



Technology Paper 007

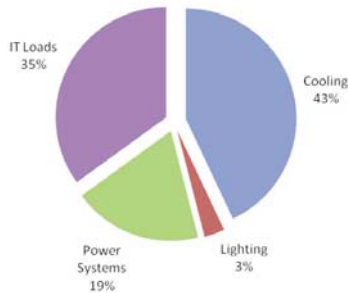
Evaporative Free Air Cooling for Data Centres



Creating an effective workspace environment

Introduction

Typically within a traditional data centre only 35% of the electricity is used by the IT equipment. The remaining 65% is consumed by chillers, UPS systems, air conditioning, power distribution units and other infrastructure components.



This means, when you pay your electric bill, 35% of it is for your IT and 65% for your supporting infrastructure. In other words, data centres typically draw more than twice as much power as their IT loads require, of which a significant proportion can be avoided. Today the majority of data centre operators are concerned about the energy efficiency of their facility. As new builds or refreshes take place data centre designers and operators are constantly innovating and working to improve the efficiency of new installations. As cooling represents a large proportion of energy overhead within a traditional data centre the use of alternative energy efficient cooling methods should be considered. This technology paper demonstrates how the deployment of evaporative fresh air cooling as an alternative to conventional cooling technology

can deliver exceptional PUE levels and help significantly reduce installation and associated operating costs.

What is Evaporative Free Cooling Technology

Evaporative free air cooling is a low cost, low carbon alternative to traditional DX (refrigerant) or Chilled Water cooling solutions for data centre and server room environments. Evaporative free air cooling systems make the use of outside air to cool the I.T equipment. Very simply free air cooling delivers outside fresh air to the equipment inlets and removes hot exhaust air from equipment outlets. During warmer periods intake air is passed through wet filter pads to make use of the natural evaporative cooling process to reduce the inlet air temperature. Thus through this use of fresh air and evaporative cooling this solution can deliver significant energy reductions for data centre and server room cooling.

The operating costs of evaporative free air cooling solutions are typically up to 90% less than other traditional air conditioning technologies.



Example Contemporary Cooling Systems

Technology	Details	Estimated PUE***
In-Row Cooling	Based on the principle of moving the cooling unit closer to the source of heat generation, In Row cooling technology provides an excellent solution for point cooling. This design helps eliminate air mixing and provides a predictable cooling architecture.	1.3 to 1.5*
Rear Rack Cooling	Rear rack technology is a proven high density rack cooling system which delivers excellent PUE performance. The rear rack doors remove heat directly from source without the need for conventional air conditioning systems. This approach effectively neutralizes the equipment exhaust air delivering it back to the room at ambient.	1.2 to 1.4*
Evaporative Free Air Cooling	Evaporative fresh air cooling delivers outside air into the data centre and removes hot exhaust air. During warmer periods the evaporative cooling mechanism will cool the inlet airflow to help maintain temperatures within ASHRAE guidelines**	>1.15

Data Centre Cooling Systems Comparison

As detailed in the introduction traditionally the percentage of energy costs associated with the cooling of the data centre space is a high proportion of the overall costs. A number of data centre cooling technologies have emerged to help improve the efficiency over the last few years.

As can be seen both In-Row and Rear Rack cooling options will deliver excellent PUE ratings when compared to traditional cooling technology. However the evaporative free air cooling

technology delivers outstanding PUE*** performance when compared to conventional "closed loop" alternatives.

* Figures are indicative annualized figures and assume chilled water circuits are combined with free cooling coils. The figures also assume that room equipment inlet temperatures are running at 24°C.** ASHRAE - American Society for Heating, Refrigeration and air-conditioning.*** Power Usage Effectiveness is the industry recognised standard for data centre room efficiency measurement developed by the Green Grid.

ASHRAE Guidelines

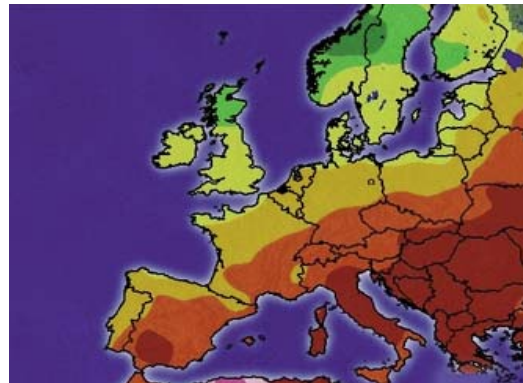
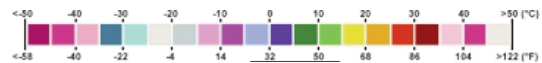
In the past, air economiser cooling solutions have been dismissed for data centre environments due to historical issues with air quality and humidity control. Evaporative free air cooling based systems challenge the barriers to air economiser cooling as a suitable technology for data centre environments. The barriers to air exchange have now been removed as modern computing equipment is much more robust with regards to both temperature and humidity. Typical computer

manufacturer environmental operating specifications are 10°C to 35°C and 10% to 95% relative humidity. It is anticipated that next generation servers will be designed to operate at even higher ambient temperatures. ASHRAE have acknowledged the advances of modern computers and the need to balance energy efficiency against system reliability. ASHRAE guidelines published in 2011 for class A1 recommends a data centre room temperature range from 18°C to 27°C with humidity levels between 8% to 80%.

Table 1. ASHRAE 2011 updated temperature and humidity ranges for data centres (ASHRAE Technical Committee 9.9, 2011)

Classes (a)	Equipment Environmental Specifications							
	Product Operations (b)(c)					Product Power Off (c) (d)		
	Dry-Bulb Temperature (°C) (e) (g)	Humidity Range, non-Condensing (h) (i)	Maximum Dew Point (°C)	Maximum Elevation (m)	Maximum Rate of Change (°C/hr) (f)	Dry-Bulb Temperature (°C)	Relative Humidity (%)	Maximum Dew Point (°C)
Recommended (Applies to all A classes; individual data centers can choose to expand this range based upon the analysis described in the ASHRAE paper)								
A1 to A4	18 to 27	5.5°C DP to 60% RH and 15°C DP						
Allowable								
A1	15 to 32	20% to 80% RH	17	3050	5/20	5 to 45	8 to 80	27
A2	10 to 35	20% to 80% RH	21	3050	5/20	5 to 45	8 to 80	27
A3	5 to 40	-12°C DP & 8% RH to 85% RH	24	3050	5/20	5 to 45	8 to 85	27
A4	5 to 45	-12°C DP & 8% RH to 90% RH	24	3050	5/20	5 to 45	8 to 90	27
B	5 to 35	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29
C	5 to 40	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29

The 2011 specification also created two new classifications of data centres A3 and A4 and expanded the range of allowable environmental conditions in order to encourage energy efficiency practices like air-side and water-side economisation. The use of evaporative free air cooling based technology is therefore encouraged by leading organisations such as the EU Code of Conduct for Data Centre Best Practice, Green Grid and ASHRAE as well as leading computer and chip manufacture's including Dell, HP and Intel. Based upon the European weather map the whole of the UK will deliver in excess of 8000 hours or 333 days below the 27°C upper limit.



Benefits of Evaporative Free Air Cooling Systems

Evaporative free air cooling technology makes the use of external air to cool server room and data centre equipment. Unlike simple air economisers which require supplemental DX or chilled water cooling when external ambient temperatures exceed 21°C, the free cooling systems will engage the evaporative cooling mechanism which reduces external air temperature by simply passing the airflow through wet filter pads.

Deployment benefits of evaporative free air cooling include:-

- Reduced CO₂ emissions
- Lower cost of installation vs. traditional technology approaches
- Significantly reduced energy consumption and operating costs
- Can co-exist with existing cooling technologies
- Improves PUE Efficiency Ratings
- Improved data centre “Green Credentials”
- Improved resilience with practical support by UPS systems
- Flexible airflow configuration options.

Reduced Operating Costs

Why do we need to run an air conditioning system when the external ambient temperature is suitable to cool computer equipment? By simply bringing in external ambient air and extracting hot exhaust air, this will keep server room computer equipment cool most of the year. The economics of using evaporative cooling are surprising to most people. An 85% reduction in energy used compared to a conventional air conditioning unit seems too good to be true but this can be achieved because in the UK it is cold most of the time. By using PLC control systems, inverter driven variable speed DC fans, coupled with evaporative cooling when outside air temperatures exceed 21°C energy consumption is minimal. The only significant energy use when evaporative free air cooling is deployed is in the fan for the air movement. Typically between 1kW to 1.5kW of power to support a 30kW I.T load in the UK. This impressive cooling coefficient cannot be achieved with any current cooling technology.

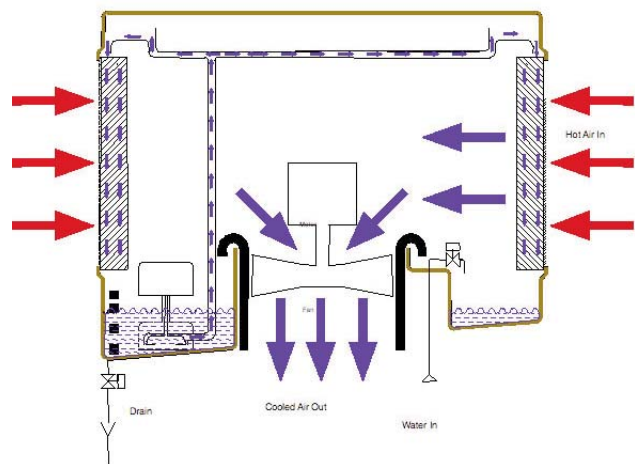
“Evaporative” Free Air Cooling in Detail

Evaporative free air cooling units typically use an evaporative heat exchange process to cool air. This process takes advantage of the principle that water evaporation requires energy (latent heat) is required to overcome the transformation between a liquid and a gas. This evaporative heat exchange system simply removes energy from the air, thus reducing the air temperature as it passes through the water filter. When compared to air-conditioning which uses mechanical refrigeration, the operating cost of evaporative heat exchange can be up to 90% less than traditional air conditioning. Typically water is brought into the cooler from a mains water supply and is pumped up to the top of the unit using a circulation pump. The water is then dispersed over filter pads using a water distribution system which allows the water to flow continually over the pad. The pads become saturated, air is drawn through the pads and the water evaporates naturally causing the air to cool.

With any water/air combined cooling products there is a risk of Legionnaires disease, however these evaporative coolers fall outside the Governments (UK) Acop L8 guidelines due to the minimal risks that these products present. This is due to the fact the units do not create a spray or aerosol and use treated mains water. Also the units operate in ‘Dry’ mode most of the year and drain down each day when ‘Wet’ mode has been enabled.

The cool air is then filtered and ducted into the data centre by means of an axial fan.

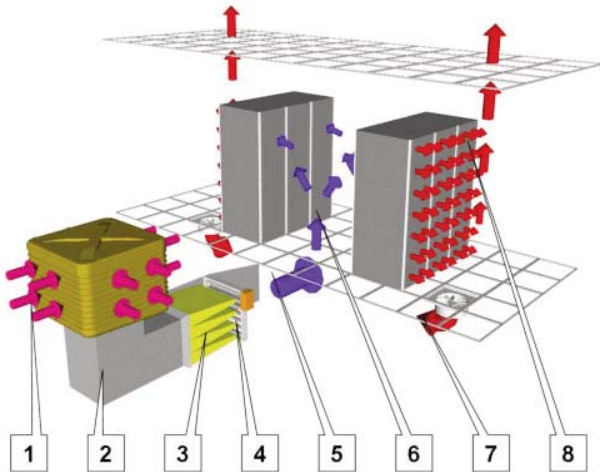
Evaporative Cooling Process



Achievable Temperatures

The hotter the outside temperature and the lower the humidity, the greater will be the cooling effect. On the hottest day in the UK up to 15°C of cooling can be achieved through this process. The air off temperature of well designed evaporative free cooling unit in the UK is always below 23°C, thus providing excellent cooling for data centre environments.

Typical Airflow Schematic using Workspace Technology's Freecool® solution.



- 1 – Fresh air is brought into the system through primary filtration and wetted filter pads
- 2 – Water detection provides additional security
- 3 – Filters remove airborne particles
- 4 – Isolation damper is linked to fire system
- 5 – Cool air is fed into void under raised floor
- 6 – Temperature compliant air is fed into cold aisle
- 7 – Warm air from hot aisle is re-circulated to heat incoming air when ambient temperatures are below set point temperature to maintain constant inlet temperature
- 8 – Hot air is extracted and exhausted to outside of building

Air Filtration

As the evaporative free cool systems rely on external air there is a requirement to provide suitable filtration. Typically well designed free air cooling designs will include primary and secondary GU4 filtration levels. Filter walls enable large volume of air to be delivered with a low pressure drop.

Temperature Control

It is recommended that a stable temperature is maintained within ASHRAE data centre guidelines. To ensure temperatures are maintained below the upper 27°C limit evaporative cooling will take place. To ensure that the lower limit is maintained during cooler periods professionally designed evaporative free cooling installations will deploy air recirculation/mixing circuits. The combined airflow will ensure the temperature is maintained above the lower limit. Typically evaporative free air cooling systems are designed to deliver cold air either directly, via a raised access floor or a ceiling void depending on the optimum arrangement. Sensors located within the data centre accurately measure the equipment "inlet" and "outlet" temperatures and associated air pressure. This allows consistent inlet temperature to be maintained through the use of a PLC system to control the Airflow Dampers. When designed correctly the airflow control system known as "atemperation" can deliver close control temperature of +/-2°C which is comparable with conventional close control systems.

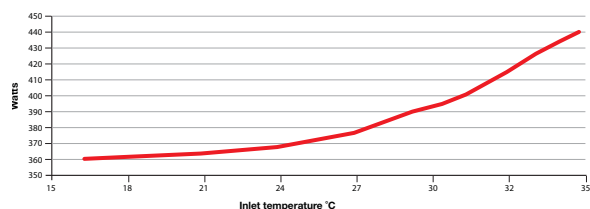
Can Evaporative Free Air Cooling be "Free"

As detailed above in response to growing data centre energy consumption ASHRAE TC9.9 committee has developed an expanded recommended thermal operating envelope for data centres.

Thus by increasing the data centre temperatures there will be a reduction in the amount of energy needed to cool the I.T load by increasing the periods of free cooling for closed loop systems. Typical design temperatures of between 24°C and 27°C are used as the set point for equipment inlet air.

Technology solutions including Rear Rack and In-Row cooling will benefit from high equipment inlet temperatures as it enables higher chilled water flow temperatures and in turn increases the amount of free cooling periods that can be obtained.

However, due to the dynamic nature of the IT equipment the inbuilt cooling fans will diminish or even negate these cooling system gains. This is because server fans will typically increase their speed/airflow as inlet temperature to the server reaches or exceeds 25°C, consequentially increasing server energy consumption.



Typical Variable Speed Fan Based Server

As can be seen on the example graph showing a typical variable speed fan based server the overall server power consumption will increase with temperature. Power consumption will rise from 360W at 18°C to 378W at 27°C representing a 5.0% (18W) increase in critical load.

This raise in critical load effectively distorts the PUE reading for In-Row and Rear Rack systems when they are operated at higher inlet temperatures.

Unlike conventional cooling there is no energy penalty by choosing to run well designed evaporative free air cooling at reduced operating temperatures. The power consumed by the cooling units, are directly related to the volume of air required which is directly related to the critical or I.T load. As the ambient within the UK is below 18°C for the vast majority of the time this allows for a greater amount of free cooling. As indicated on the example graph reducing the operating temperature will also reduce overall server power consumption and as a side effect the equipment reliability will also be increased.

The chart below shows the difference between I.T Load power consumption of a typical data centre installation.

Equipment Inlet Temperature	I.T Load
27°C	263kW
18°C	250 kW
Saving	13kW

Based on a typical 250kW evaporative free cooling system will use approximately 12kW of energy. If the system is set to 18°C inlet temperatures then the free cooling system will genuinely be free to operate based as this will reduce the I.T. load by 13kW due to the fan power savings on the equipment when compared to conventional cooling system which rely on higher ambient inlet temperatures to maximise their free cooling potential.

Table 2 – Comparison of energy running costs for typical data centre’s with different efficiency ratings (10p per KW/hr)

Critical Load Kw	PUE 4.0	PUE 2.0	PUE 1.5	PUE 1.25	PUE 1.0
10	£35,040	£17,520	£13,140	£10,950	£8,760
20	£70,080	£35,040	£26,280	£21,900	£17,520
25	£87,600	£43,800	£32,850	£27,375	£21,900
50	£175,200	£87,600	£65,700	£54,750	£43,800
100	£350,400	£175,200	£131,400	£109,500	£87,600
150	£525,600	£262,800	£197,100	£164,250	£131,400
200	£700,800	£350,400	£262,800	£219,000	£175,200
300	£1,051,200	£525,600	£394,200	£328,500	£262,800
500	£1,752,000	£876,000	£657,000	£547,500	£438,000
750	£2,628,000	£1,314,000	£985,500	£821,250	£657,000
1000	£3,504,000	£1,752,000	£1,314,000	£1,095,000	£876,000

Evaporative Free Air Cooling Impact on Data Centre Efficiency

Traditional cooling technology is a major contributor to data centre infrastructure power overhead. The chart above shows typical examples. Often even with energy efficient technology, PUE figures of only 2.0 can be achieved.

The deployment of a professionally designed evaporative free air cooling technology makes it possible for data centre efficiency figures to achieve PUE ratings >1.15 when combined with additional energy saving technology e.g. passive aisle containment and airflow management technology.



Table 3 – Comparison of CO₂ with different efficiency ratings

Critical Load Kw	PUE 4.0 CO ₂ Tonnes	PUE 2.0 CO ₂ Tonnes	PUE 1.5 CO ₂ Tonnes	PUE 1.2 CO ₂ Tonnes	PUE 1.0 CO ₂ Tonnes
10	2,102	1,051	788	657	526
20	4,205	2,102	1,577	1,314	1,051
25	5,256	2,628	1,971	1,643	1,314
50	10,512	5,256	3,942	3,285	2,628
100	21,024	10,512	7,884	6,570	5,256
150	31,536	15,768	11,826	9,855	7,884
200	42,048	21,024	15,768	13,140	10,512
300	63,072	31,536	23,652	19,710	15,768
500	105,120	52,560	39,420	32,850	26,280
750	157,680	78,840	59,130	49,275	39,420
1000	210,240	105,120	78,840	65,700	52,560

Kw to CO₂ Kw Conversion

0.006



Conclusions

In conclusion this paper demonstrates that the use of evaporative free air cooling will deliver significant energy performance benefits for data centre operator when compared with other contemporary data centre centric cooling technology.

A good example of this technology is Freecool® by Workspace Technology Limited. Freecool® is one of the UK's leading data centre evaporative free cooling solutions. Freecool® has been installed successfully for many public and private sector organisations keen to obtain quick energy efficiency wins and enhance their green credentials. Typically Freecool® solutions by Workspace Technology when installed as part of an AC upgrade or replacement programme will deliver an 18 months to 3 year payback based on energy savings.

Workspace Technology have gained a reputation as the UK's leading expert in the design and installation of evaporative free air cooling solutions with its Freecool® range of products and services.

About Workspace Technology

Workspace Technology is a design and build, data centre specialist that leads the industry with its expertise in the implementation of energy efficient data centre solutions.

Workspace Technology's Freecool® evaporative free air cooling systems have been successfully installed for public sector and commercial clients across the UK. Freecool® by Workspace Technology has a proven track record for delivering exceptional PUE performance figures saving company's many thousands of pounds through reduced operational costs.

If you required further information on Freecool® please contact Workspace Technology's expert consultants at sales@workspace-technology.com or call 0121 354 4894.

Further details on Workspace Technology's full range of products and services can be found on www.workspace-technology.com.

Freecool® is registered trade mark of Workspace Technology Ltd.

Workspace Technology Limited

Technology House, 5 Emmanuel Court, Reddicroft, Sutton Coldfield,
West Midlands B72 1TJ.

Tel : 0121 354 4894 Fax: 0121 354 6447
email : sales@workspace-technology.com
www.workspace-technology.com



Creating an effective workspace environment