Energy Efficient Trends for IT Environments

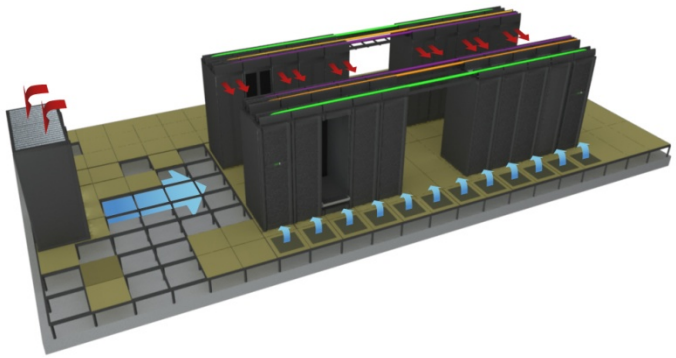
Dan Barrango
Cooling Business Development Manager

Schneider Electric

Data Center Cooling Architectures

- The two main cooling equipment functions are to…
  - Provide the bulk cooling capacity
  - Distribute the air to the IT loads
- The major difference in architectures lies in how they perform the second task.
  - Airflow is crudely constrained by room design, is not visible in implementation, and varies considerably between installations.

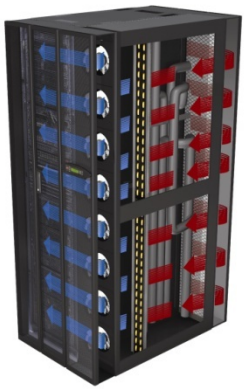
Room Cooling



Close Coupled Cooling



Row Cooling

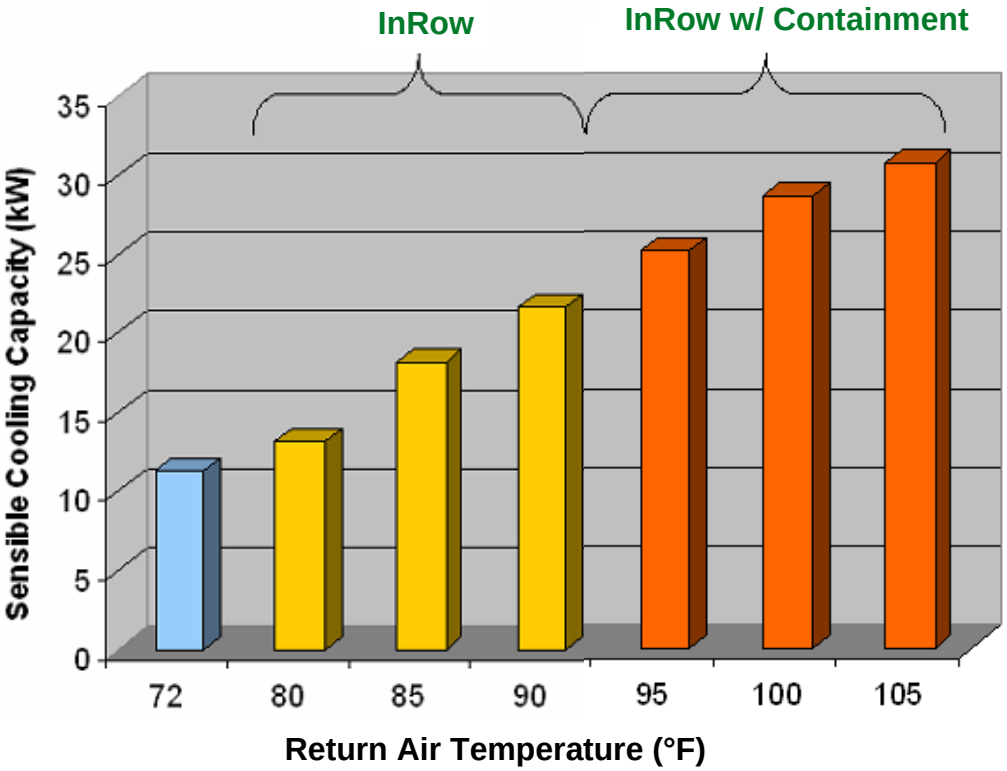


Rack Cooling

Energy Efficient – Close Coupled & Containment

Contain the heat to Increase efficiency

- Increase Cooling Capacity
- Reduce Power Consumption
- Increase Economizer Hours



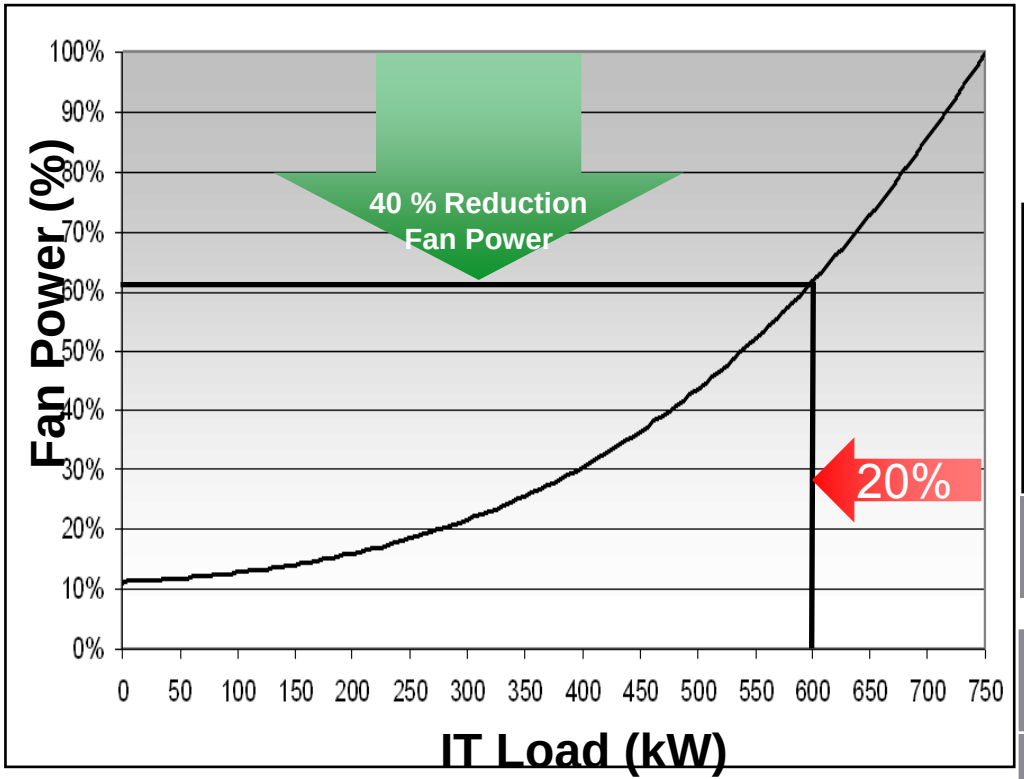


Containment Reduces Fan Power by

30-50%

Energy Efficient – Variable Capacity Control

750 kW Data Center Example – Operating at 80%

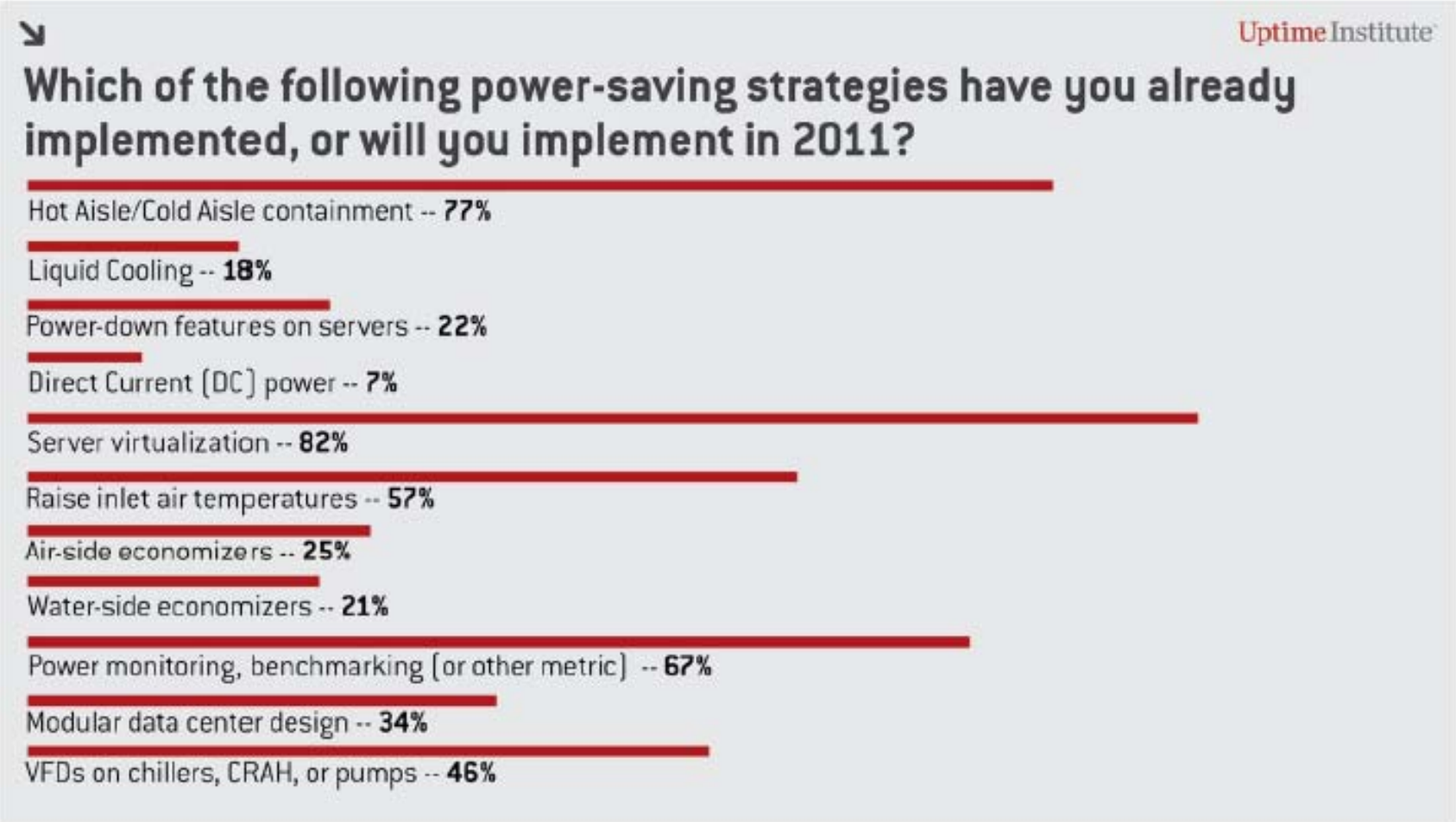


Component Power	Variable Speed Fans: InRow Air Handler	Constant Speed Fans: Computer Room Air Handler	Units
Fans (750 kW IT Load)	30.6	88.0	kW
Fans (600 kW IT Load)	18.4	88.0	kW
SAVINGS	12.2	0	kW

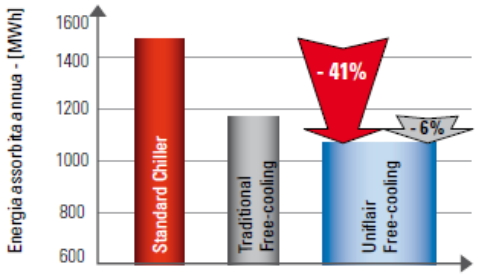
Variable Cooling Capacity Follows The IT Load

Reduces Load on Chiller

Uptime 2011 Survey



Cooling Best Practices - Key Benefits

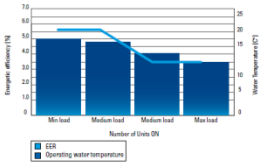


- Enhanced Free Cooling Modes reduce energy consumption as much as 41% over standard chillers and 6% over traditional free cooling chillers



- EC Fans reduce fan energy and provide variable load control







- Optimized management of cooling units to adjust chiller temperatures to maximize efficiency



- Low Noise to minimize impact on surrounding environment

Economizer Cooling Solutions

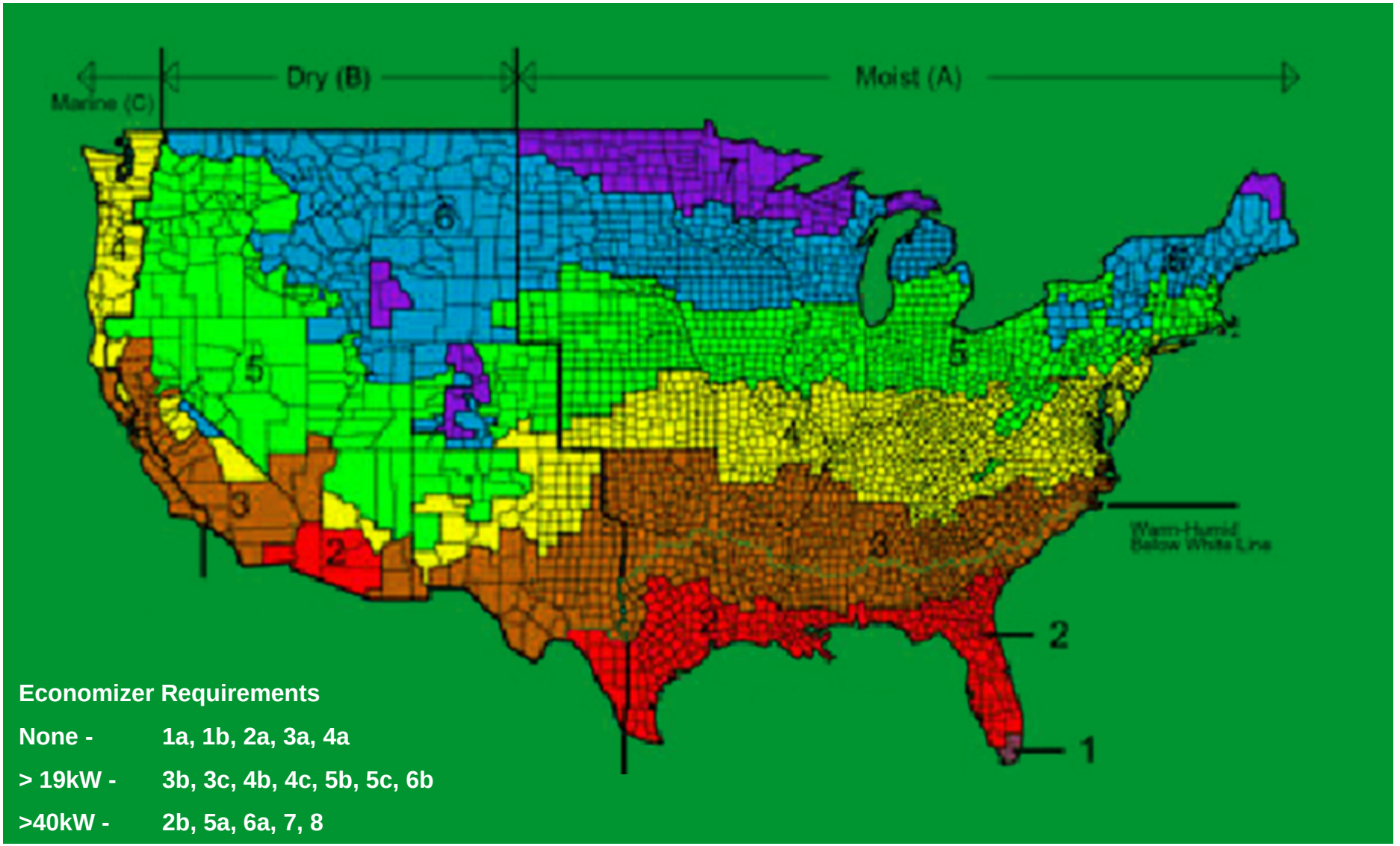
Drivers for Economizers

Energy Costs and Constraints

- Data centers are constantly expanding which requires more energy
- Local energy companies place heavy restrictions on gaining more power from the grid
- There is a need to reduce cooling power consumption to allow room for value-added IT equipment



United States ASHRAE Climate Zones



Economizer Requirements

None - 1a, 1b, 2a, 3a, 4a

> 19kW - 3b, 3c, 4b, 4c, 5b, 5c, 6b

>40kW - 2b, 5a, 6a, 7, 8

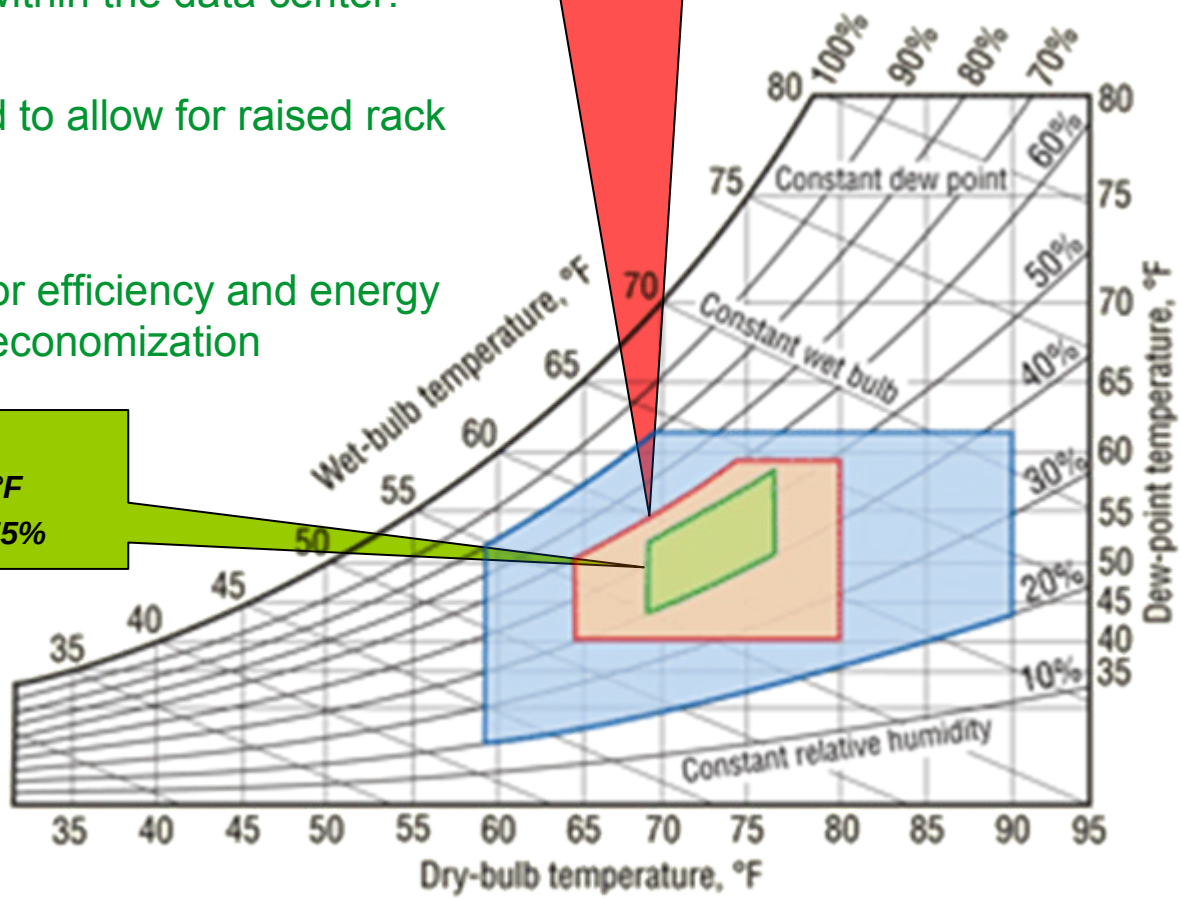
Increased Operating Temperatures

ASHRAE TC9.9

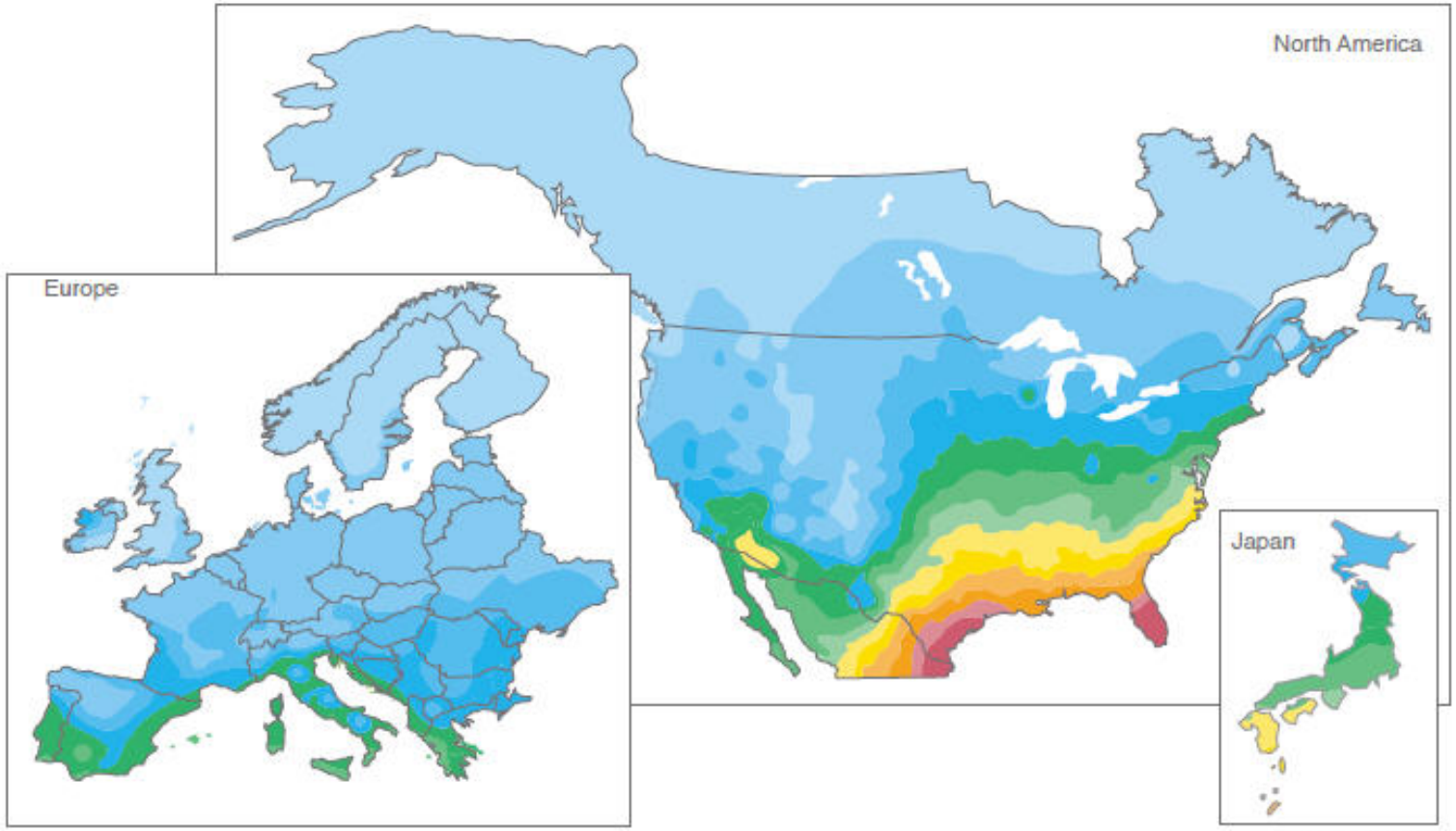
- ASHRAE (Technical Committee)9.9 sets the recommended operating limits within the data center.
- In 2008, the limits were widened to allow for raised rack inlets temperatures.
- This widened envelope allows for efficiency and energy savings through more hours of economization

2008 Limits
Temp Range: 64.4-80.6°F
Humidity Range: (DP 42°F) – (60% RH & DP 59°F)

2004 Limits
Temp Range: 68-77°F
Humidity Range: 40-55%



Envelopes represent conditions at information-technology-equipment inlet
ASHRAE 2004 – Recommended
ASHRAE – Allowable
ASHRAE 2008 – Recommended



Air-side free cooling map

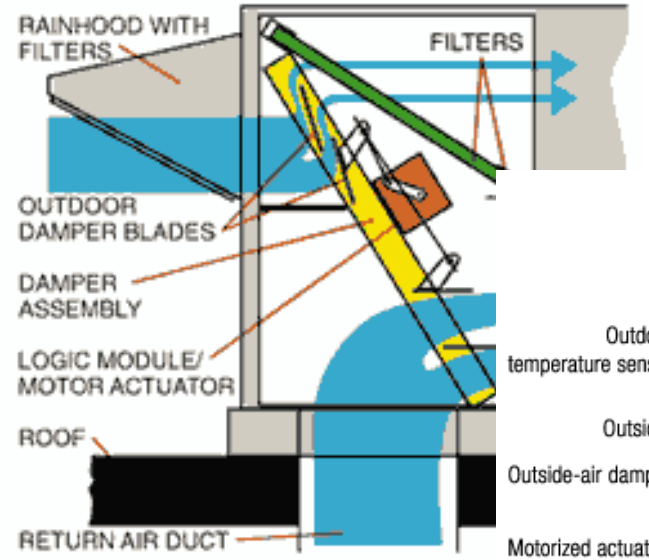
Estimate of full air-side economizer hours for data centers

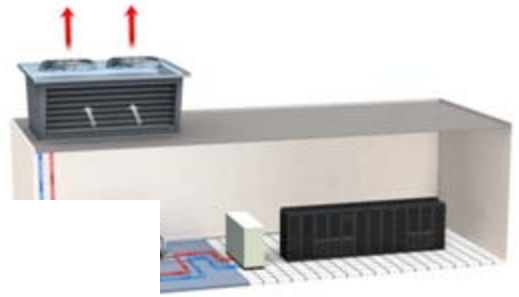
Fully populated EcoBreeze (40ft Frame, 8 modules)
Supply air setpoint of 27°C
Temperature change across EcoBreeze 17°K
Full Airflow Capacity 370kW
Operating Load of 247 kW (2/3 Full Airflow)

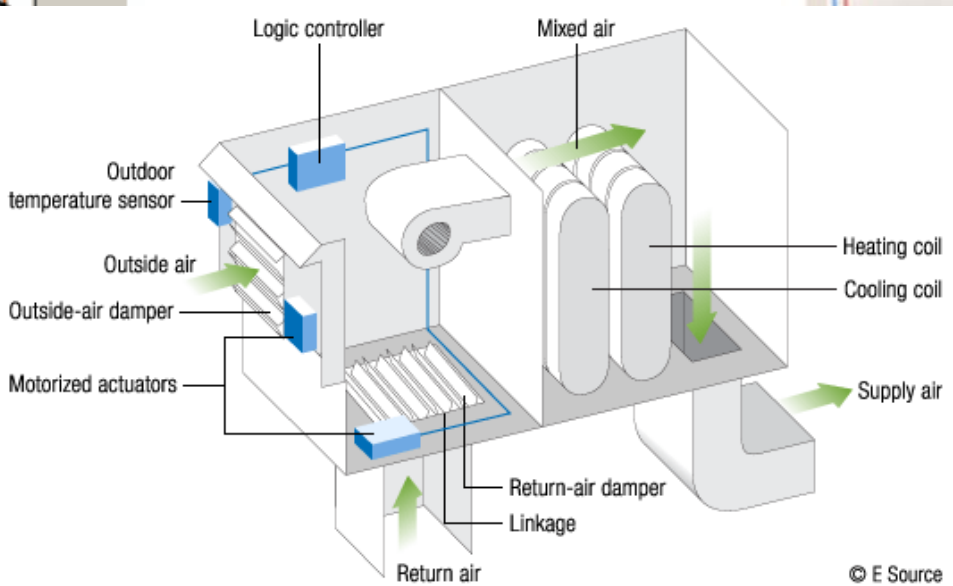
EcoBreeze based upon the above provides full Econ for ambient conditions ≤ 27°C DB and ≤ 15°C Dewpoint

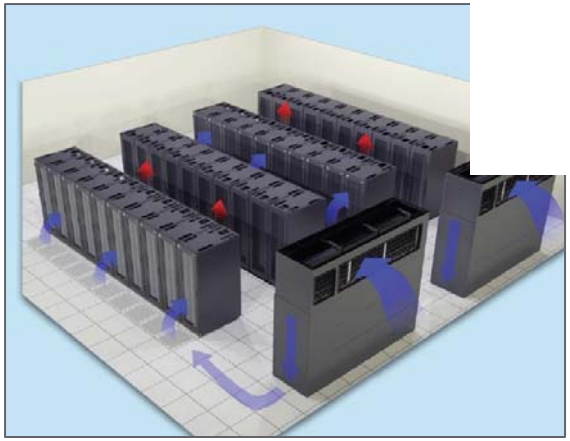
8500 Hours
8000 Hours
7500 Hours
7000 Hours
6500 Hours
6000 Hours
5500 Hours
5000 Hours
4500 Hours
4000 Hours
3500 Hours
3000 Hours
2500 Hours
2000 Hours

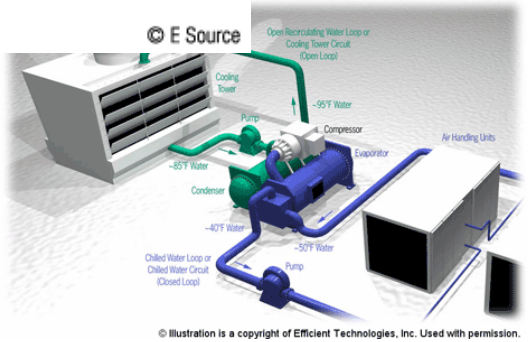
What are some potential limitations or challenges associated with economizers?





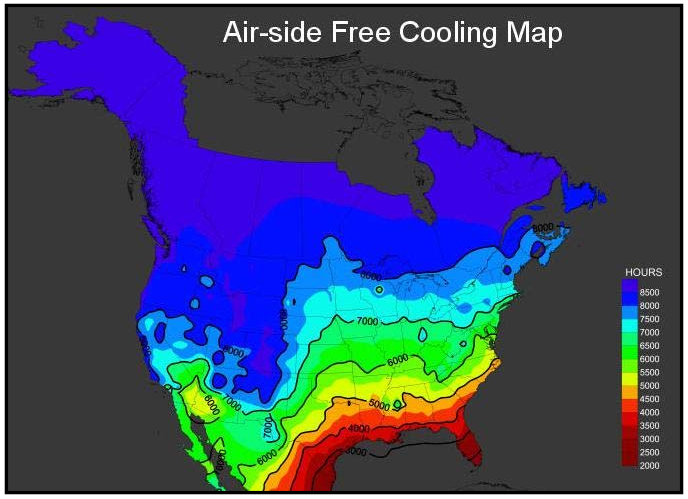






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Economizers

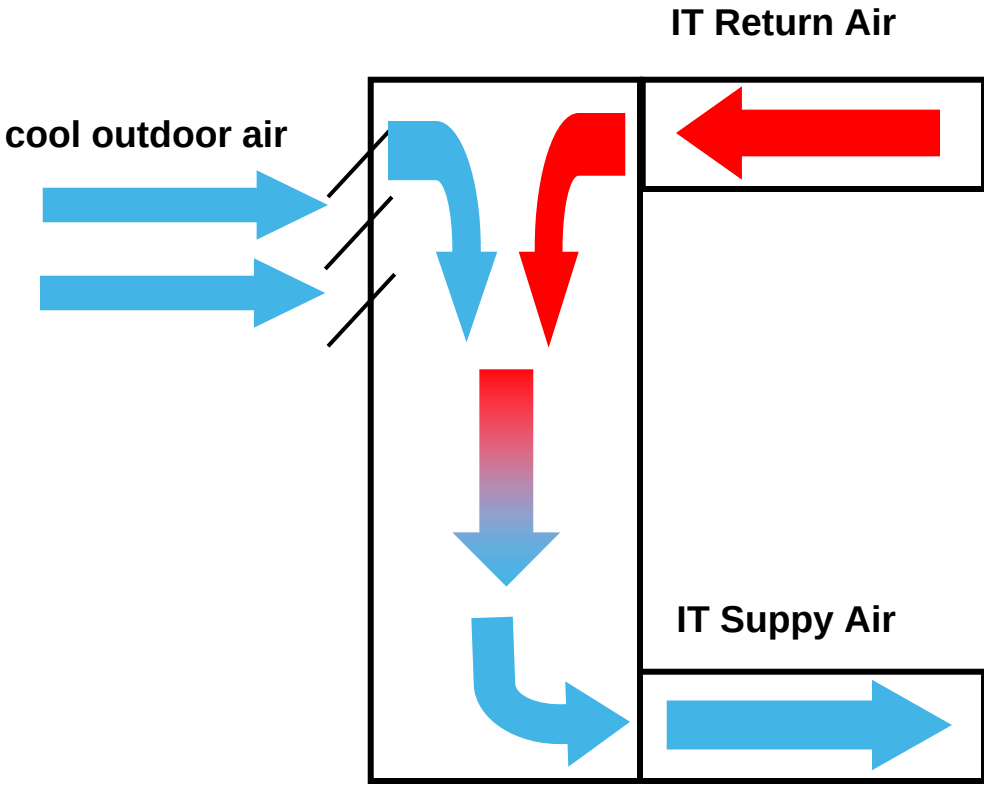


- **Air Side Economizer**
  - **Requires 'cool enough' outside air** to maintain desired temperature in data center
  - **Outside Air <u>DRY BULB</u>** temperatures from 40°F (4.4°C) to 80.6°F (27°C)
  - **Humidity control** required when outside of control range typically less than 40% or greater than 60% RH
  - **Requires pre-treatment & filtration** of outside air to mitigate potential for particulate contamination within data center
  - **Custom designed** solution

- **Water Side Economizer**
  - **Requires 'cool enough' outside air** to chill water/glycol
  - **Water treatment** is required to maintain performance
  - **Outside WET BULB** temperatures 40°F (4.4°C) to 64.4 F (18°C)
  - **Custom designed** solution

Fresh Air Economizers

- Fresh air economizers allow cool ambient air from outside to mix freely with the return air from the data center
- This causes wild fluctuations in humidity and moisture within the data center depending on the ambient conditions
- High efficiency filters and ample humidity controls are required for a fresh air system
- Contaminants like pollen, diesel exhaust and wild fire smoke can also be a risk with a fresh air system



ASHRAE TC 9.9 2011

Server Reliability vs Moisture, Contamination

High End RH Concerns

- **conductive anodic filament (CAF) -** Based on extensive reliability testing of printed circuit board laminate materials…conductive anodic filament (CAF) growth is strongly related to RH
- **Disk and Tape Drives -** In disk drives… head flyability and corrosion issues. In tape drives… increase frictional characteristics of tape and increase head wear and head corrosion.
- **Atmospheric Corrosion -** High RH…is required for atmospheric corrosion.

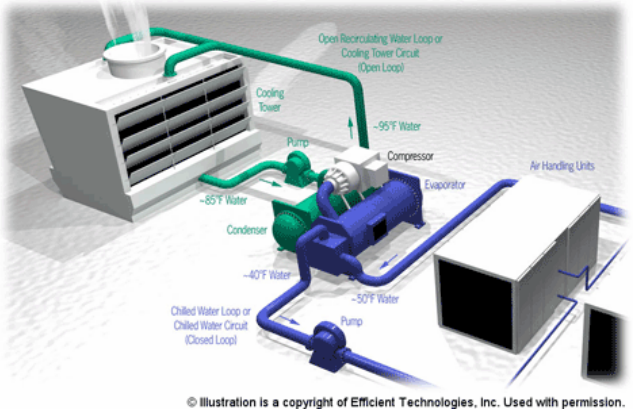
If protection of mission-critical data center hardware is paramount , keep relative humidity < 60% and limit particulate & gaseous contamination

Custom Economizers

Custom Economizer Systems

- Complex infrastructure requires special controls, installation, and maintenance
- Multiple vendors involved
- These systems have a higher chance of failure and emergency maintenance

Complex System



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Modular Indirect Evap Cooler vs Traditional CW Plant

Design characteristic	Modular Indirect Evaporative Cooler	Traditional chilled water plant
Primary mode of operation	Economization modes (air-to-air heat exchanger and evaporative cooling) with DX coolers as backup	Chiller operation with plate and frame heat exchanger as backup
Controls and management software	Standardized, pre-integrated controls ensures optimal operation mode at all times; few devices to control	Many devices to control; complex custom controls often result in a cooling plant not in optimal mode of operation
Form factor	Modular design, accommodates scaling of capacity over time	Chillers, pumps, and cooling towers are generally installed on day 1 for final worse case loads, resulting in significant oversizing
IT space footprint	Zero IT space footprint; sits outside the data center	Consumes approximately 30 sq m for every 100 kW of IT load, or approximately 5% of computer room space

- White Paper 136 High Efficiency, Economizer based Modular Cooling System, Page 13

Modular Indirect Evap Cooler vs Traditional CW Plant (pt 2)

Design characteristic	Modular Indirect Evaporative Cooler	Traditional chilled water plant
Ability to retrofit	Not logical to retrofit into existing facilities; only cost effective for new facilities	Practical if space is available; requires running additional pipes
Adapts to redundancy requirements	Modular design easily adapts to varying redundancy requirements – i.e. additional module can be added for N+1 configuration	Certain components in architecture can be cost prohibitive in redundant configurations (i.e. chiller)
Energy use	Operates in economizer mode > 50%* of year; Typically designed to never require full mechanical cooling; 1 heat exchange means economizer mode can run at higher outdoor temperatures * Based on assumptions of Figure 3	Operates in economizer mode approximately 25%* of year; Primary mode of operation is full mechanical cooling; 3 points of heat exchange means greater temperature difference required between IT inlet temperature and outdoor temperature * Based on assumptions of Figure 3
Dependence on water	Lower probability of losing water at the same time evaporative assist is required	Loss of utility water is critical – cooling tower depends on makeup water 8760 hours of the year
Controlled environment	Outside air contaminants are isolated from IT intakes reduces risk of downtime	Outside air contaminants are isolated from IT intakes reduces risk of downtime
Upfront cost	$2.4 / watt for entire system	$3.0 / watt for entire system

- White Paper 136 High Efficiency, Economizer based Modular Cooling System, Page 13

pPUE Efficiencies

	Partial PUE		
	Small (0-200kW)	**Medium** (201-1MW)	**Large** (Over 1MW)
Modular Air Economizer with IEC 	1.12	1.14	1.14
InRow units with Free Cooling Chiller 	1.17	1.16	1.16
CRAC units with Free Cooling Chiller 	1.25	1.22	1.22

Increasing Efficiency

- Based on 6 kW per Rack using Hot Aisle Containment
- Location: St. Louis, MO
- Packaged Air Cooled Free Cooling Chillers

Which Cooling Strategy Works for You?

Cooling Economizer Mode PUE Calculator

Schneider Electric

INPUTS

About this tool

Data center location

Country: United States

Region / State: Washington

Site: Seattle Seattle-Tacoma Airport

Cooling & power characteristics

Data center capacity: 1000 kW

Data center IT load: 50%

IT operating environment: User defined temperature

IT inlet temperature: 70 °F

Power & lighting: No power or lighting losses

Electricity cost & carbon emissions

	Country default	Override default?
Currency	$	
Electricity cost per kWh	0.07	
CO2 emissions (kg/kWh)	0.111	



RESULTS

PUE | Energy cost | Carbon | Economizer mode hours

Power usage effectiveness

Baseline (no economizer)

	Cooling only PUE
Chiller with cooling tower and perimeter CRAH	1.66

Chilled water architectures

	Cooling only PUE
Chiller with cooling tower, plate & frame HX and perimeter CRAH	1.42
Containerized packaged chiller with dry cooler and row-based CRAH	1.22

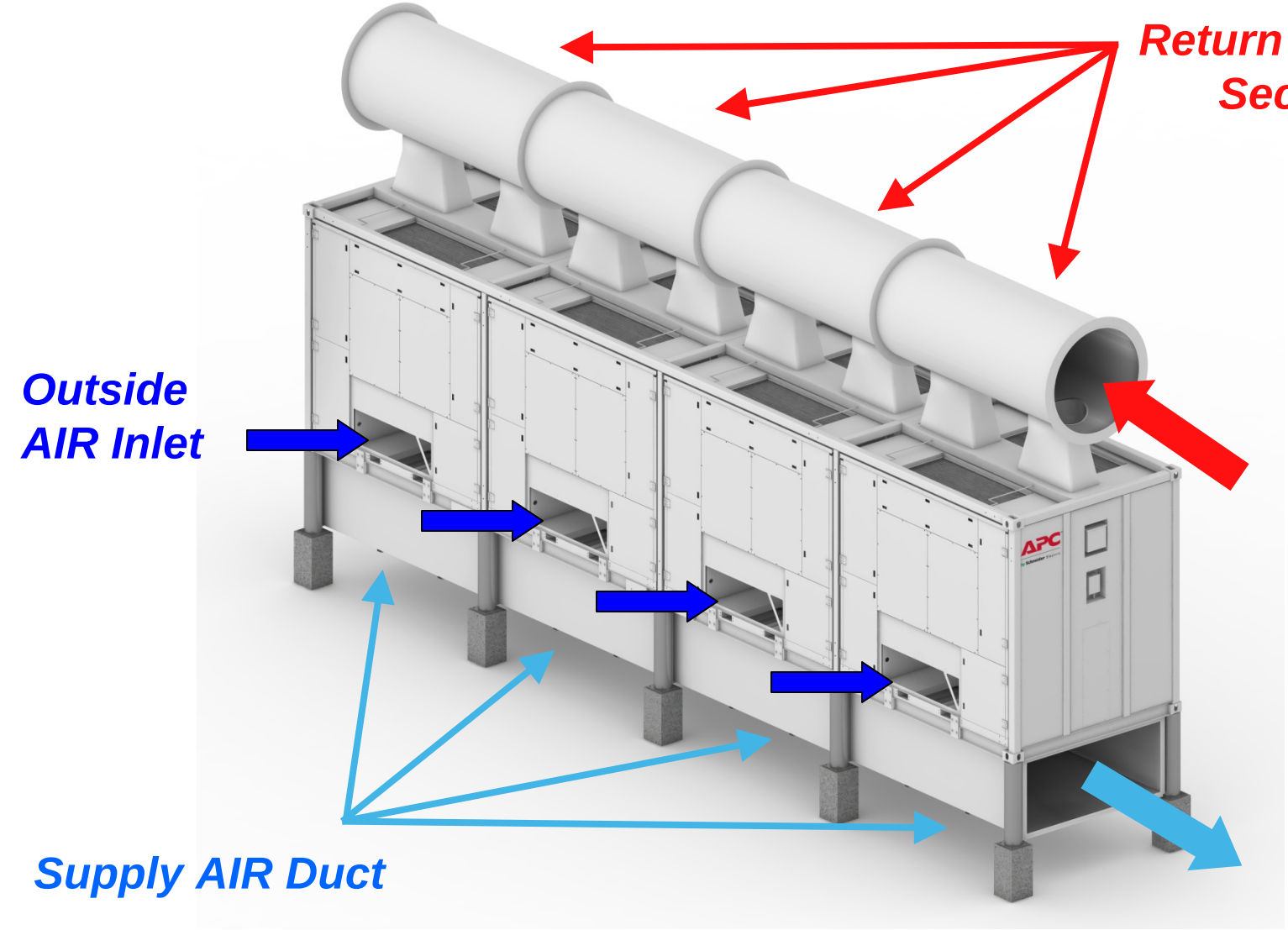
Glycol-cooled architectures

	Cooling only PUE
DX perimeter CRAC with dry cooler	1.38

Air-cooled architectures

	Cooling only PUE
Air conditioner with direct fresh air and evaporative assist	1.11
Air conditioner with heat wheel and evaporative assist	1.05
Indirect air evaporative cooler	1.05

Indirect Outside Air Economizer Solution



Best Practice for Highly Efficient Cooling

Outside Air Economization





- Sits outside the Data Center
- More room for IT equipment
- Indirect Air and Water Methods of Economization
- Can be mounted ground level or on the roof
- Add modules as load increases
- Can be used with or without a raised floor

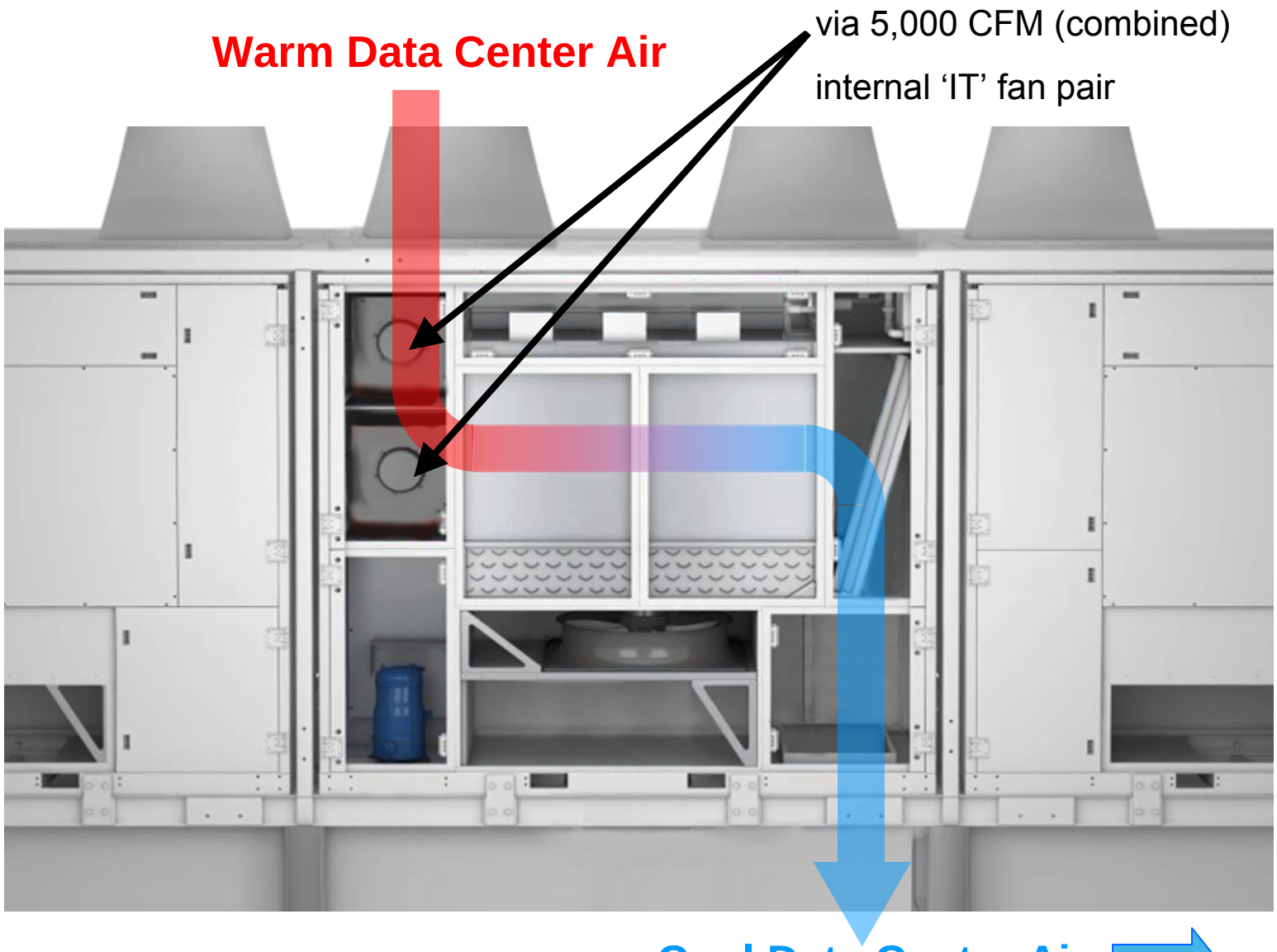
Modular Economizer Solution

with Air-To-Air and Evaporative Economizer Modes

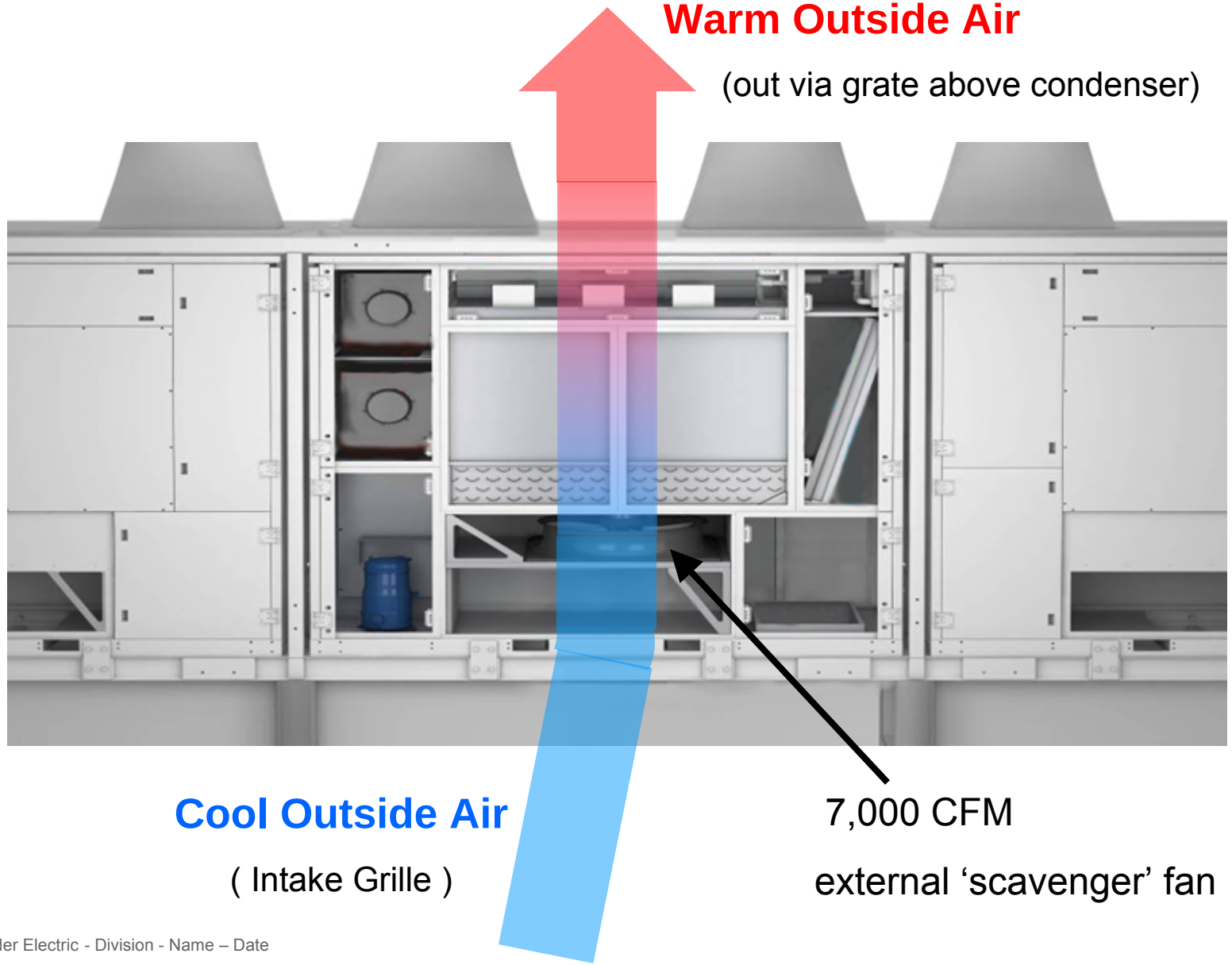


- Redundant Modules
- Scalable from 50kW - 400kW per frame
- 20 ft Frame – Up to 4 Modules per frame
- 40 ft Frame – Up to 8 Modules per frame

Indirect Economization …. Inside Air Path



Indirect Economization …. Outside Air Path



Air to Air (dry) Operation

- In cold ambient conditions (<45°F, adjustable), the module switches to air-to-air heat exchange mode.

- The cool ambient air absorbs the heat from the hot IT return air through the IEC heat exchanger surface.

(IT Return Air Dry Bulb – Ambient Dry Bulb) x IEC Dry Mode Effectiveness = Cooling Potential

(IT Return Air Dry Bulb – Cooling Potential) = Temp. out of IEC

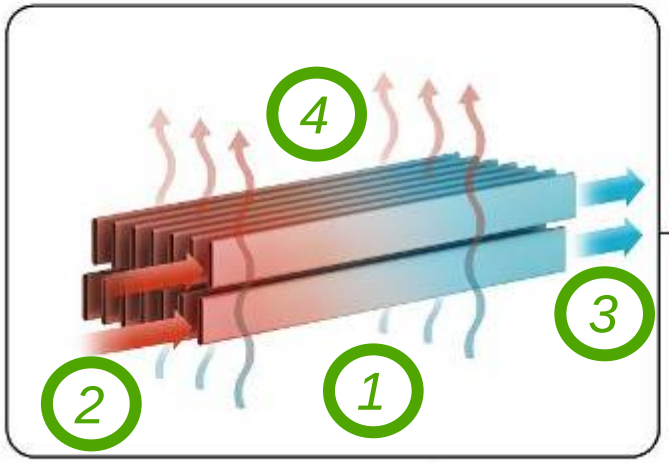
Example:

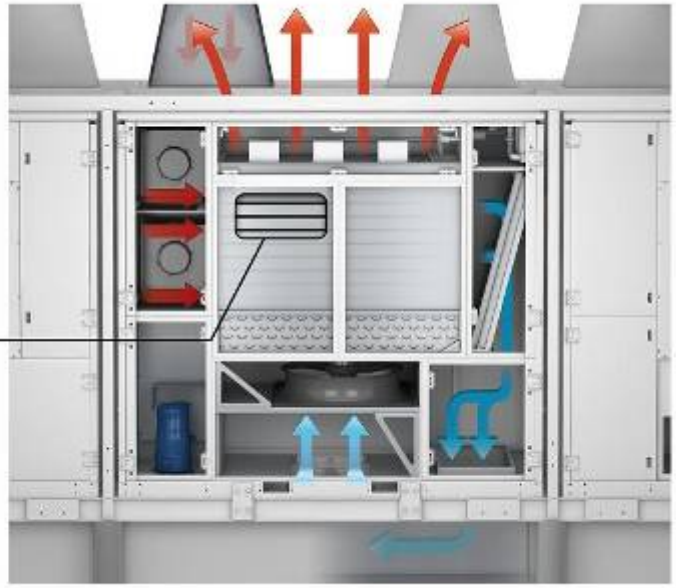
(100°F – 30°F) x 50% = 35°F

(100°F – 35°F) = 65°F

Supply Air Setpoint = 75°F

1. *Cool Ambient Air*
2. *Hot IT Return Air*
3. *Cool IT Supply Air*
4. *Hot Ambient Exhaust Air*





Air + Water (wet) Operation

- In warm ambient conditions, the module will switch to Evaporative Cooling mode.
- In Evaporative Cooling mode, water is sprayed evenly across the heat exchanger. Warm ambient air is then blown across the outside of the heat exchanger, cooling the water down to the wet bulb temperature at which it will evaporate and absorb the heat from the IT Return Air.

(IT Return Air Dry Bulb – Ambient Wet Bulb) x IEC Wet Mode Effectiveness = Cooling Potential

(IT Return Air Dry Bulb – Cooling Potential) = Temp. out of IEC

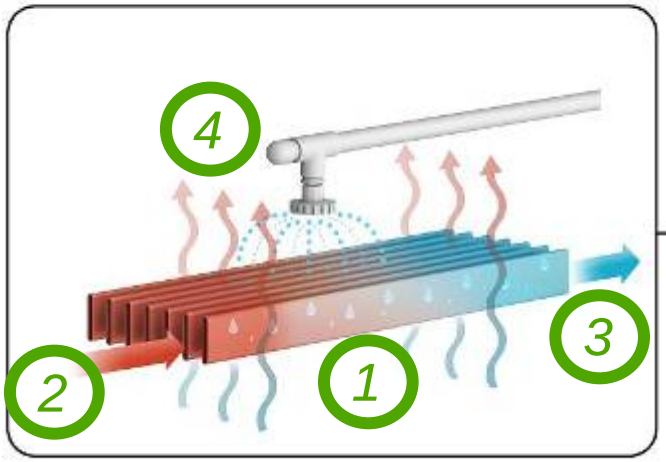
Example:

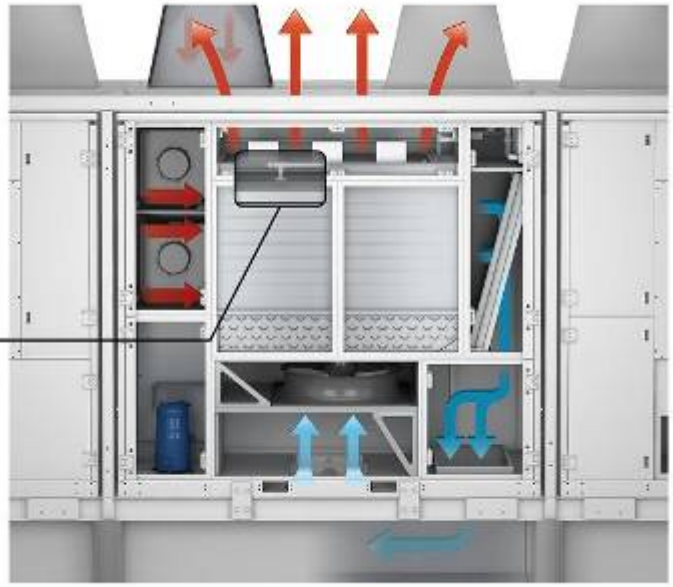
(100°F – 60°F) x 66% = 26.4°F

(100°F – 26.4°F) = 73.6°F

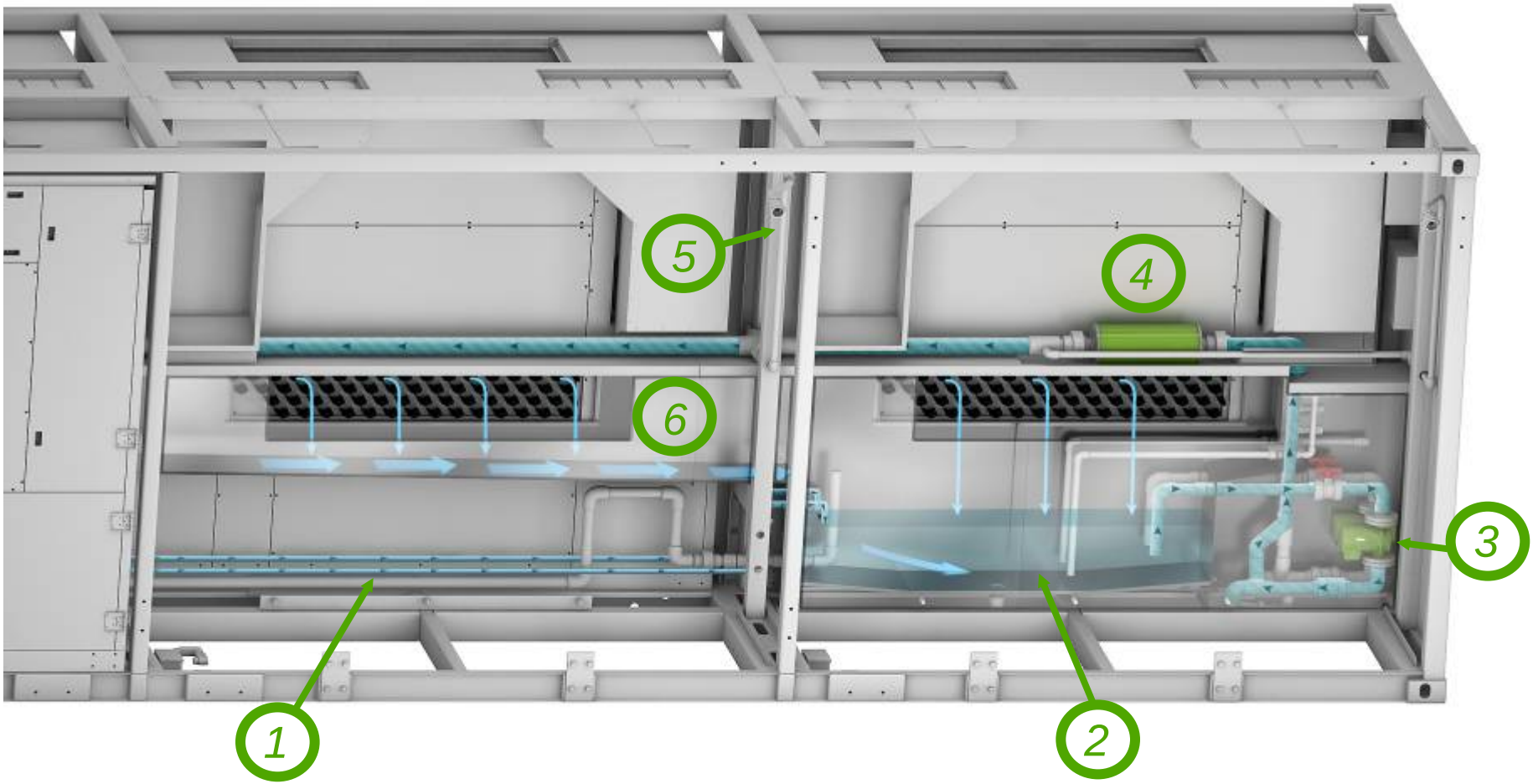
Supply Air Setpoint = 75°F

1. *Cool Ambient Air*
2. *Hot IT Return Air*
3. *Cool IT Supply Air*
4. *Hot Ambient Exhaust Air*



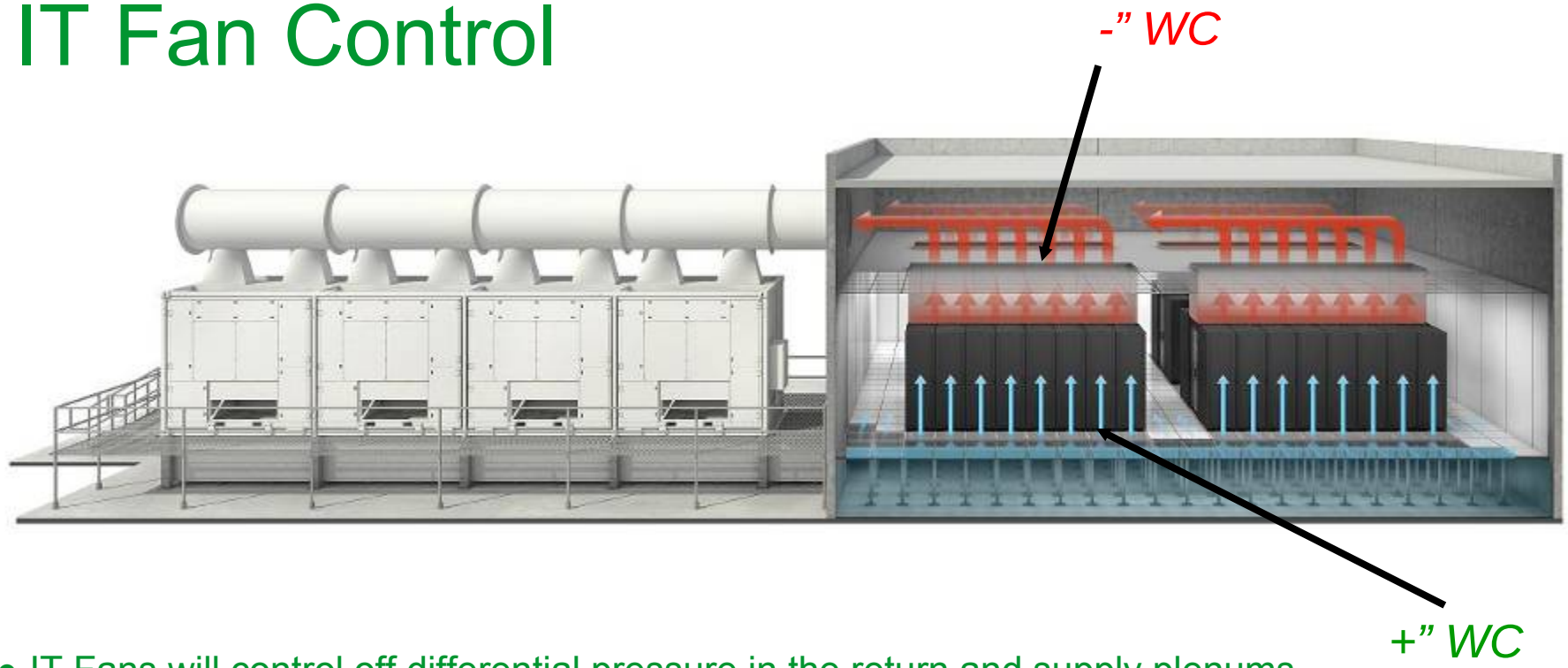


Evaporative Cooling Operation



1. *Water Inlets*
2. *Water Sump Tank*
3. *Redundant Water Pumps*
4. *Chemical-Free Water Treatment*
5. *Water Distribution to Modules*
6. *Central Water Return Back to Sump*

IT Fan Control



- IT Fans will control off differential pressure in the return and supply plenums
- Pressure sensors will keep the supply plenum slightly **positive**
- Pressure sensors will keep the return plenum at a slight **vacuum/suction**
- The EcoBreeze will sense server airflow and vary the IT fans to keep the return plenum at a vacuum

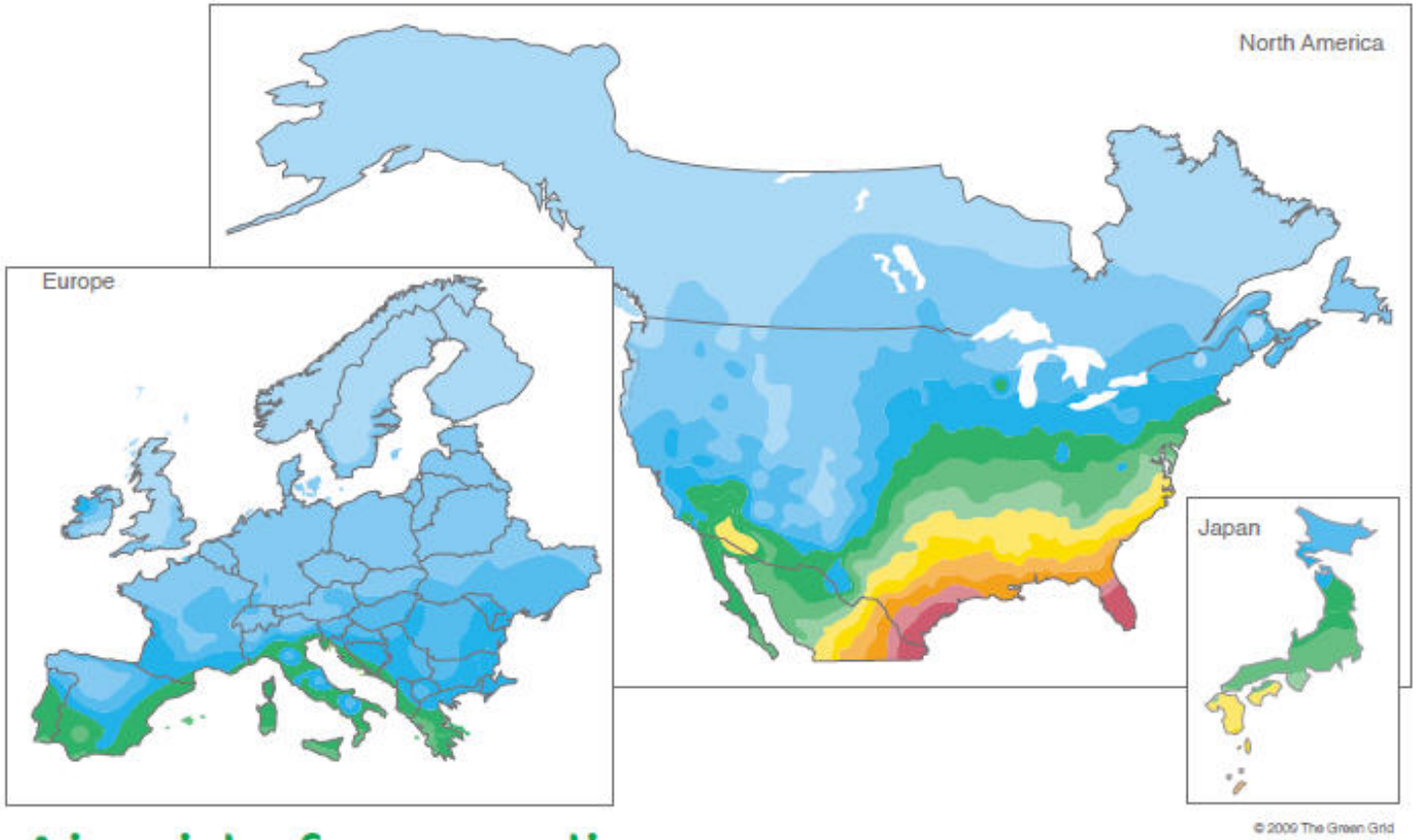
- In the case of one EcoBreeze unit supplying multiple HACS, the IT fans will vary based on the “worst case”
  - If one HACS pod requires more airflow, the EcoBreeze will control off that pod

Add or Remove Modules as Needed…



- Modular, Pay as you Grow
- Unused bays are isolated with dampers and blanked off
- Quick connect water and power lines

Economization Anywhere….



Air-side free cooling map

Estimate of full air-side economizer hours for data centers

Fully populated EcoBreeze (40ft Frame, 8 modules)
Supply air setpoint of 27°C
Temperature change across EcoBreeze 17°K
Full Airflow Capacity 370kW
Operating Load of 247 kW (2/3 Full Airflow)

EcoBreeze based upon the above provides full Econ for ambient conditions ≤ 27°C DB and ≤ 15°C Dewpoint

8500 Hours
8000 Hours
7500 Hours
7000 Hours
6500 Hours
6000 Hours
5500 Hours
5000 Hours
4500 Hours
4000 Hours
3500 Hours
3000 Hours
2500 Hours
2000 Hours

Compare Performance and pPUE

* Based on BIN data from St. Louis, MO

2 MW Design Data Center @ 60% Load					
System Architecture	Partial PUE	kW-Hr/Yr	Relative Power	Annual Full Econ	Annual Part Econ
Indirect Evap Cooling, Qty (41)	1.089	939,764	100%	64%	36%
Water Cooled Chiller w/ Econ	1.156	1,644,290	175%	42%	31%
Air Cooled Chiller w/ Econ	1.166	1,749,732	186%	54%	27%
Fresh Air Econ w/ Evap Assist	1.185	1,949,454	207%	59%	0%
DX Fluid Cooled CRAC w/ Econ	1.216	2,266,299	241%	49%	51%
Heat Wheel Econ w/o Evap	1.093	987,008	105%	50%	50%

EcoBreeze Load Profile (WASHINGTON-Seattle.csv) 41 Modules

Power	IT Actual Load (2000kW Design)						
Consuming	100%	90%	80%	70%	60%	50%	40%
Pump [kW-Hr/Yr]	18,587	18,587	18,587	18,587	18,587	18,587	18,587
IT Fan [kW-Hr/Yr]	1,328,859	989,368	711,428	489,501	317,909	190,807	102,152
Comp [kW-Hr/Yr]	110,210	65,909	35,783	17,357	7,420	2,590	662
OA Fan [kW-Hr/Yr]	586,899	519,141	440,259	337,269	237,088	152,915	86,883
Total [kW-Hr/Yr]	2,044,555	1,593,005	1,206,057	862,714	581,004	364,900	208,284
COP	8.6	9.9	11.6	14.2	18.1	24.0	33.6
Annual Dry Operation	14%	14%	14%	14%	14%	14%	14%
Annual Water Use [Gal]	127,218	113,627	100,638	88,408	77,115	66,928	57,884
Max Compressor Load %	23.6	19.1	15.0	11.3	7.9	4.9	2.3

Supply Air Setpoint: 75°F

Temp change through IT servers: 36°F

IT Design Load: 2MW

EcoBreeze

Modular Indirect Economization

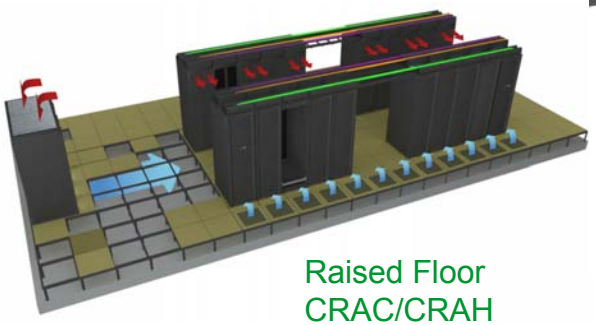


- Multiple forms of Economization
  - Air-to-Air heat exchanger
  - Indirect evaporative cooling
- Proportional DX refrigeration circuit
  - Variable speed compressor
  - Electronic expansion valve
- Electronically Commutated Fans
  - Variable speed fans
- Zero White Space Solution
  - Systems sit outside the data center
- Modular Design
  - For expansion & redundancy
  - Continued operation during maintenance
- Nominal 50kW Sensible Cooling Per Module
  - Up to 8 modules per frame (400kW)
- IEC Heat Exchanger
  - No mixing of IT air and ambient air
- Environmentally Friendly
  - Chemical-free water treatment
  - Ozone friendly R410a refrigerant

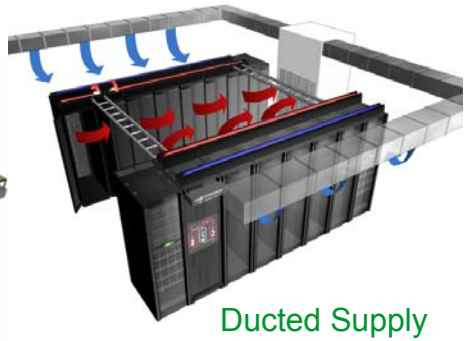
Best Practice Room Cooling

Flexible and efficient cooling of network/server/telecom rooms and data centers

- Flexibility
  - Room level control and air distributi
    - Humidity Control
    - Lighting/People
  - Racked and Non-racked IT loads
  - Raised floor and Ducted

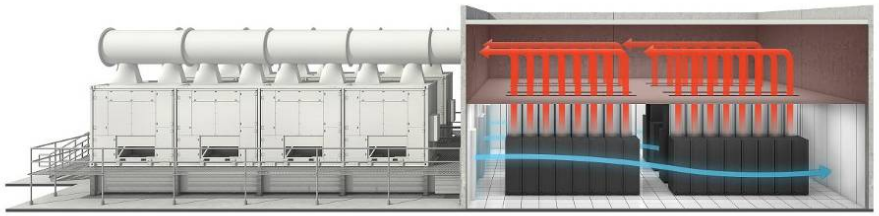


Raised Floor
CRAC/CRAH



Ducted Supply
CRAC/CRAH

- Efficiency
  - EC Fan Technology to reduce fan power
  - Large Coil area to maximize capacity and Economizer Hours
  - Air Economizer to minimize mechanical cooling



Ducted Return
Air Economizer

Thank You



Questions?