Free Cooling Technologies in Data Centre Applications

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Executive Summary

When preparing to design a new data centre or upgrade an existing facility, many owners and operators take the opportunity to increase overall facility efficiency in an endeavour to reduce ongoing running costs or increase company commitment to sustainability, most commonly a combination of both.

Green technologies, such as Free Cooling systems, enable data centre operational costs to be cut dramatically and allow further IT equipment to be supported by the same overall facility supply. Naturally, however, every data centre is different, so careful consideration of the most suitable and effective technologies must be a priority for each individual organisation.

This paper is a short guide and introduction to some of the leading Free Cooling technologies available to support data centre owners in meeting their personal energy efficiency goals. The information within this paper aims only to provide a starting point for which the most important research areas can be identified for the next stages of development.

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Notes & Resource

Since Free Cooling has gradually become a dominant phrase within the data centre industry, the purpose of this paper is to provide end users and those with an interest in data centre systems with a brief introduction to Free Cooling technologies, which begins to discuss both the crucial considerations and benefits within a modern, efficient data centre.

Target Audience: End User

1. Data Centre Energy Usage

Data centres can be one of the most power intensive zones within an organisation, and since exemption from the Carbon Reduction Commitment (CRC) is not usually an option, data centre efficiency, and the resultant carbon reduction, has become one of the primary targets for many organisations.

A common metric for assessing the efficiency of a data centre is Power Usage Effectiveness (PUE), which provides a good indication of the overall efficiency of data centre infrastructure, although the efficiency of the actual IT load itself must be considered separately. Average PUE ratings typically range between 2 and 2.5, with more efficient facilities achieving values between 1.2 and 1.8.

Shown below is a graphical representation of the energy flow for a data centre with a PUE rating of around 1.6. When looking to reduce the PUE of the facility, the obvious candidate, excluding the critical IT load, is the cooling system. That is not to say efforts should not be made to reduce the energy consumption within other aspects of the facility such as energy efficient lighting systems or critical power protection, however cooling largely remains the leading contributor and therefore substantial consideration should be given to its efficiency.

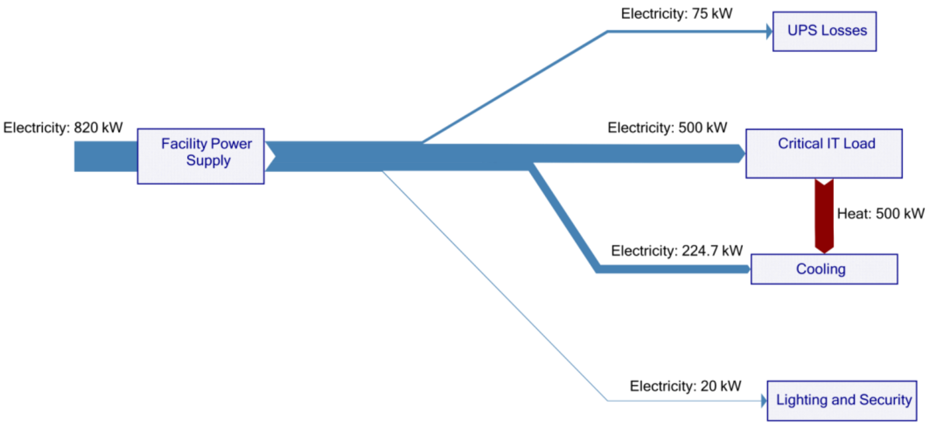

Figure 1: A typical data centre energy flow diagram.

2. "Free" Cooling Defined

Conventional cooling techniques present an increasing problem in the data centre, because these standard cooling systems are based on the mechanical process of compression and expansion of refrigerant. This working fluid evaporates into a vapour when it absorbs thermal energy however in order to force the fluid to reject this heat to the outside air, the refrigerant is compressed, increasing its temperature, after losing enough heat to the external air the fluid is then allowed to expand back to its original, lower, pressure, reducing its temperature and allowing the process to repeat.

The compression part of this cycle is a significant consumer of energy and therefore makes cooling one of the primary areas where organisations can make significant energy savings.

Free cooling aims to maximise the use of the natural energy transfer that will occur when the ambient external temperatures are less than that either supplied or exhausted from the data centre. Despite the name, free cooling systems can only be 'truly' free when they are 100% passive, with no moving parts, such as fans or pumps. In reality this cannot be achieved on the scale of a datacentre and as such applicable free cooling technologies are not entirely 'free' but do offer a greatly reduced energy usage for a datacentre.

These methods notably present a viable option for the majority of geographical locations across the UK whose low temperature and humidity conditions are favorable.

3. Types of Free Cooling Systems

3.1 Direct Air Economisers and Fresh Air Cooling

Direct Air Economisers work on the basis that for a certain period of time in the year, the ambient air conditions fall within those allowable within the data centre. During this time fresh air can simply be drawn directly into the data centre and hot air exhausted, as illustrated below. In the instance that external conditions become cooler than required, hot exhaust air can be mixed with cool fresh air to produce an acceptable temperature supply.

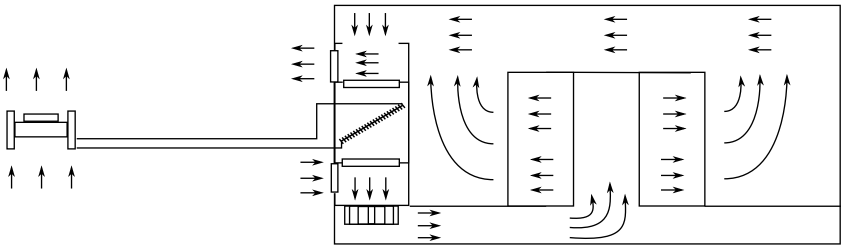

Figure 2: A Simple Direct air economiser with Supplementary DX

The obvious advantage with this system is the particuarly low levels of energy consumption. A system capable of delivering about 3 m^3/s can sustain about 30kW of cooling and consumes only around 1.5kW, relating to a Coefficient of Performance (COP) of 20 and greatly reducing the overall PUE.

This level of performance is highly attractive for data centre owners and operators due to the high potential for savings, however, there are key considerations which have to be made:

Absence of any **supplementary cooling**, such as a traditional DX system, means fresh air cooling will be incapable of providing air cooler than the ambient air outside, resulting in the data centre operation being relient on outside conditions. For most data centre owners this is unsatisfactory, however, for some this is not an issue. Some equipment can have particuarly high allowable temperatures, reducing the possibility of any failures due to high temperature whereas other operators may be able to move operations to other resources and only function during the cooler months of the year.

Humidity is a key consideration. Humid air can increase the growth of conductive whiskers within the data centre and can increase the rate of corrosion and degradation which can occur to PCBs and soldering joints. Conversely, air that is too dry has been associated with static build up and discharge, damaging some equipment. The ambient relative humidity is typically quite high in the UK, however due to the inability of cold air to sustain water vapor, very cold air even with a high relative humidity can become too dry when heated up to the desired supply air temperatures.

Dust, Smoke, and Air Bourne Contaminents become a concern when the data centre enviroment is changed from a closed architecture to an open system. Mitigation procedures and control must be implemented to prevent any ingress which will cause damage or malfunction. Dust and air bourne contaminents build up over time and suitible filtration can be implemented to filter these out. Smoke can enter a data centre through air inlets systems unless properly mitigated against. Smoke within the data centre can trigger fire suppression equipment and cause false alarms on fire detection equipment, potentially halting operations within the data centre.

Filtration systems range in type, quality, effectiveness and cost depending greatly on the air quality being filtered and the requirements with the data hall. The pressure drop across filtration systems increases the work on fans so an optimum level of filtration should be used to keep operating costs and noise low while not comprimising the reliability, availiability efficiency of the system.

3.2 Indirect Air Economiser

Indirect Air Economisers operate through utilising air to air heat exchanger allowing for the transfer of heat with little to no transfer of external air to the internal data centre environment allowing closer control of internal conditions and air quality, including air borne containments such as dust and smoke. However, as with all coils and heat exchangers, a large quantity of contaminants in the air passing through the heat exchanger will build up over time and will reduce the effectiveness of the heat exchangers and increase maintenance frequency.

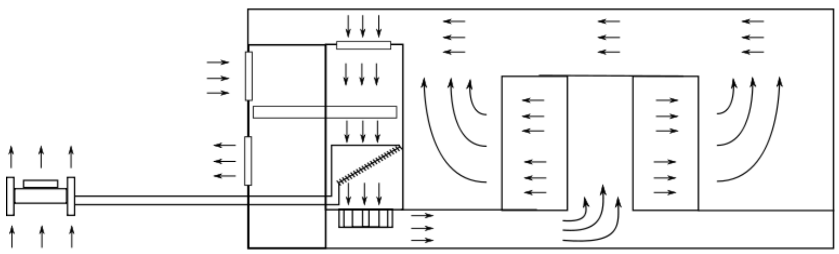

Figure 3: A simple representation of a heat wheel based indirect air economiser.

A well known example of an indirect air economiser system is the Kyoto wheel system, illustrated above, which encompasses a rotary heat wheel air to air heat exchanger with a DX cooling system and controls to manage the system. This allows air supplied to the data centre to meet tighter operating bands while still utilising Free Cooling when available and falling back on to traditional cooling when required.

The annualised COP of these systems is reported at about 8 to 10 comparing well to traditional cooling systems which can lie around the 3.5 mark. These systems, although very efficient, can be quite large, due to the sizeable surface area required while maintaining an acceptable pressure drop and heat transfer, and as such, the suitability of these systems can be limited due to the size but can be considered on a case by case basis for suitability.

Just as for direct fresh air economiser systems, if the system is not supplemented with another cooling system, such as that discussed, then it can only be relied on to produce supply air within the acceptable bounds for part of the time, outside of which the data centre is not operable.

3.3 Water Side Economisers

Systems which are based on a chilled water infrastructure are good candidates for Free Cooling as the free cooling process can be introduced without compromising on the internal environment. In addition to this there is flexibility on the final load type and density, either supplying chilled water air handling units or providing cooling for one of the many chilled water high density systems available.

3.3.1 Free Cooling Water Cooled DX CRAC Units

Water cooled DX CRAC units condense the refrigerant within the unit using a water circuit to transfer the heat released to a dry cooling unit finally rejecting the heat into the ambient external surroundings.

The Free Cooling variants of this system employ a second coil within the CRAC unit such that when the water from the dry coolers is returned sufficiently cold as a result of low external temperatures, flow is diverted through a chilled water coil reducing or eliminating the need for mechanical cooling.

The downside to this type of system is that when Free Cooling is not possible the system operates in traditional DX cooling mode but with less efficiency than normal due to the additional coil in the air path increasing the fan pressure and energy consumption. If installed correctly, the additional running costs associated with the mechanical cooling phase should be more than compensated by the efficient Free Cooling operation available during cooler ambient temperatures.

CRAC units available in this arrangement will be larger than standard which can make them less suitable for larger data centre applications or where floor space is a premium.

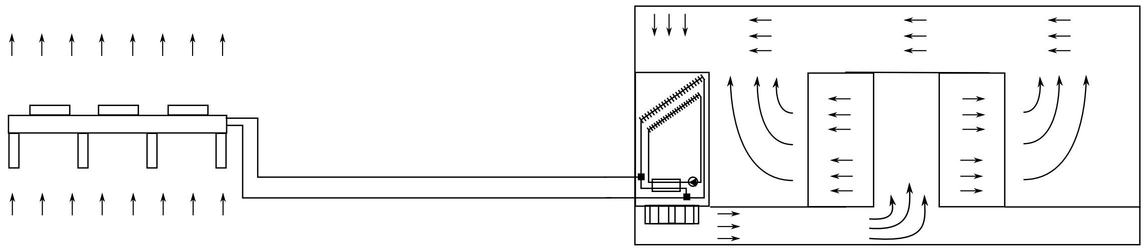

Figure 4: Water cooled, free cooling CRAC Unit, incorporating the free cooling and DX loop within the CRAC unit and rejecting heat through an external dry cooler.

3.3.2 Air Cooled DX Chillers with Free Cooling

Air Cooled Chillers supply chilled water to within the data centre which can provide cooling to CRAC units or High Density cooling systems. Integrating efficient Free Cooling coils within the chiller unit itself allows a simple design with the ability to provide redundancy by duplicating chiller units and with the right design more free cooling can be achieved through the increased surface area possible by running redundant chillers during the cooler months.

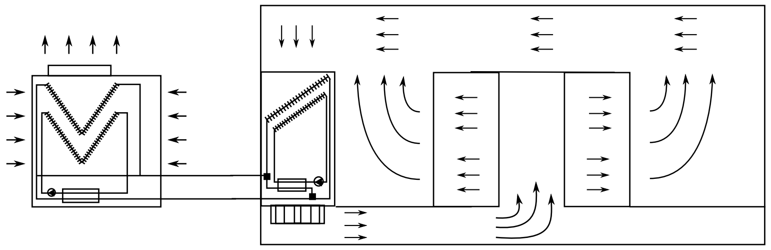

Figure 5: A packaged air cooled chiller with free cooling coil operating with a chilled water CRAC Unit.

3.3.3 Water-Cooled Chillers with Free Cooling

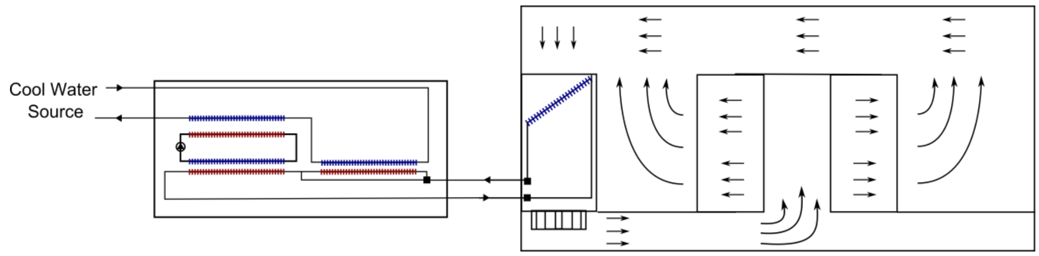

Figure 6: A simple schematic illustrating the operation of a water cooled chiller incorporating a free cooling heat exchanger.

Water-cooled chiller units use a secondary water circuit to condense the refrigerant and as such must be coupled with a secondary heat rejection system such as a dry cooler or transfer the heat elsewhere through the use of heat exchangers

One application of water-cooled chillers is the ability to utilise natural bodies of water such as lakes, rivers or canals for cooling. Large bodies of water are less susceptible to peak air temperatures due to the significant thermal mass. For this reason they can mostly be assumed to maintain a temperature close to the average ambient temperature over the preceding 48 hours.

Extraction of water from these sources often requires a permit and a cost is sometimes payable to the water source owner. Environmental Agency approval is also required for returning water of a higher temperature to the source. The procedure is relatively simple and can be a major source of significant savings and reduced carbon emissions while maintaining a closed system within the datacentre and subsequent control over the datacentre environment, acting as a key driving factor behind the use of water-cooled chillers with Free Cooling.

3.4 Evaporative Cooling

Fresh air evaporative cooling systems fundamentally operate on the basis of latent heat absorbed during the evaporation process. When water is evaporated into an air stream, energy is required in order to transform water from a liquid to a vapour. If this energy is not introduced into the system, adiabatic cooling occurs in the air reducing the temperature of the air while maintaining the overall enthalpy. The resultant effect is cooler air with higher relative humidity.

The UK climate more often requires heating to achieve temperatures of around 21°C. For this reason, and to maintain a stable temperature, the return airflow is mixed with the supply air, resulting in warmer air with less relative humidity.

Evaporative cooling systems can be **Direct**, **Indirect** or a **Hybrid** operation, which have differing levels of performance and standards depending on the application and environmental conditions.

Evaporative cooling is also the principle by which **cooling towers** operate, allowing more waste heat to be transferred to the atmosphere. Although cooling towers can be relied upon for a large proportion of the year, at the chilled water temperatures required within a data centre environment and the resilience and reliability required, they are usually supported by chillers, further increasing the required external plant area.

Due to the possibility of warm water remaining in the open system for periods of time, potentially high maintenance costs and L8 Health and Safety Compliance have to be considered when looking at Evaporative cooling technologies however due to a strong perception of cooling towers and evaporative cooling technologies as a source of Legionella, many manufacturers incorporate processes to mitigate this risk through automatic draining and treatment of the water used.

4. Overall Performance Comparison

	Suitable Applications	Footprint	Achievable PUE	Cost
Direct Air Economiser	Equipment with wide operating area and consistent ambient temperatures.	Small	1.05 - 1.25	Low
Indirect Air Economiser	Larger data centre requiring close control of IT Conditions and high efficiency goals.	Large	1.15 - 1.35	High
Free Cooling CRAC Unit	Medium sized data centre requiring close control.	Medium	1.45 - 2	Medium
Free Cooling Chiller (Air Cooled) – Packaged.	Medium to large data centre with outdoor compound.	Medium to Large	1.3 - 2	Medium to High
Free Cooling Chiller (Water Cooled)	Large data centre with access to a supply of cool water e.g. large lake, river or canal.	Medium	1.15 - 2	Medium to High
Fresh Air Evaporative Cooling	Small to large data centre with high energy efficiency aspiration.	Small	1.05 - 1.25	Low to Medium
Cooling Tower	Medium to large data centre needing close control of IT Conditions with high energy efficiency aspiration.	Large	1.2 - 1.7	Medium to High

Note:

All Free Cooling technologies by their nature require favourable ambient conditions. Footprint size provides a guide, however it should be noted that through the need to transfer heat naturally, a larger coil is more productive and efficient allowing highly efficient systems to be substantial in size.

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