates higher servers' working temperatures, lower pPUE



LIEBERT® PDX – FROM 5 TO 120 KW

Liebert® EC Fan 2.0

- Increased Efficiency
- Reduced Noise
- New Blade Design

EUROVENT CERTIFIED PERFORMANCE

Freecooling Modes

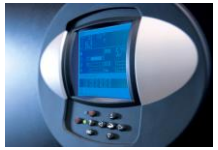
- Direct Freecooling
- Water/Indirect Freecooling
- Liebert® EconoPhase™ Pumped Refrigerant Economizer

Liebert® MC – Microchannel Condenser

- Microchannel Coil
- EC Fan To Maximize Efficiency at Part Load

iCOM™ Control

- First Networking Controller
- Featuring teamwork capabilities with other Liebert units thus optimizing resources within the controlled space
- IP based



Digital Scroll Compressor

- Capacity modulation
- Quick adaptation to changing heat loads
- Strongly reduces energy consumption with SmartAisle

LIEBERT® PDX WITH ECONOPHASE™ – 80 - 170 KW

EconoPhase Solution

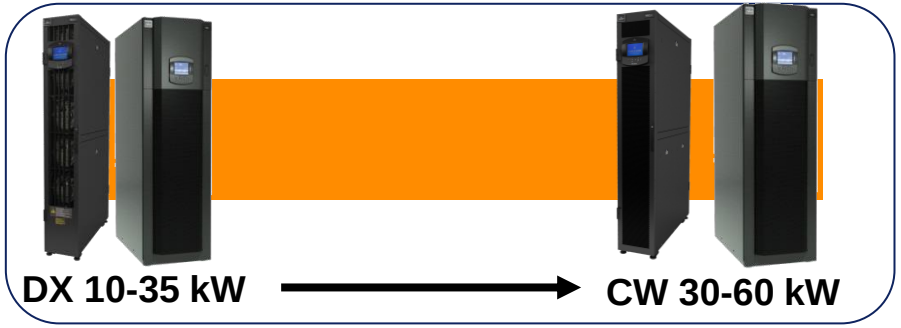
- **The most efficient direct expansion solution in the industry**
- The possibility to reach incredibly **low pPUE** with the **scalability** of a Direct Expansion Solution

Project Details

- Expand the **Liebert PDX range up to 170 kW** including the Econophase Solution
- Biggest Direct Expansion Unit in whole EMEA

Liebert® PDX with EconoPhase™, our direct expansion solution with the pumped refrigerant economizer, has won the 2016 **DCS Award** under the category **Data Center Cooling Product of the Year**

LIEBERT® CRV – IN ROW COOLING

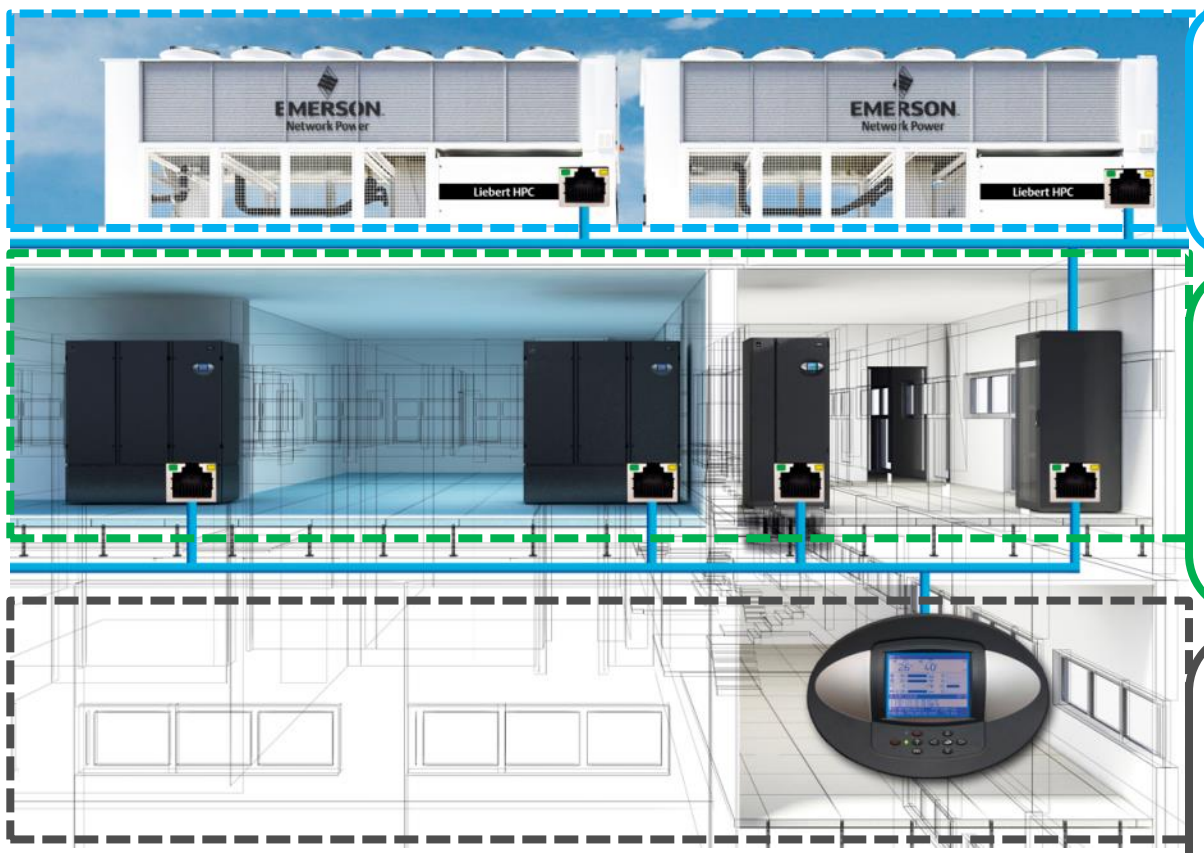


- Positioned directly **in the row of racks**
- Cooling Capacity **10-60 kW**
- **DX and CW** versions
- **Heat density up to 11 kW / Rack**
- For applications **with or without raised floor**
- **Flexible air distribution** – left, right or both sides (adjustable on site)

	Direct Expansion (DX) Air Cooled / Water Cooled				Chilled Water (CW)			
	CR011RA	CR021RA	CR020RA/W	CR035RA/W	CR038RC	CR060RC	CR040RC	CR050RC
kW	11.0	20.7	23.4	36.4	38.5	57.0	46.6	58.0
Width	300 mm Frame		600 mm Frame		300 mm Frame		600 mm Frame	

Rating Conditions:
DX – 38 °C, 22% RH, 35 °C Outdoor Temperature
CW – 38 °C, 22% RH, 7/12 °C CW Temperature

CHILLED WATER SOLUTION



Freecooling Chillers:

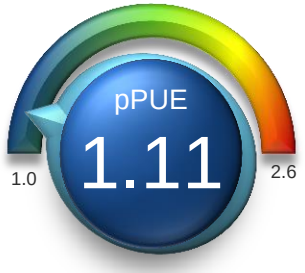
- Maximizes the freecooling effect
- Increases CW temperatures (up to 26/20°C CWT)

CW Floor-Mount Units:

- Full range from 30 to 200 kW
- Up to 70% improvements compared to industry standards
- Economizer to provide Direct Freecooling for Data Center

Control of airflow and temperature in front of servers:

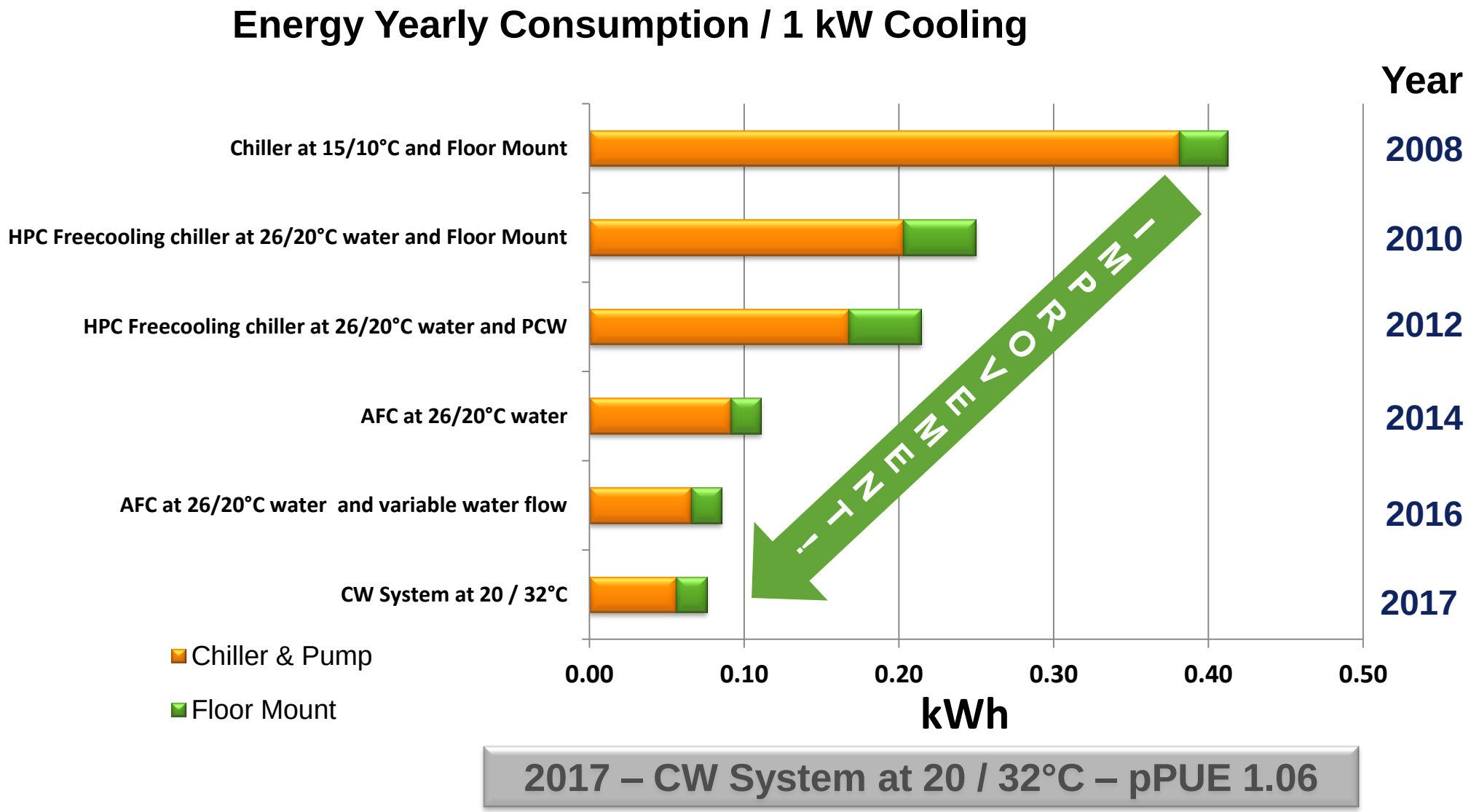
- Always provides the right quantity of air at the right temperature
- Freecooling chillers and floor mount control and set point integration



EFFICIENCIES IMPROVEMENTS IN THE CW SOLUTIONS

Market and Customer Requirements:

The data center technology trend anticipates higher servers' working temperatures, lower pPUE: increase of water T and water Delta T

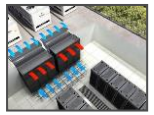


2017 – CW System at 20 / 32°C – pPUE 1.06

LIEBERT® PCW – FROM 5 TO 220 KW

Liebert Economizer

- Direct freecooling for data centers using outside air when appropriate thus enabling energy optimization



iCOM™ Control

- Control and Monitoring through the iCOM control
- Delivering BMS & NMS Connectivity
- IS Cards available as standard option

Liebert® EC Fan 2.0

- New fans technology with composite material fans to optimize unit efficiency

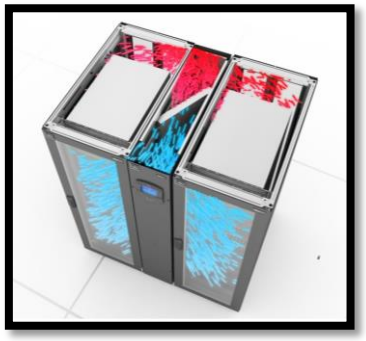
Aerodynamic Internal Design

- Unique unit design granting the best efficiency
- Reduces unit pressure drop via: coil geometry, distance between fans and coil, filter positioning

LIEBERT® DCL – RACK COOLING

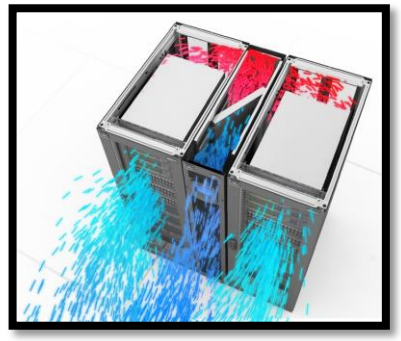
Thermal Management solution consisting of the Liebert DCL cooling module and Knuerr DCM Racks

- Two different architectures:
  - Closed Loop
  - Hybrid Loop
- Multiple combinations with up to 4 server racks
- Dual CW coil version for redundancy



CLOSED LOOP

- Hot and cold air contained inside the system
- No heat load, no airflow in the room, high noise attenuation
- Complete separation of IT equipment from room



HYBRID LOOP

- Hot air contained in the system, cold air discharged to the room
- Distribution of cold air throughout the room
- Cold air reserve in case of cooling system failure

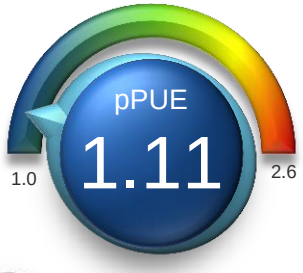
	DC032	DC038
Net Sensible Cooling Capacity (kW)	30	34.6
Airflow (m^3/h)	4850	6000

** **Note:** The performances shown above refer to an air inlet temperature of 37°C and chilled water temperature of 10/15°C for a closed loop configuration with rack on both sides*

LIEBERT® HPC: FREECOOLING CHILLERS

Fast Start Ramp

- Fast restart after power failure: first compressor ON after 20 seconds



Cooling Range
50 – 1600 kW

Freecooling with SmartAisle™

- High water temperatures allow for a high freecooling effect: high system efficiency

iCOM™ Control

Strategies for system efficiency:

- Freecooling chiller teamwork and integration with Liebert® floor mount units
- Complete monitoring product offer

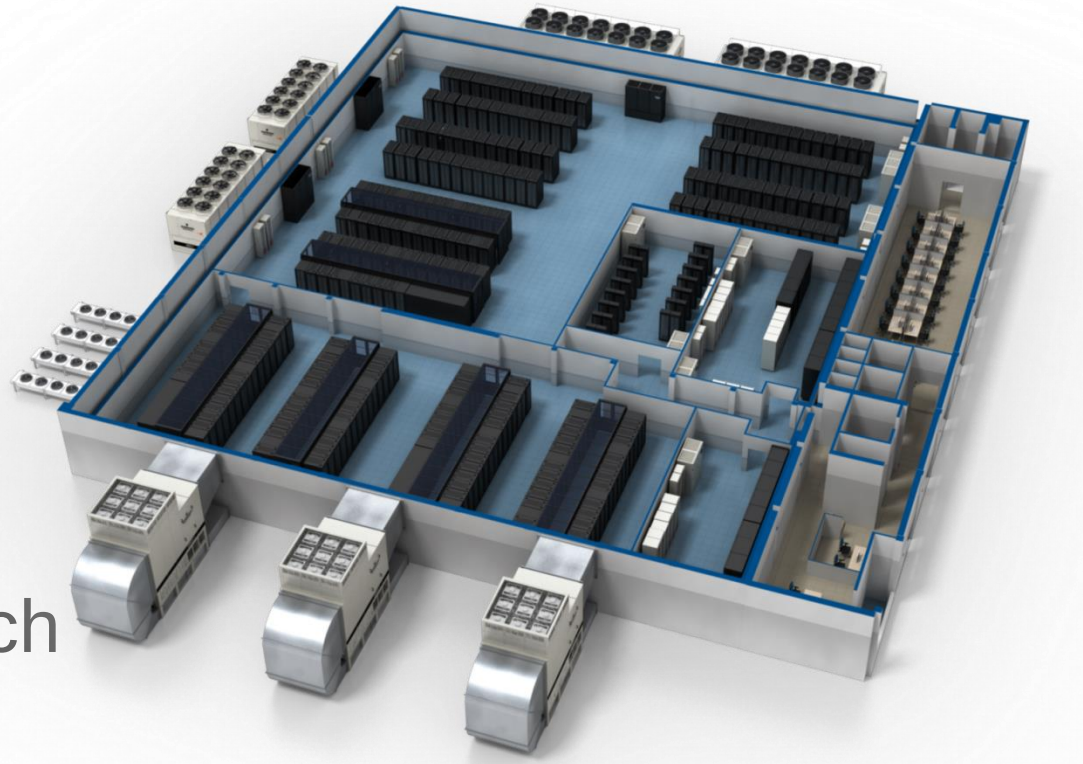
High Efficiency Components

- EC Fan
- Electronic expansion valve
- Pumps with efficiency class IE3
- Scroll / Screw compressors

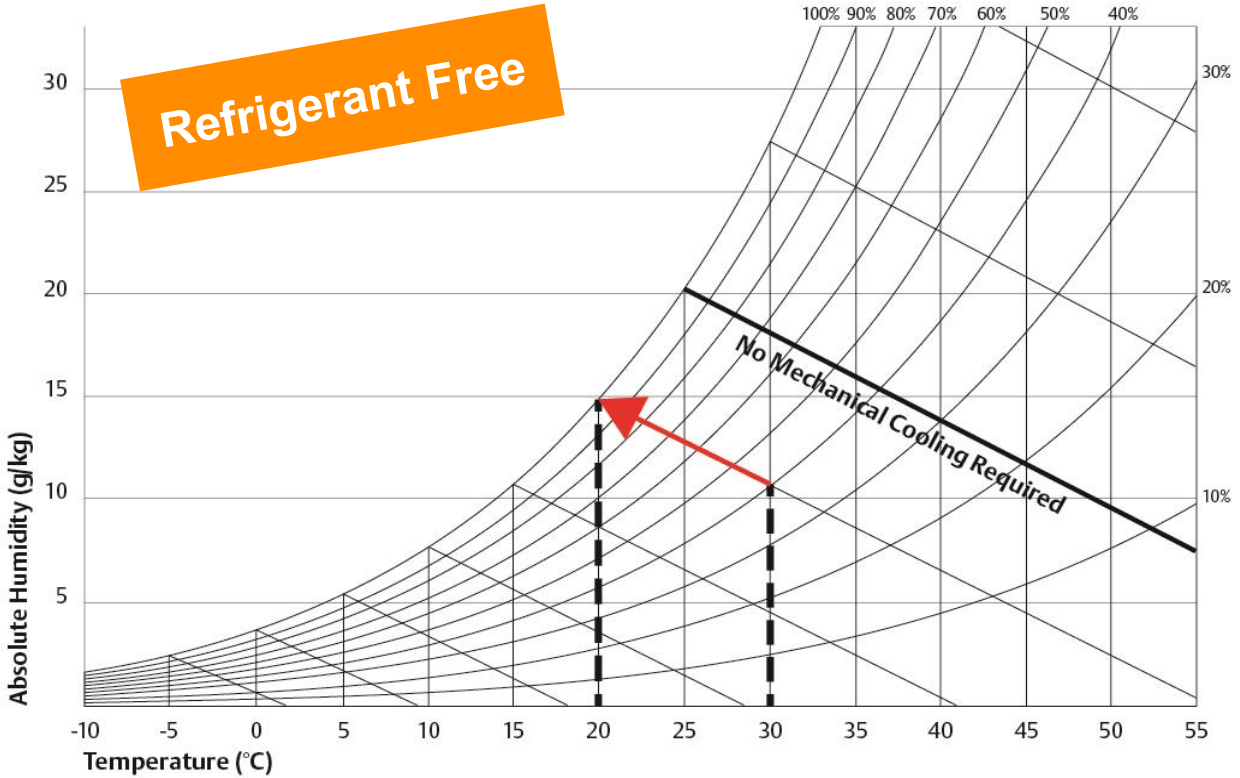
DATA CENTER OPERATING THRESHOLDS

- The definition of the data center required temperature and humidity relies also on the **external environment conditions**.

- The increase in operating temperatures within which IT infrastructure functions, allows the application of **new technologies** such as evaporative and adiabatic cooling



COOLING WITH WATER



- Water Evaporation removes surrounding heat and thus cools down the air temperature.
- Colder air allows the transition from Dry Bulb to Wet Bulb Temperature (the graph shows the change from 30°C to 20°C)

LONDON – DRY/WET BULB AND THE EVAPORATIVE EFFECT

Dry Bulb

Wet Bulb

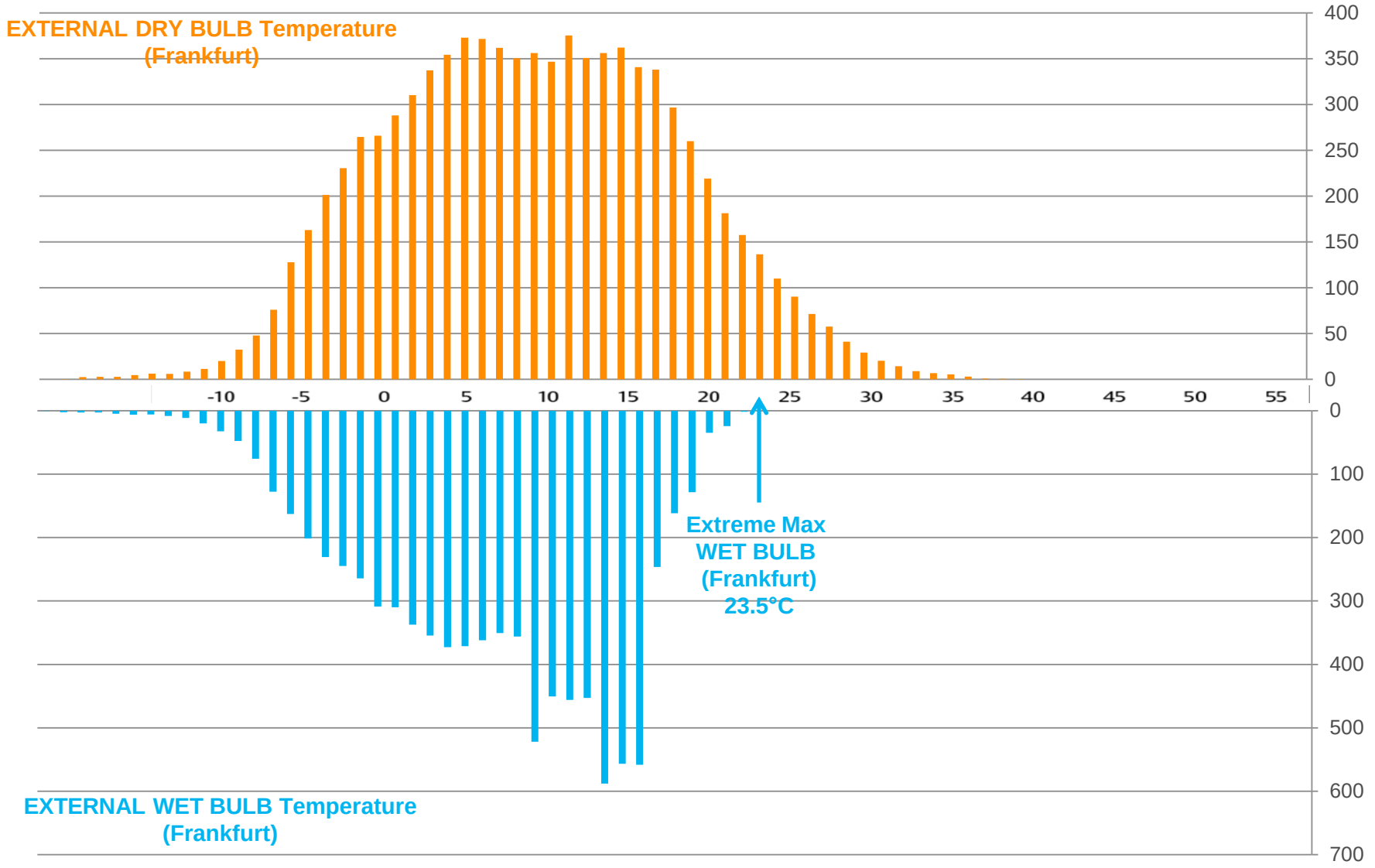
- 93% Recommended 2011
- 98% Allowable A1
- 100% Allowable A2-A4

- 100% Recommended 2011
- 100% Allowable A1-A4

FRANKFURT – DRY/WET BULB AND THE EVAPORATIVE EFFECT

Dry Bulb

Wet Bulb



- 93% Recommended 2011
- 98% Allowable A1
- 99% Allowable A2
- 100% Allowable A3-A4

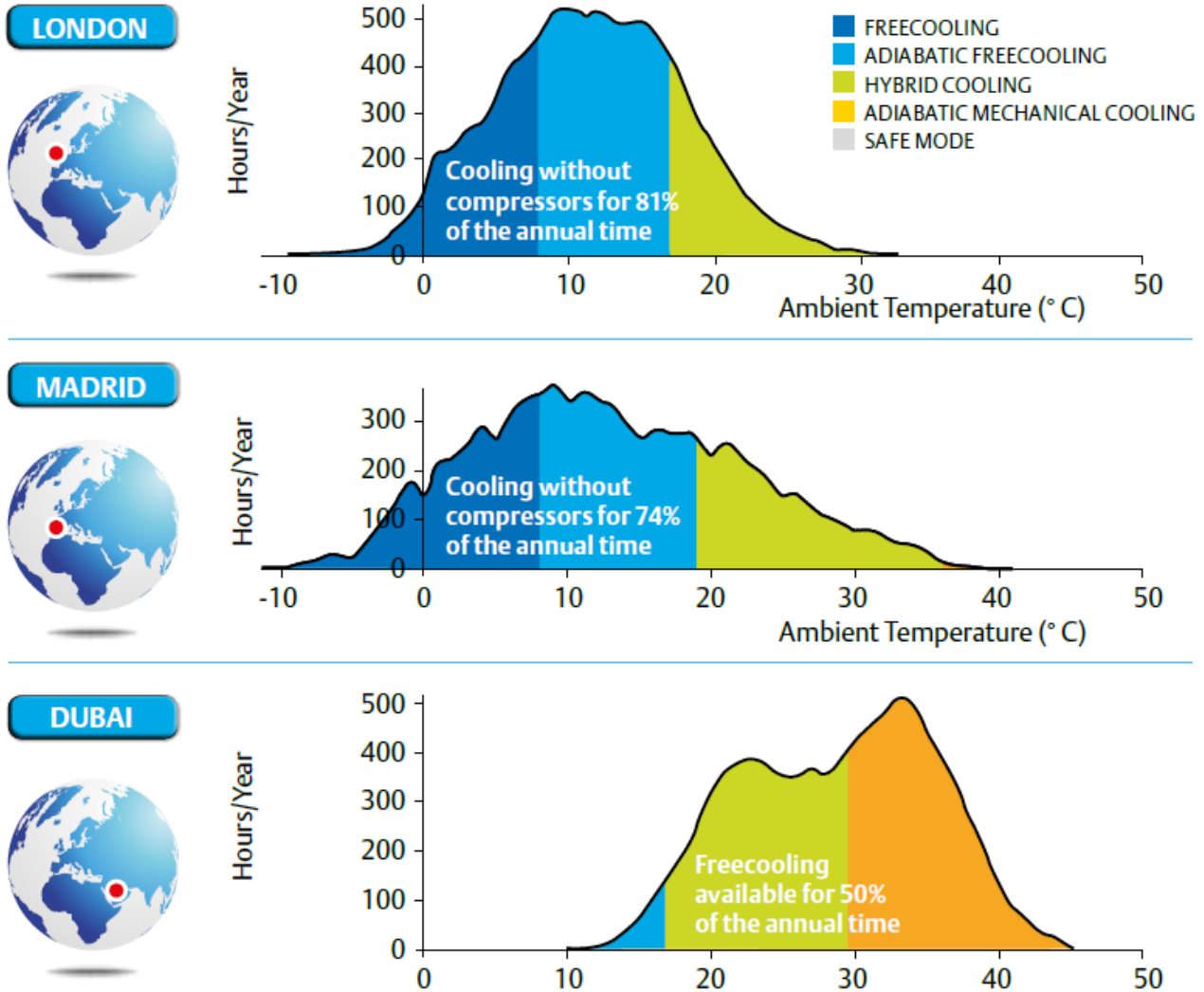
- 100% Recommended 2011
- 100% Allowable A1-A4

LIEBERT® AFC PRODUCT FAMILY

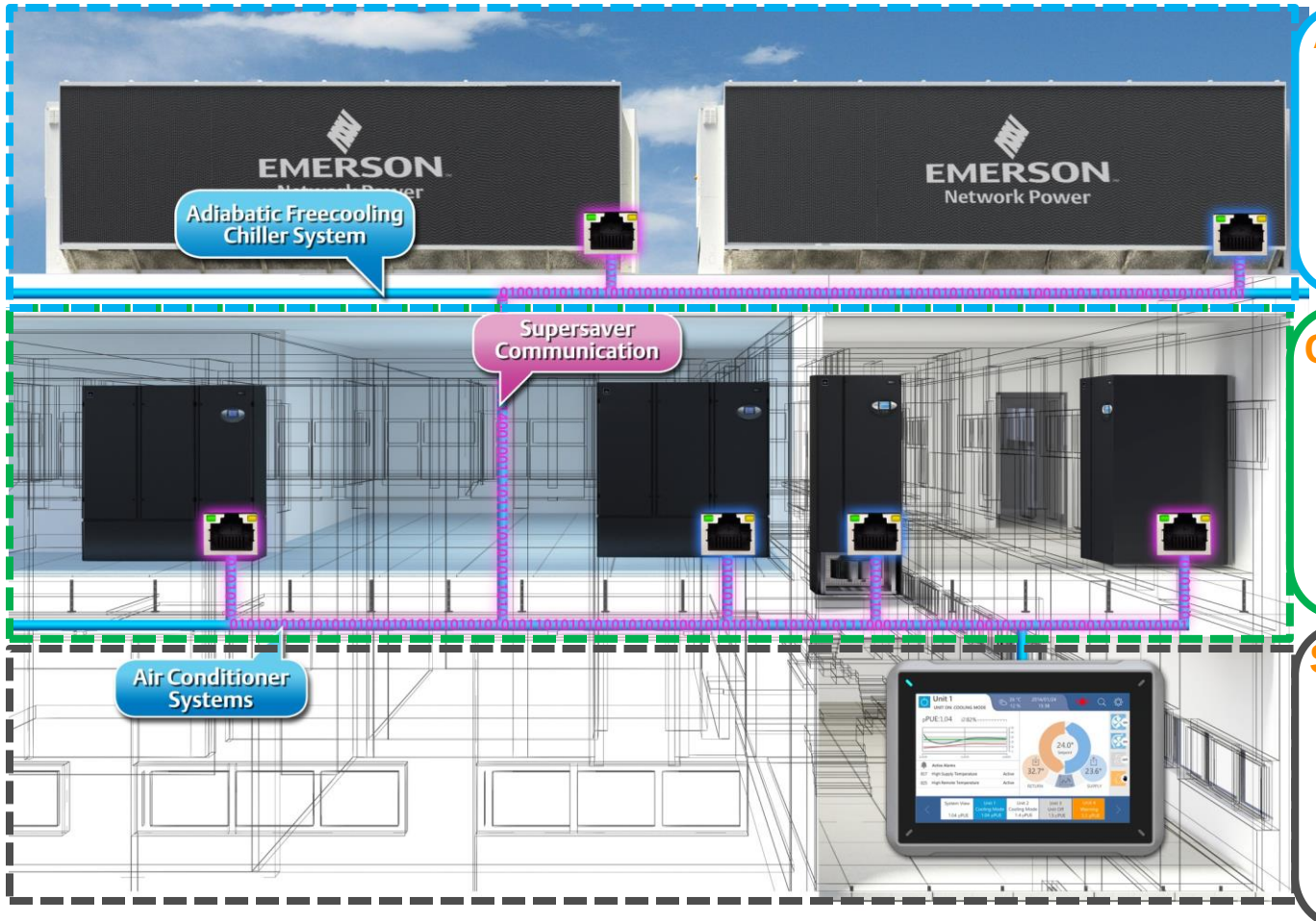
Top Efficiency and Availability

- **Freecooling** and **Adiabatic Freecooling** version
- **Multi-Scroll** compressor range 400-1450 kW
- **Screw** compressor range 1000-1450 kW

2017 New Product



ADIABATIC CHILLED WATER SOLUTION



Adiabatic Freecooling Chillers:

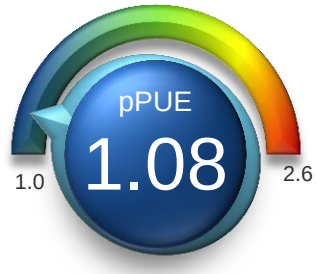
- From 500 to1450 kW
- 100% Compressor Back-up
- Maximizes the freecooling effect
- Increases CW temperatures (up to 26/20°C CWT)

CW Indoor Units:

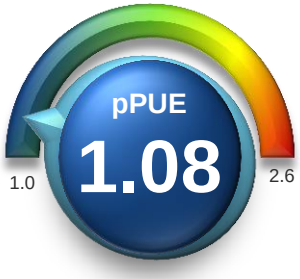
- Full range from 30 to 200 kW
- Up to 70% improvements compared to industry standards
- Economizer to provide Direct Freecooling for Data Center

System Optimization:

- Control of air flow and temperature in front of the servers via the iCOM™ Control
- The Supersaver software logic optimizes the entire cooling system



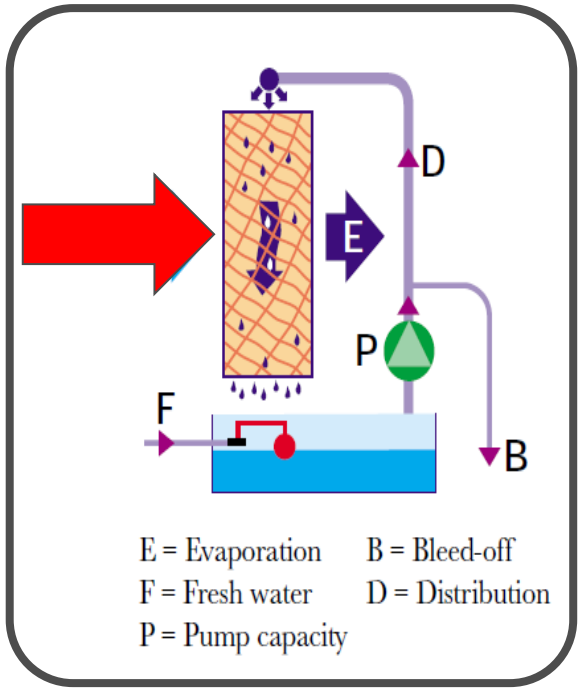
LIEBERT® AFC - ONE UNIT, 3 COOLING TECHNOLOGIES



Freecooling

Patent Pending

Adiabatic Cooling



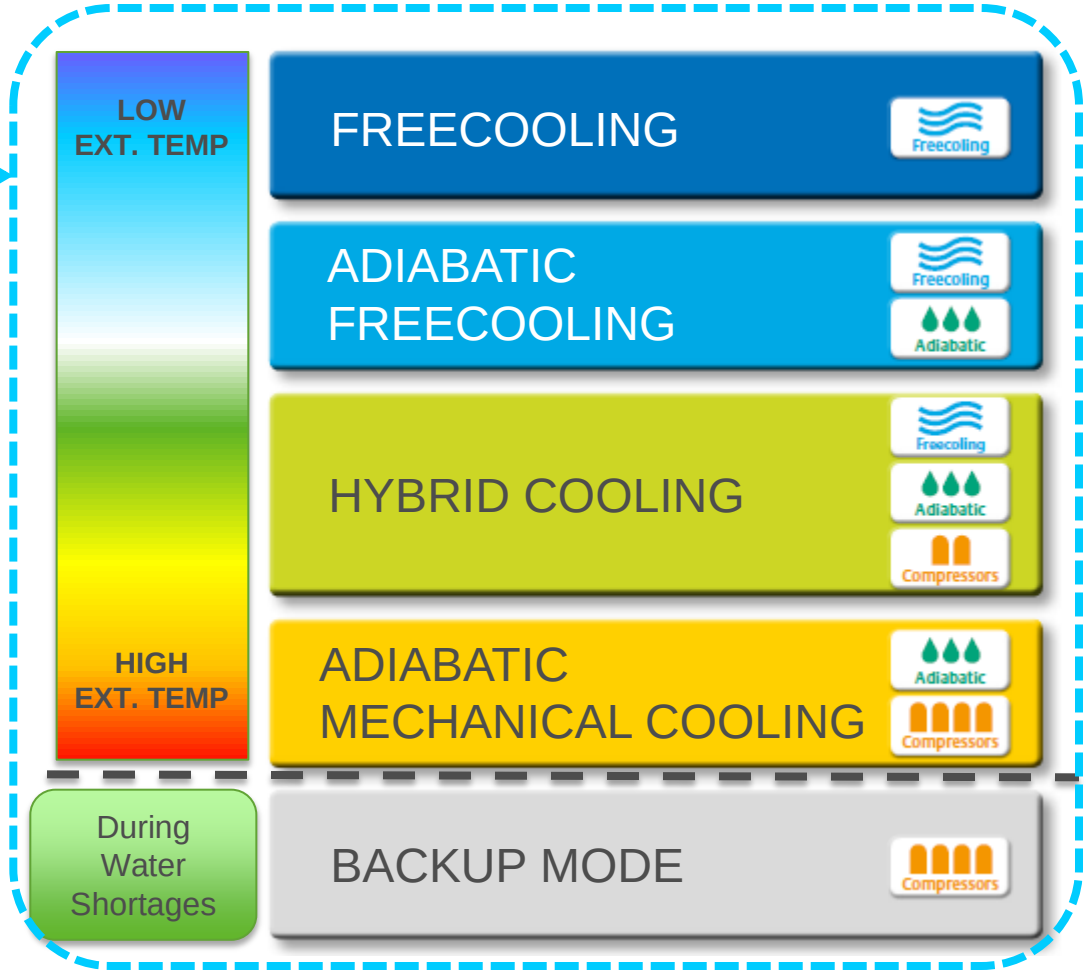
100% Back-Up

100% Compressor Back-up

LIEBERT® AFC – OPERATING MODES

- The **iCOM™ Control logic** constantly measures the external temperature and humidity in order to activate the most efficient operating mode

Range
From 500 kW to 1450 kW
50 Hz and 60 Hz



INDIRECT EVAPORATIVE SOLUTION

Evaporative Cooling Units:

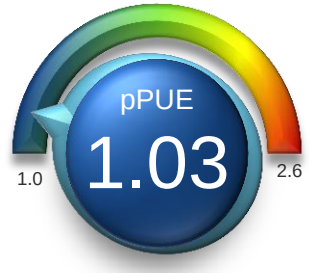
- Indirect evaporative freecooling
- Range: 100 and 350 kW
- Perimeter or roof installation
- Reduced installation costs, located outside the white space

Racks Arrangements:

- Hot or cold aisle containment
- Control of air at servers level

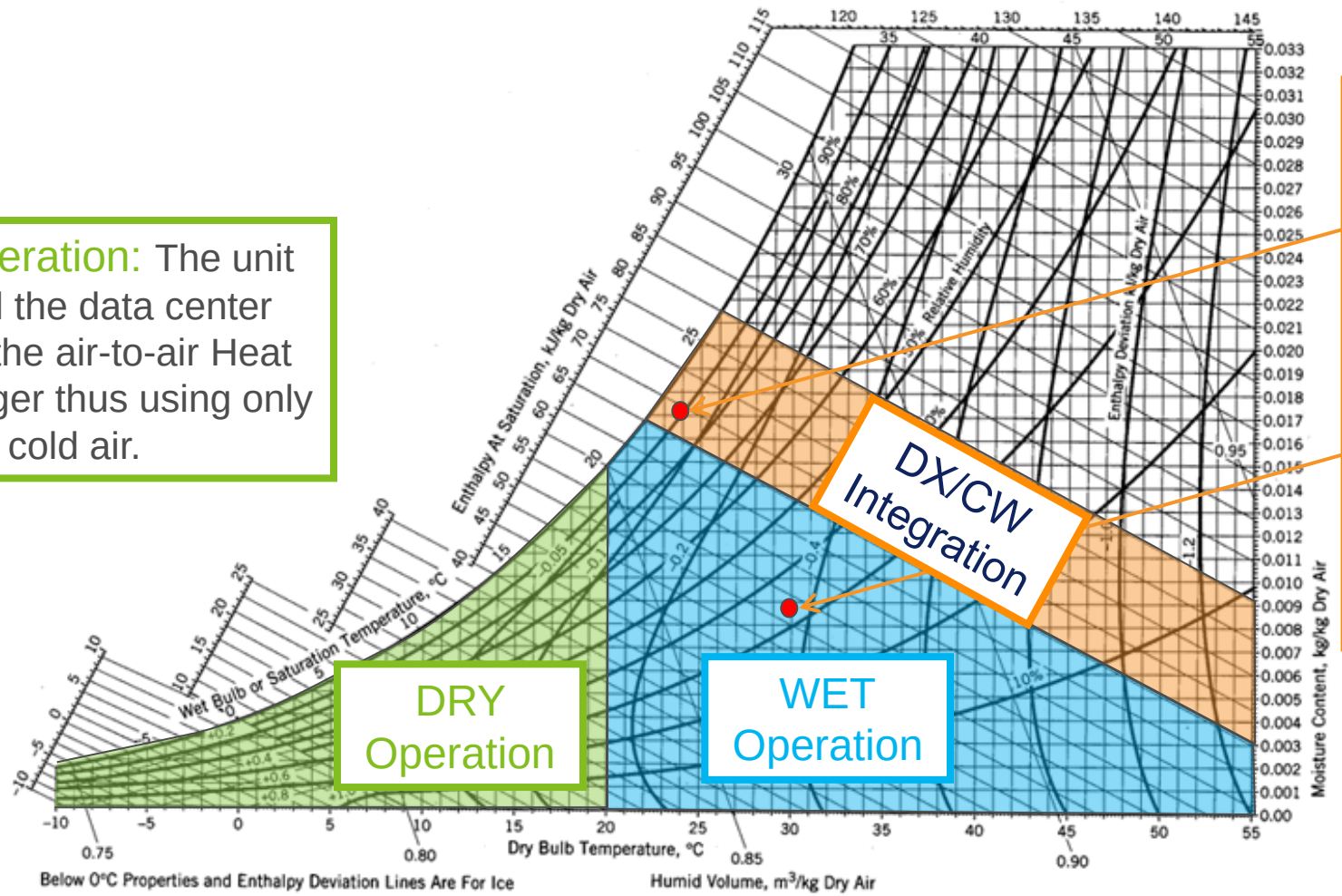
System Optimization:

- Control of air flow and temperature in front of the servers
- Always provides the right quantity of air at the right temperature



INDIRECT EVAPORATIVE SOLUTION

Dry Operation: The unit can cool the data center just via the air-to-air Heat Exchanger thus using only external cold air.



DX/CW Integration:

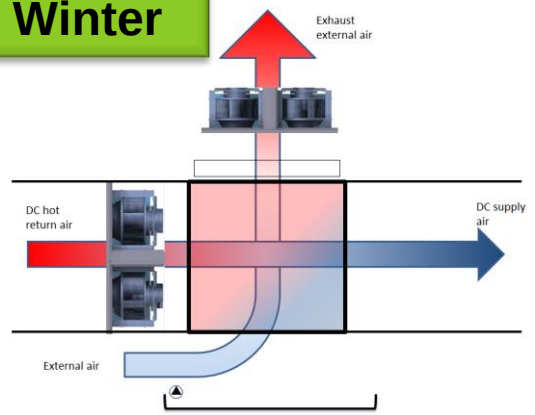
- At 24°C and 90% relative humidity, the unit might require DX/CW integration.
- But, at 30°C (higher temperature) and 35% (lower relative humidity) the unit can work just with evaporative.

WET Operation: The unit can here exploit the evaporative effect via humidification.

Assumptions:
- Data Center 36°C → 24°C
- 100% of Full Load per Unit

INDIRECT EVAPORATIVE SOLUTION OPERATION MODES

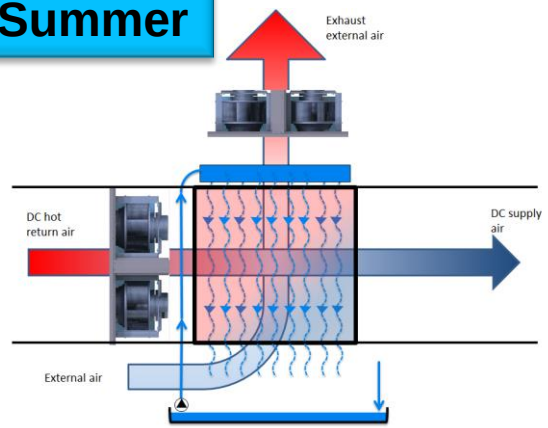
Winter



AIR-TO-AIR HEAT EXCHANGE WITHOUT SPRAYING WATER

Dry Operation

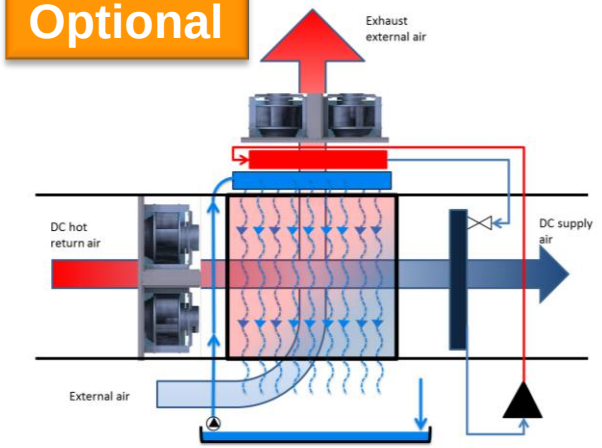
Summer



AIR-TO-AIR HEAT EXCHANGE VIA THE SPRAYING OF WATER TO THE EXTERNAL AIR SIDE

WET Operation

Optional



EXTERNAL AIR TEMPERATURE IS TOO HIGH TO HAVE 100% COOLING WITH EVAPORATIVE, THE DX MODULE IS THUS INTEGRATED TO COVER THE MISSING CAPACITY

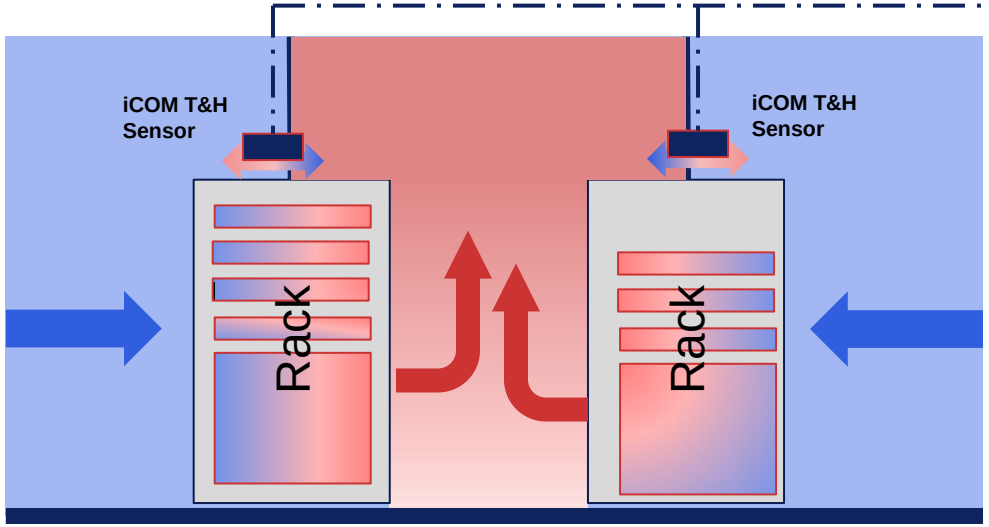
DX/CW Integration

UNIT CONTROL – THE SMARTAISLE™

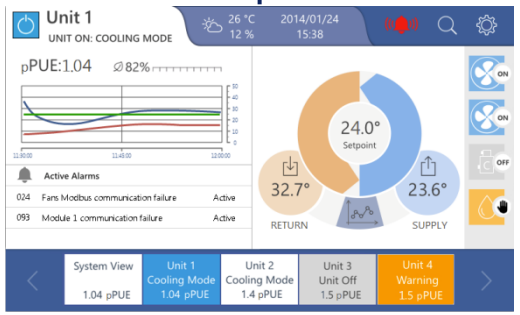
Does the cooling unit have the right TEMPERATURE & AIRFLOW CONTROL?

- **SmartAisle control logic** optimizes internal air volumes and temperatures following the specific servers' needs.
- **SmartAisle control logic** allows Liebert® EFC to exactly match servers' airflow thus ensuring that not a single Watt is wasted in moving or cooling unrequired air.

Important!



Hot aisle or cold aisle containment can be managed in the same way

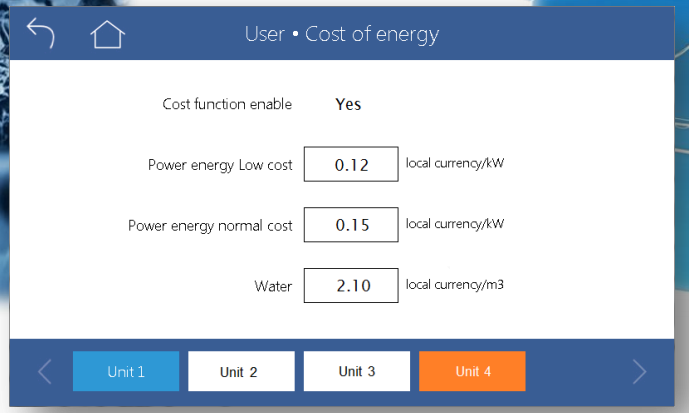


UNIT CONTROL – THE COST FUNCTION

Patent Pending

WATER or ELECTRICITY, what costs less?

The user-friendly control, enables users to select the exact temperature at which the evaporative device starts to spray water in the air. This is how Liebert® EFC can optimize the operation based upon different customer's needs.



THERMAL MANAGEMENT CUSTOMER EXPERIENCE CENTER

NEW
Freecooling Chiller Validation Area
SUMMER 2017

CUSTOMER EXPERIENCE CENTER

VERTIV.

Vertiv's Customer Experience Center located in Tognana (Padova - Italy), is specifically designed for customers to interact with Thermal Management data center technologies.

The center gives our customers the unique opportunity to witness pre-installation demonstrations, covering technical performance, interoperability and efficiency of Vertiv's Thermal Management solutions under a broad range of real field conditions.

Customers visiting the center may also benefit from a comprehensive consultation from our R&D, engineering and application specialists. The Customer Experience Center provides customers, consultants and data center specialists with the most complete testing area to experience the capabilities of our technologies at peak conditions. All our measuring tools are periodically tested to adhere to current international quality procedures.

Every customer visit is accompanied by a complete final report which includes each and every tested parameter as well as the relevant outputs for the specific Thermal Management unit validated. With our constant focus on our customers' needs, we guide them through a first-hand experience with full transparency and flexibility, enabling them to achieve the highest standards of technical excellence.

The Academy

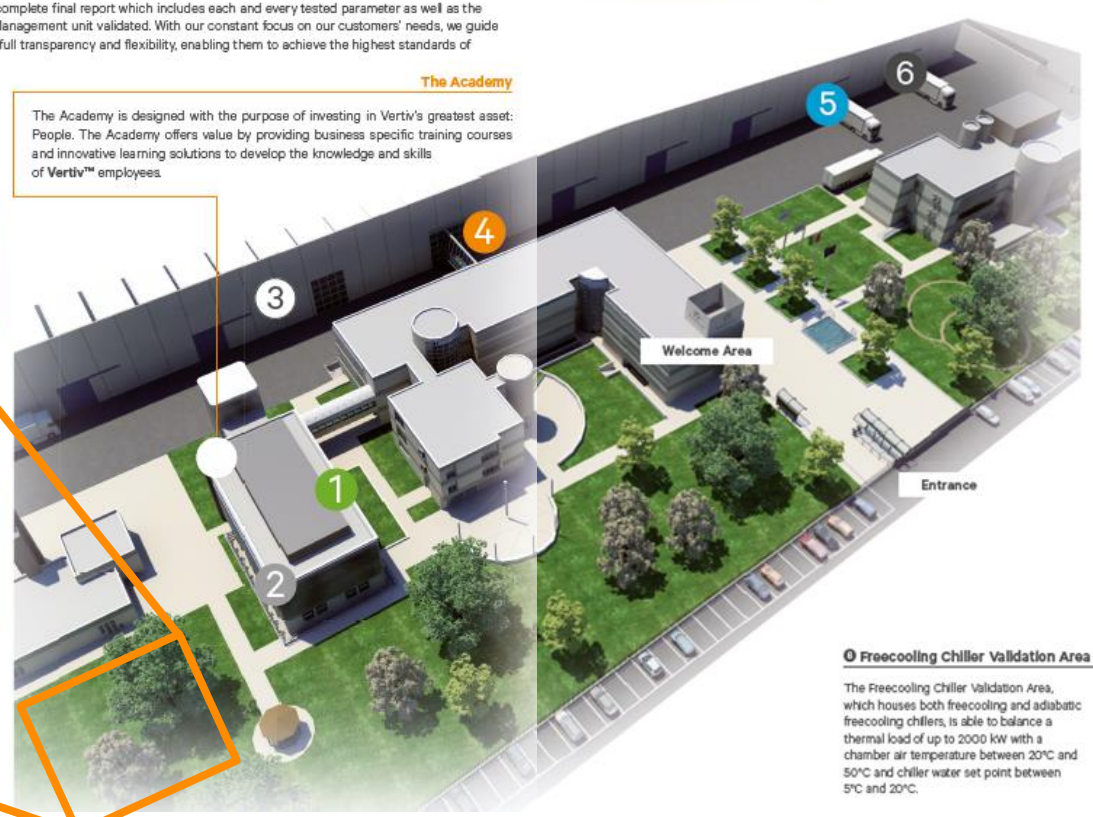
The Academy is designed with the purpose of investing in Vertiv's greatest asset: People. The Academy offers value by providing business specific training courses and innovative learning solutions to develop the knowledge and skills of **Vertiv™** employees.

1 R&D Validation Area

The Research & Development Validation Area n. 1 is specifically designed to test floor-mount units and can balance a thermal load of up to 150 kW with a chamber air temperature between 0°C and 60°C.

2 R&D Validation Area

Designed for conditioners belonging to the Telecom sector, the Research & Development Validation Area n. 2 includes two different testing chambers: one simulating internal ambient conditions from [illegible]°C to 60°C and the other simulating external ambient conditions from -32°C to 60°C. This validation area can balance a thermal load of up to 100 kW (50 kW in each room).



3 Floor-Mount Validation Area

The Floor-Mount Validation Area meets the increasing requests for witness tests and specific product-type approvals. Equipped with a highly automated testing chamber, this validation area can balance a thermal load of up to 200 kW and can simulate a test environment within a temperature range of 0°C to 60°C.

4 Showroom

The Customer Experience Center's Showroom is specifically designed for customers to interact with Thermal Management units:

- **Liebert® PDX**, available from 15 to 120 kW. The direct expansion solution ideal for small and medium data centers
- **Liebert CRV**, available from 11 to 50 kW. The row-based cooling unit designed to deliver the highest availability
- **Liebert MC**, available up to 160 kW. The highly efficient Microchannel Condenser.

5 Evaporative Cooling Validation Area

Our Thermal Management Customer Experience Center features a dedicated area to test the state-of-the-art Liebert EFC - Vertiv's highly efficient indirect evaporative freecooling unit. The Evaporative Cooling Validation Area testing parameters include IT loads of up to 400 kW and an airflow of up to 100,000 m³ per hour at any external ambient temperature required to simulate typical peak conditions across the EMEA region.

6 Freecooling Chiller Validation Area

The Freecooling Chiller Validation Area, which houses both freecooling and adiabatic freecooling chillers, is able to balance a thermal load of up to 2000 kW with a chamber air temperature between 20°C and 50°C and chiller water set point between 5°C and 20°C.

TOGNANA AND NOVE MESTO PLANTS

SUMMARIZING

- There is not one best technology that can suit to any data center: the best solution depends on the customer's **requirements** and on the data center **constraints**

- The Thermal Management Solution provides:
  - Air temperature and airflow control at the **servers' level**
  - **Water / electricity cost optimization**
  - Unit and **team working** control

- It is important to **test and prove cooling capacity and energy consumption** at specified customer's temperature and humidity conditions.

- **Refrigerant free solutions** are available

START STRONG FINISH STRONG

VERTIV™