Airedale by MODINE

Applying advanced cooling technology to reduce data centre cooling energy use by 44%

WHITEPAPER

Contents

In industries where cooling is critical, you need a critical cooling specialist.

At Airedale, we recognise that air conditioning is vital in keeping an increasingly connected world up and running. At a time where sustainability is a particularly pressing matter for the future of our planet, we also strongly believe that air conditioning technology must be designed with environmental responsibility in mind.

Airedale is a global specialist in providing complete cooling solutions in industries where HVAC is mission-critical, including data centres, healthcare, telecommunications and pharmaceuticals. Our innovative products – which include chillers, close control and air handling units – are backed by intelligent software solutions, complete applications and service support.

With a strong R&D ethos rooted in sustainability and quality, Airedale's team of approximately 1000 employees is committed to providing products, services and solutions that enable our clients to meet their performance, efficiency and sustainability goals.

Based in Leeds (UK), Airedale also has facilities in Consett (UK), Guadalajara (Spain), Dubai (UAE), Rockbridge (US) and Grenada (US). Airedale is part of Modine (NYSE: MOD), a diversified global leader in thermal management technology and solutions.

For more information, visit **www.airedale.com.**

Abstract

Data centres are at a critical moment when it comes to technological advancement and environmental sustainability.

The big question

With the world becoming an increasingly digitised place, data centres are consuming an ever-larger share of natural resources. This poses serious questions about their environmental sustainability, with a clear need to keep their carbon footprint within certain limits.

Data centres are being deployed at rising speeds and scale. They now account for around 3% of total global energy consumption, while data centre cooling systems are responsible for between 25-40% of an individual data centre's overall energy use. This poses a central question: how do we quench this global thirst for data while keeping energy consumption to a minimum, cooling the internet without warming the planet?

What we found

Air-based cooling systems are – and will continue to be – the technology of choice for many data centres, in the current decade and beyond.

Our research shows that, while great strides towards improved energy efficiency have been made in recent years – including, for example, via free cooling, temperature optimisation and advanced software systems – there remains considerable room for improvement. In particular, there is scope to significantly improve the energy efficiency of air-based cooling systems.

In a study based on a 10MW London data centre, we found that by deploying enhanced cooling technologies across CRAHs, chillers and controls, energy savings of around 44% are attainable, depending on site loading.

Why it matters

These findings go a long way to answering the question we posed above: how to meet the growing global demand for data while ensuring environmental sustainability. Data centre cooling systems must be made more energy efficient in order to deliver on this.

It is incumbent on our industry to play a responsible role in limiting climate change. At the same time, air-based cooling systems must also remain competitive, both from a cost perspective as well as an environmental one, as well as keeping up with the general pace of innovation as new technologies continue to enter the market.

Introduction

Problem

As data centres continue to evolve and adapt, so too does the wider world. Data centre cooling system designers are having to go back to the drawing board to maintain resilience and redundancy at the lowest possible energy costs, as pressures on resources including energy and water continue to mount.

There is also increasing pressure from governments, clients and members of the general public to take decisive action as climatic conditions become increasingly extreme, volatile and unpredictable. As cooling systems take up such a large proportion of data centre energy needs – around 40% – it's no surprise that there is so much pressure on the supply chain to accelerate innovation and improve efficiencies.

Some technologies use water to reduce energy consumption, but water is itself the world's most precious natural resource – and as a result, many operators are moving away from adiabatic/evaporative solutions that waste water.

Chilled water systems, meanwhile, risk being under-utilised and inefficient as a result of their inherent design limitations, equipment specifications and real-world operating and maintenance conditions. However, vast improvements have been made in chiller technology over the years, by manufacturers concerned about competing technologies such as adiabatic dry coolers.

For some time, chiller operating limits and efficiencies hindered the industry from achieving its desired PUEs. Simply put, past efficiencies were no longer sufficient. In free-cooling operation, until recently, typical approach temperatures were wide, resulting in low supply water temperatures – which had a significant impact on energy usage.

2001

First UK manufacturer to develop a free-cooling chiller

2010

Developed the world's first concurrent free-cooling chiller with centrifugal compressor

2021

Introduced Enhanced Free Cooling™

Data centre cooling

In the late 2000s, the introduction of air management infrastructure into data halls enabled operators to raise air supply temperatures. Techniques such as hot aisle containment minimised air mixing and ensured that air temperature gaps between the cooling equipment and the server inlet were kept as narrow as possible.

However, the real catalyst for raising air temperatures in data halls came in 2011, with the publication of ASHRAE's influential technical paper, 'Thermal Guidelines for Data Processing Environments'. This provided guidance on the reliability of IT equipment, introducing the concept of 'allowable' envelopes.

In turn, this gave operators the data and the confidence needed to run equipment outside of stringent conditions set by manufacturers wishing to play it safe.

Higher data temperatures, coupled with new thinking around chillers and free cooling systems where approach temperatures are narrow and Delta Ts are wide, have meant that free cooling benefits outweigh the extra upfront costs associated with chillers.

Chilled water systems have proven to be increasingly resilient due to innovations in both chiller and controls system design. While chiller sequencers were once the pinnacle of cooling plant optimisation, the whole chilled water system must be considered holistically in order to meet the demands of an always-on industry striving for sustainability.

Advances in controls technology, meanwhile, now permit refined monitoring and adjustment of systems, thereby delivering maximum efficiencies.

Our approach

We believe that it is the cooling provider's remit to consider all the variables in the complete water system, matching these against the ideal conditions and employing intelligent software in order to constantly meet the ideals. This delivers more free cooling, greater reliability and redundancy, thus minimising energy use.

As with all technologies, it is our view that ongoing commitment to research and development in the areas that mater to our clients is the key to progress.

The introduction of free cooling technology was a significant milestone. Since then, we have been able to make incremental improvements in this field, achieving improved PUEs by making adjustments. Critically, we have changed our approach to cooling from a unit level to a system level, now working to optimise the performance of the room beyond just one product.

The study

Airedale recently conducted a study comparing the energy consumption of a real-life data centre scenario, operating under assumed conditions with a highly efficient, low-GWP Airedale chiller, both at full and part load.

We then replicated this same scenario, in the same conditions, but instead employing an Airedale DCS chiller. The key differences were the increased coil rows and fan size, as well as the implementation of the controls system optimiser. Our findings were significant.

In particular, our results show that significant energy savings can be made by implementing new technology in existing and new data centre set-ups. These savings are both meaningful and relatively straightforward to attain, given the right design, product and system installation.

We recommend early collaboration between the end user, consultants and cooling specialists to allow for a design that works within the building's constraints in order to maximise the system's cooling potential.

Therefore, we would recommend liaising with an experienced data centre cooling solutions provider before finalising any building decisions, to discuss design options and facilitate the implementation of a cooling system capable of delivering maximum sustainability without compromising on performance.

Methodology

Assumptions

For the purpose of this analysis, product selections and IT loads are taken from an actual project, quoted in the last three years. This gives us an accurate and current baseline specification from which to apply energy use improvement technologies.

Site

Colocation data centre in London, UK

A 10MW IT Load, with an annual energy consumption of 87,600,000 kWh at full load.

The same data centre, with a part loaded IT suite of 7MW, delivering an annual energy consumption of 61,320,000kWh.

Design ambient temperature was set at 40°C.

Cooling system

- Supply air temperature - 24°C
- Return air temperature - 36°C
- Supply water temperature - 20°C
- Return water temperature - 28°C
- Approach temperature - 4°C
- Waterside Delta T - 8K
- Architecture - Primary / secondary water circuit (fixed primary, variable secondary)
- Redundancy - N+1 (Chillers and CRAHs)

Electricity / Carbon

0.2kg of CO_2 per kWh electricity used. The carbon factor of electricity varies according to power generation on given day.

According to UK Government Green House Gas Conversion Factors for Company Reporting, emissions associated with electricity generation in 2022 = 0.193kgCO_2eq per kWhr

This does not include transmission and distribution losses and many other sources estimate above 0.2, so we have used 0.2kg of CO_2 per kWh.

We have used a figure of £0.18 per kWh to calculate the electricity cost (data taken from UK gov figures.)

Energy analysis

Energy performance calculations were carried out using our DeltaChill Performance and Energy Analysis software program. Weather data entered for London is provided by the UK Met Office and cross referenced against ASHRAE data.

Cooling technology

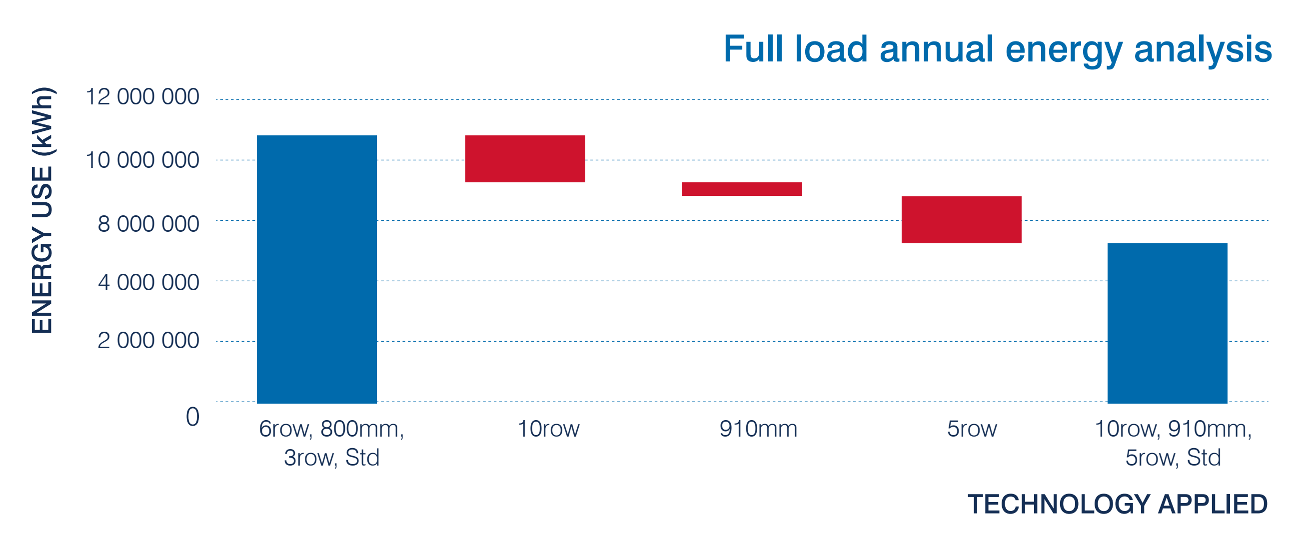
The equipment we have used for the baseline calculations for this project was specified by the consultant and supplied.

Chiller cooling availability was set at 10800kW (vs full IT load of 10,000kW). The chiller cooling availability is 800kW oversized to cover ancillary loads and CRAH fan power inputs.

- Chiller - 7 x 1800kW (N+1)
- CRAH - 77 x 142kW (N+1 in 7 blocks of 10+1). The CRAH net sensible capacity matches to the 10MW load.
- Refrigerant - R32

Results

Full Load Analysis



Baseline

The first column shows our baseline energy use calculation, based on 6 row CRAHs in the data halls and free cooling chillers with 800mm fans and 3 row free cooling coils.

10 Row CRAH

The second column shows the annual energy saving achieved when replacing the 6 row CRAH with a 10 row fan wall. This delivers an energy saving of 662,256 kWh in the CRAHs themselves and 1,084,403 kWh in the chillers.

The total energy saving delivered from moving to a 10 row CRAH is 1,746,659 kWh. This is a total energy cost saving of £314,399.

910mm fans

The third column shows the annual energy saving achieved when replacing the 800mm chiller condenser fans with 910mm ones. This delivers no energy saving in the CRAHs and an additional (on top of the saving delivered by the 10 row) 424,659 kWh in the chillers. This is a total energy cost saving of £76,439.

5 Row free cooling coil

The fourth column shows the annual energy saving achieved when replacing the 3 row free cooling coil with a 5 row. This delivers no energy saving in the CRAHs and an additional 1,765,617 kWh in the chillers. This represents an energy cost saving of £317,812.

Total

The total energy saving from implementing the 3 enhancements is 3,936,934 kWh, representing an annual energy cost of £708,648.

			Energy Usage			
Scenario	Description	IT Load kW	IT kWh	CRAH kWh	Chiller kWh	Total Cooling kWh
Baseline	6row, 800mm, 3row, Std	10000	87600000	3777312	6291636	10958088
2	10row, 800mm, 3row, Std	10000	87600000	3115056	5207233	9211429
3	10row, 910mm, 3row, Std	10000	87600000	3115056	4782575	8786771
4	10row, 910mm, 5row, Std	10000	87600000	3115056	3016958	7021154

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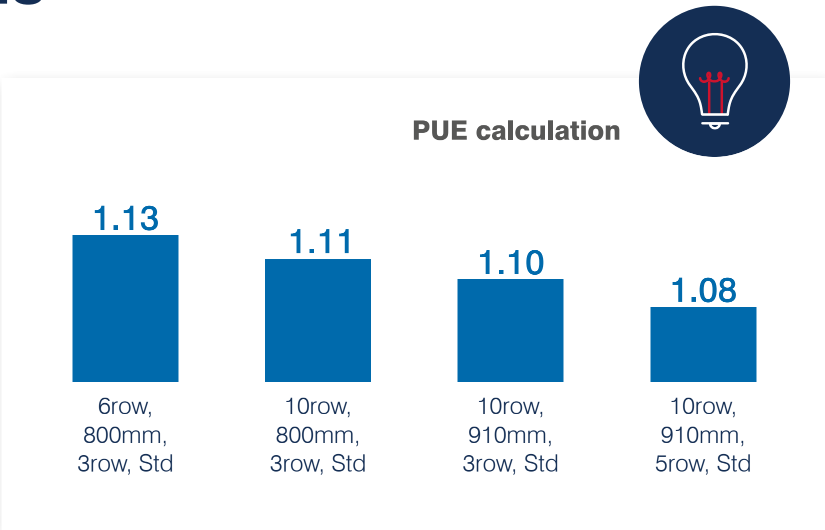
Full Load Analysis

PUE calculation

The predicted PUE is calculated by using the following formula:

$$\frac{\text{IT kWh} + \text{Total Cooling kWh}}{\text{IT kWh}}$$

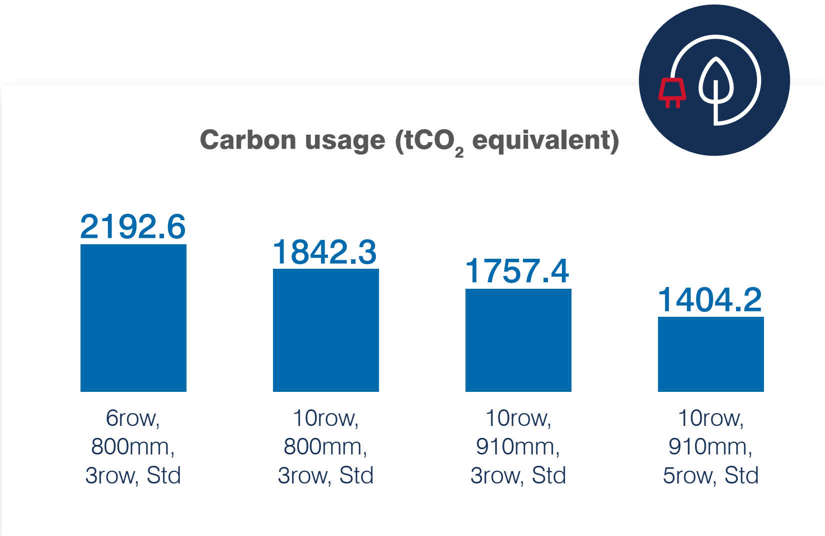
This is an annualised mechanical PUE, not representative of the full site (eg electrical losses etc), and is predicted based on full load operation.



Carbon usage calculation

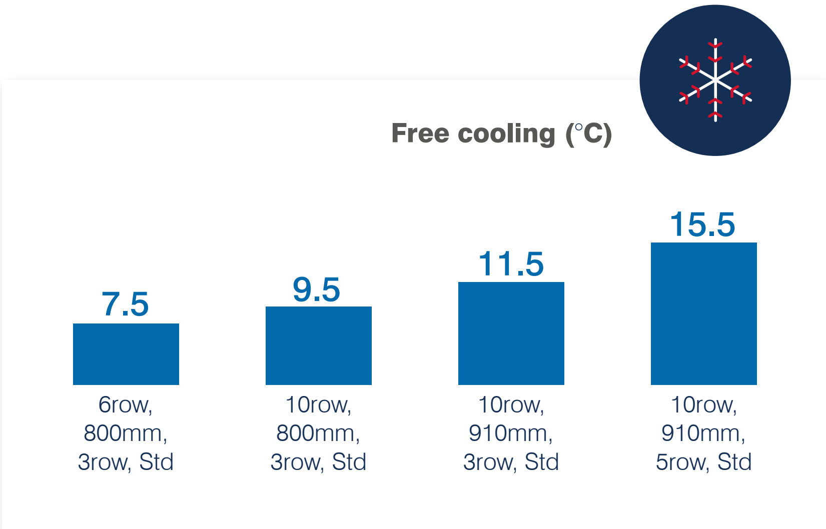
The carbon usage calculation is determined using the energy usage figures and a value of 0.2kg of CO_2 per kWh of electricity used.

The enhanced cooling technologies, when implemented, show an annual saving of 787.4 tons of CO_2 for the 10MW site. This is equivalent to the carbon footprint of 60 average UK homes (Source: www.carbonindependent.org)

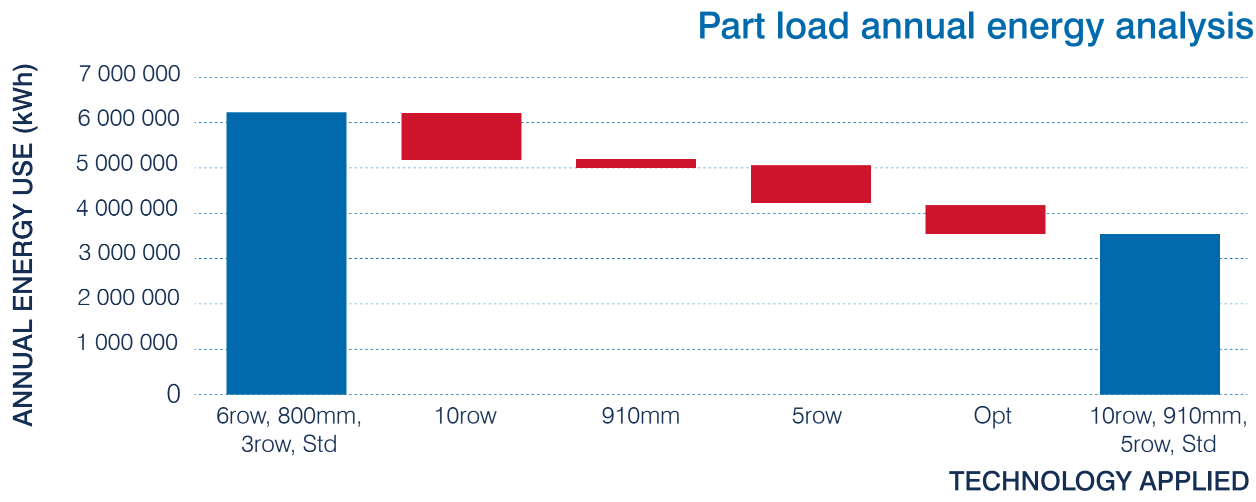


Free cooling calculation

The ambient temperature at which full chiller free cooling is available is a basic measure of how well the free cooling system performs. The graph shows an increase in this figure of 8°C. For a London ambient profile, this equates to a further 4168 hours (47.6% of the year).



Part Load Analysis (70% Load)



Baseline

The first column shows our baseline energy use calculation, based on 6 row CRAHs in the data halls and free cooling chillers with 800mm fans and 3 row free cooling coils.

10 Row CRAH

The second column shows the annual energy saving achieved when replacing the 6 row CRAH with a 10 row fan wall. This delivers an energy saving of 79,716 kWh in the CRAHs themselves and 884,373 kWh in the chillers. The total energy saving delivered from moving to a 10 row CRAH is 964,089 kWh. This is a total energy cost saving of £173,536.

910mm fans

The third column shows the annual energy saving achieved when replacing the 800mm chiller condenser fans with 910mm ones. This delivers no energy saving in the CRAHs and an additional (on top of the saving delivered by the 10 row) 227,988 kWh in the chillers. This is a total energy cost saving of £41,038

5 Row free cooling coil

The fourth column shows the annual energy saving achieved when replacing the 3 row free cooling coil with a 5 row. This delivers no energy saving in the CRAHs and an additional 931,676 kWh in the chillers. This represents an energy cost saving of £167,702.

Optimiser

The fifth column shows the annual energy saved when adding an Optimiser controls solution to the cooling system. This delivers an annual energy saving of 159,621 kWh in the chillers and 453,768 kWh in the pumps. The total energy saving delivered from applying the Optimiser is 613,389 kWh. This is a total energy cost saving of £110,410.

Total

The total energy saving from implementing the 3 enhancements is 2,737,142 kWh, representing an annual energy cost of £492,686.

			Energy Usage			
Scenario	Description	IT Load kW	IT kWh	CRAH kWh	Chiller kWh	Total Cooling kWh
Baseline	6row, 800mm, 3row, Std	7000	61320000	1355172	3977247	6221559
2	10row, 800mm, 3row, Std	7000	61320000	1275456	3092874	5257470
3	10row, 910mm, 3row, Std	7000	61320000	1275456	2864886	5029482
4	10row, 910mm, 5row, Std	7000	61320000	1275456	1933210	4097805
5	10row, 910mm, 5row, Opt	7000	61320000	1275456	1773589	3484417

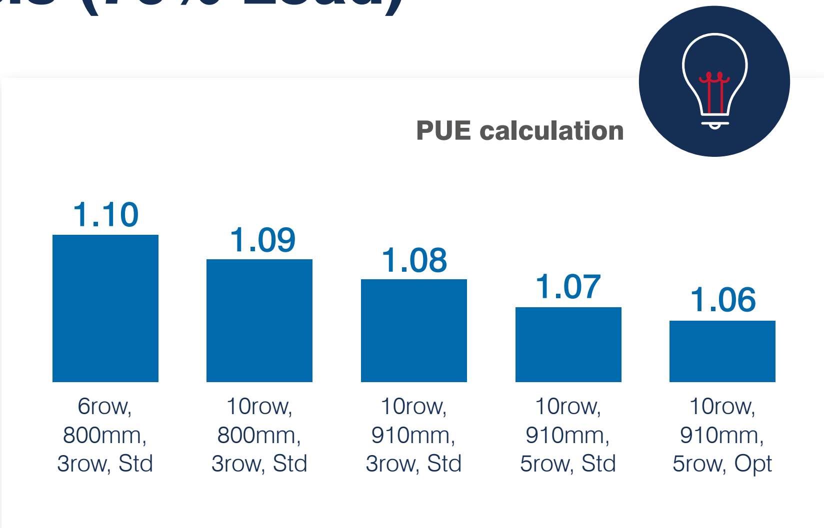
Part Load Analysis (70% Load)

PUE calculation

The predicted PUE is calculated by using the following formula:

$$\frac{\text{IT kWh} + \text{Total Cooling kWh}}{\text{IT kWh}}$$

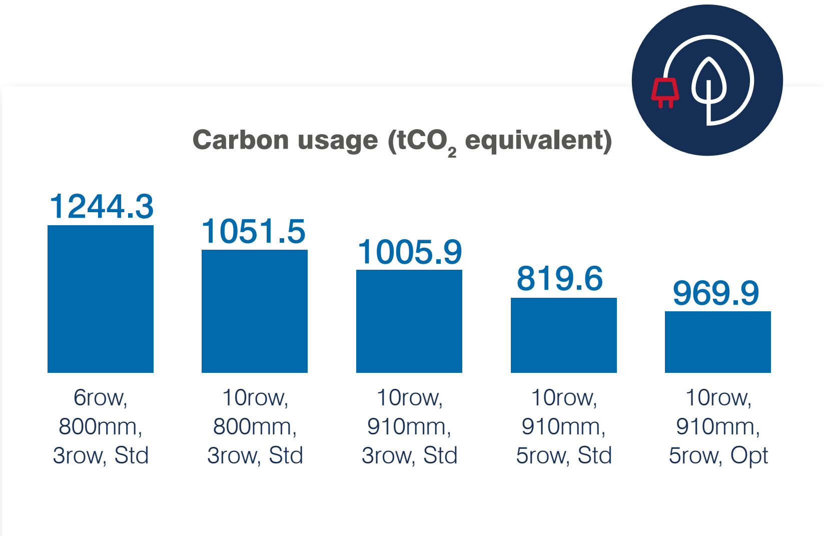
This is an annualised mechanical PUE, not representative of the full site (eg electrical losses etc), and is predicted based on full load operation.



Carbon usage calculation

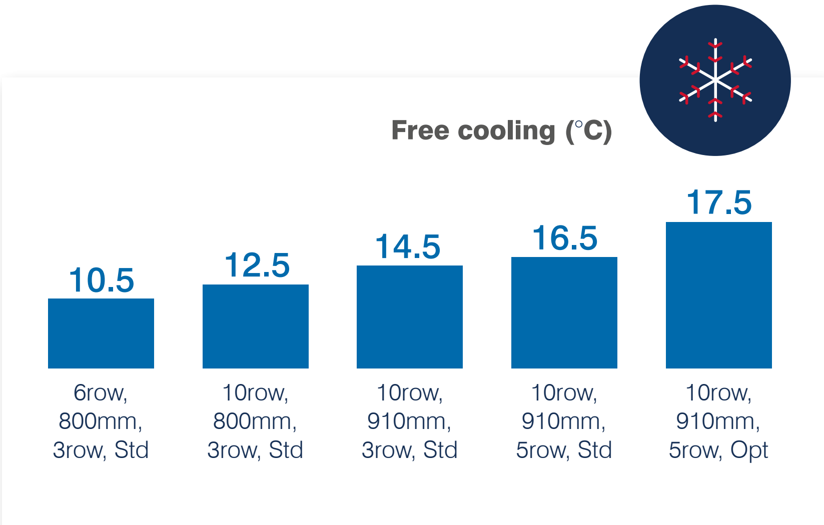
The carbon usage calculation is determined using the energy usage figures and a value of 0.2kg of CO_2 per kWh of electricity used.

The enhanced cooling technologies, when implemented, show an annual saving of 547.4 tons of CO_2 for the part loaded 10MW site. This is equivalent to the carbon footprint of 43 average UK homes (Source: www.carbonindependent.org)



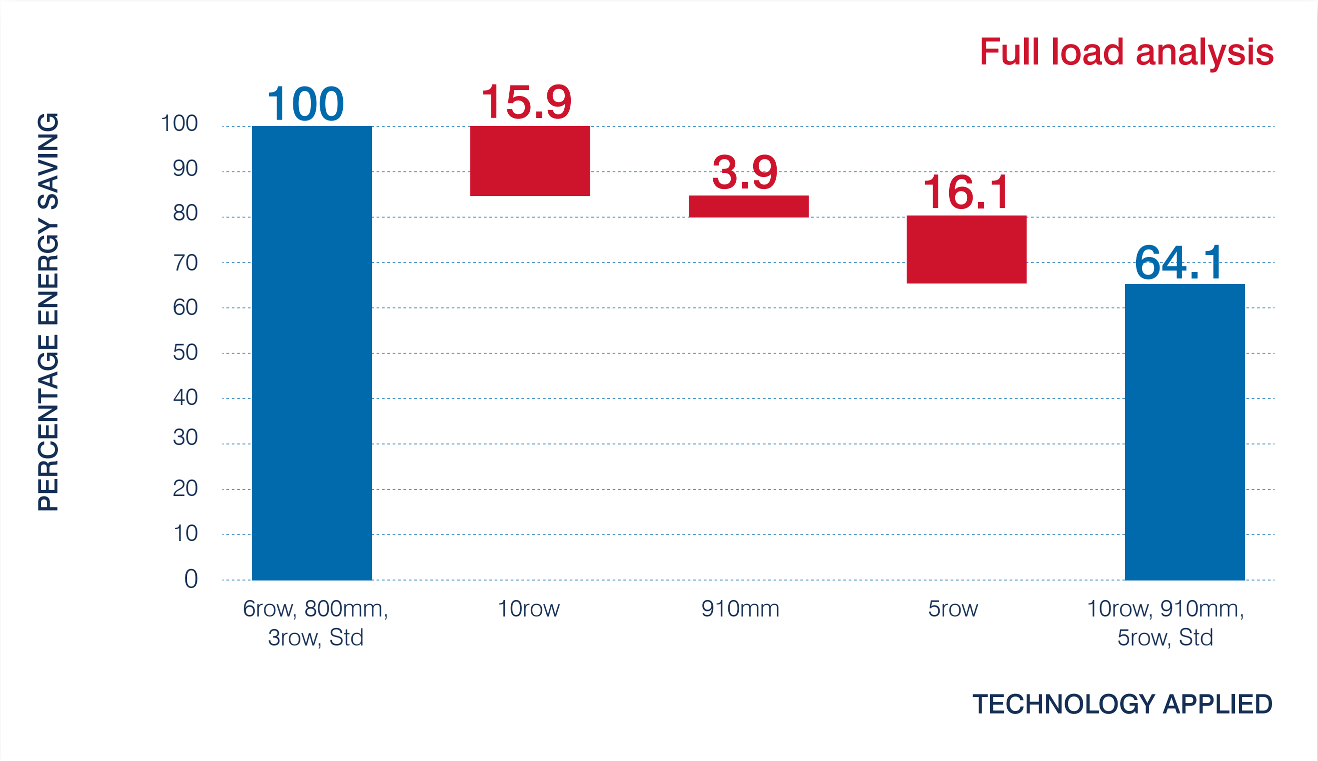
Free cooling calculation

The ambient temperature at which full chiller free cooling is available is a basic measure of how well the free cooling system performs. The graph shows an increase in this figure of 7°C. For a London ambient profile, this equates to a further 3221 hours (36.8% of the year).

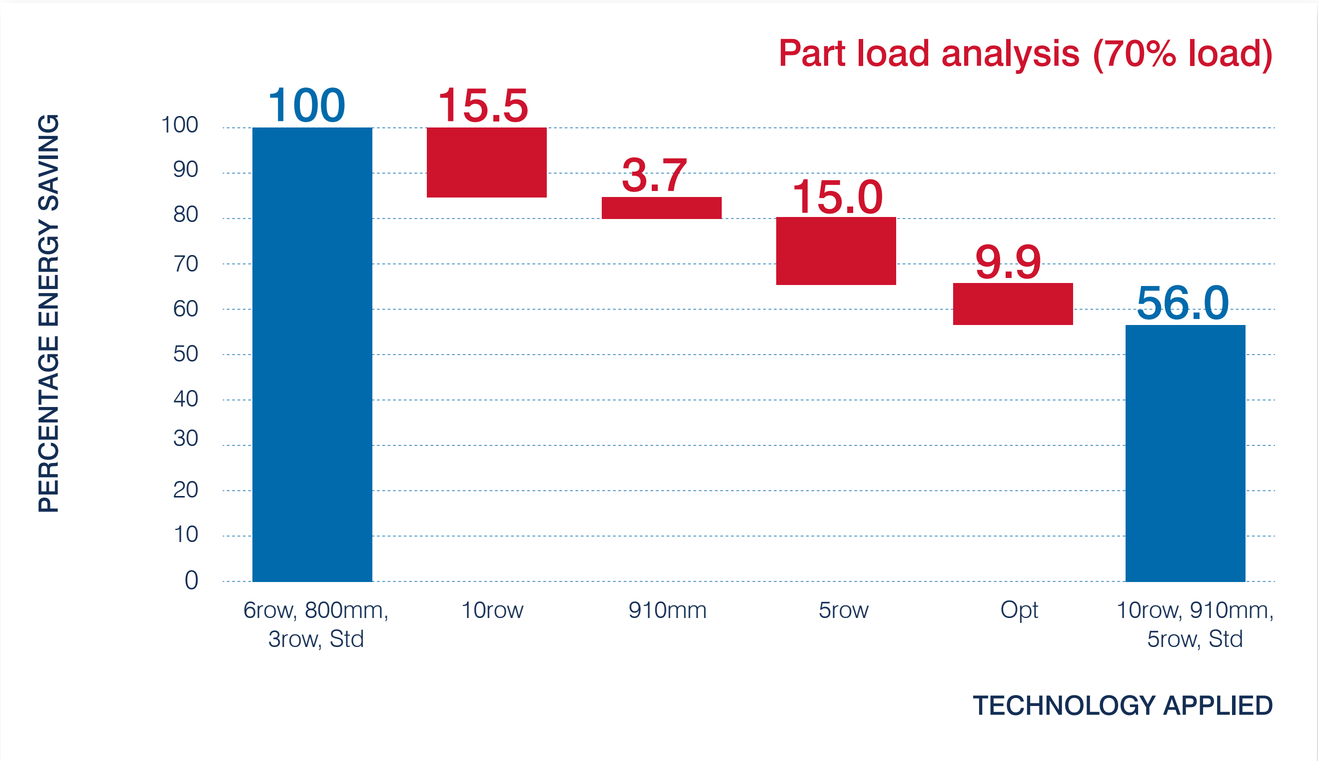


Comparison

Full load analysis



Part load analysis (70% load)

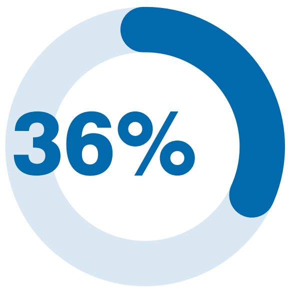


Comparison

The results show significant energy savings at full and part load.

Part load percentage energy savings are higher, mainly as a result of higher savings with the increase in coil rows in the CRAHs. The addition of the Chilled Water System Optimiser is unique to the part load analysis, as its direct / measurable energy efficiency benefits are only tangible at part load.

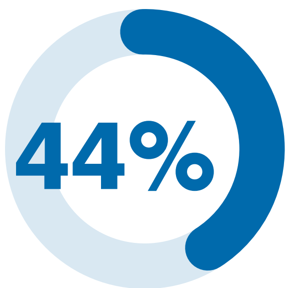
Full load saving



£708,648

787.4 tons of CO_2

Part load saving



£492,686

547.4 tons of CO_2

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Analysis

What we found

We found that by implementing enhanced cooling technologies at a mechanical and software level, we could demonstrate significant energy savings both in full and part load.

Overview of technology

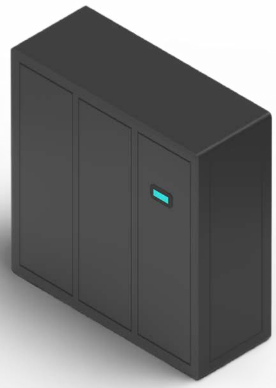
Sometimes, it's best to let data speak for itself. We decided that the most effective way to demonstrate the benefits available would be to simulate a typical data centre design and share the energy consumption data, carbon equivalent and a mechanical PUE calculation, comparing these figures with the same data centre, deploying Airedale's enhanced data centre cooling solutions.

Here we share our assumptions – which, please note, are based on a typical environment.

The baseline energy consumption calculations are also based on a standard chilled water system solution, a specification that we often see in consultant designs and instantly recognisable as current practise by data centre professionals.

The enhanced cooling technology used is composed of two key mechanical solutions and one key software solution, working together to deliver significant overall benefits. These are as follows:

1. Enhanced CRAH with deeper chilled water coil
2. Enhanced Free Cooling™ chiller with deeper free cooling coil and larger EC fans
3. Cooling System Optimiser™ software solution



CRAH

Heat exchange vs. fan power input

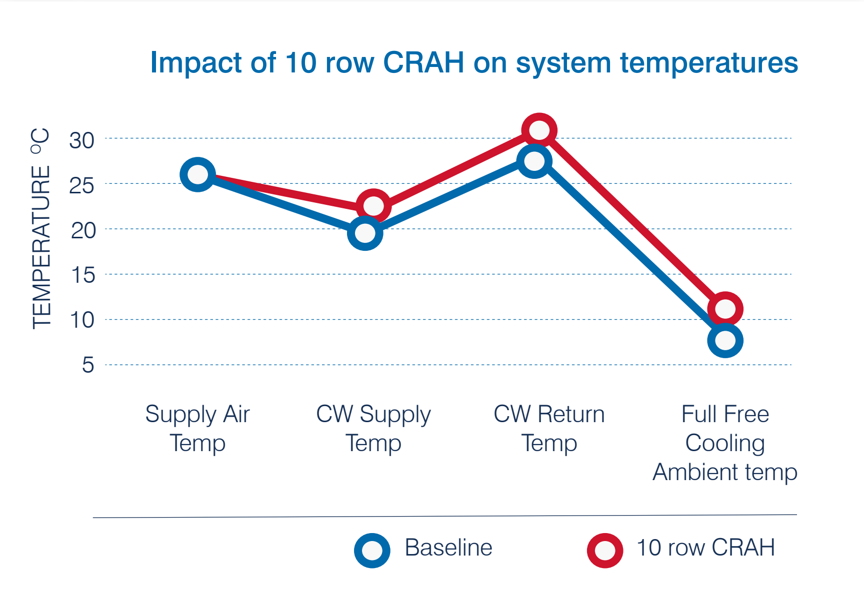
Maximising the coil surface area – i.e. the amount of coil exposed to the air passing through it – is crucial to an efficient exchange of heat. Manufacturers may choose to add extra rows to the coil to increase this surface area, but this must be balanced against the potential increase in pressure drop and fan power input, as the air must work harder to move through the deeper coil.

The key feature of the CRAH units deployed in this study is increasing the coil depth in order to achieve the capacity required while maintaining a close approach temperature.

We would highlight that Airedale SmartCool ONE™ units have a number of different coil configurations (six, eight and 10 rows) to achieve this. With this increase in coil depth comes a pressure drop and potential increase in fan power. To overcome this on the 10 row case, the unit depth is increased. As well as the number of rows, we can also adjust the coil fin spacings and geometry to match our unit selection to the DC requirements.

In addition, air movement through the unit is carefully considered as an integral part of the unit design. The design process utilises computational flow dynamics (CFD) modelling to optimise fan performance and airside pressure drop.

As you can see in the chart below, which details the evolution of system temperatures as the 10-row CRAH is applied, increasing the CRAH's coil surface area allows the temperature of the chiller supply water to be increased by 2°C, from 19°C to 21°C. This reduces the overall cooling demand to which the chiller is subjected, therefore also reducing energy input.

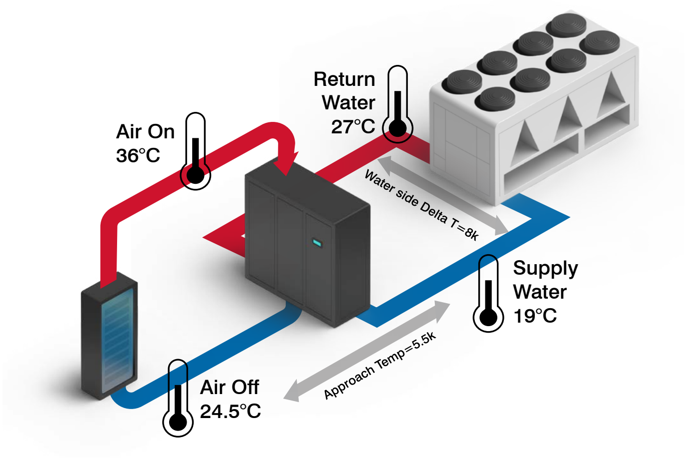


CRAH

Increasing the coil depth of the CRAH has a more significant energy saving impact on the chillers than on the CRAHs themselves. The diagrams below show how moving to a 10 row CRAH impacts the various system temperatures.

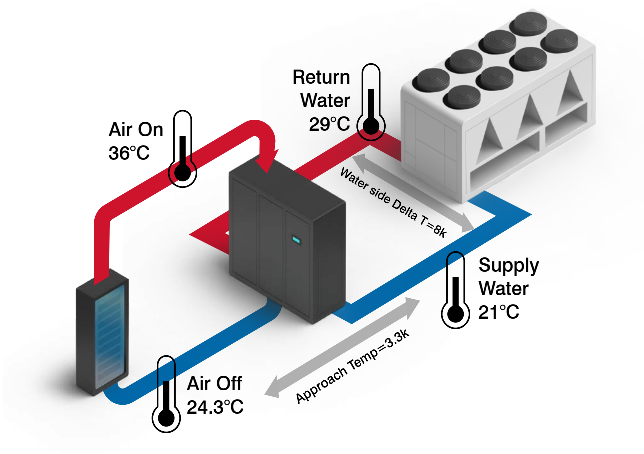
Baseline – 6 row CRAH

Supply water from the chiller is 19°C and supply air from the CRAH is 24.5°C.

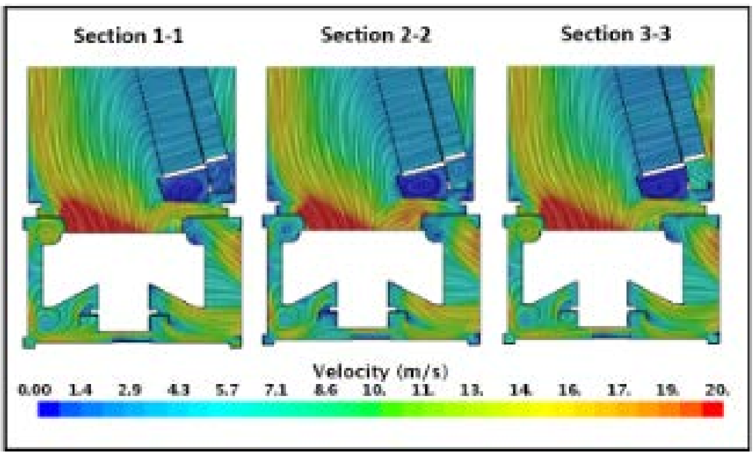


10 row CRAH

Supply water from the chiller is able to be increased to 21°C.



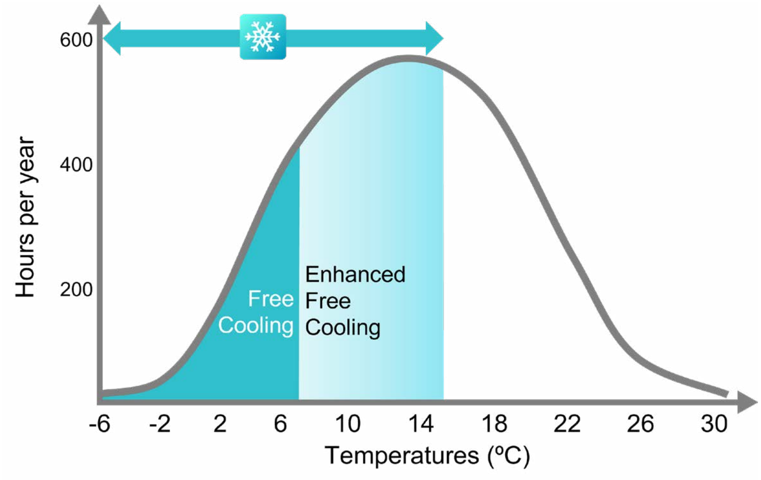
CFD modelling recently completed when we changed the coil angle on the 890mm case and details the air stream velocities in three cross-section views.



Chillers

Enhanced free cooling

Free cooling is the process of using external ambient temperature to reject heat, as opposed to using the refrigeration process. If used within an optimised system, free cooling can deliver significant energy savings, taking effect when the difference between the outside supply and return temperatures is as little as 1ºC. This means that in a 24/7 data centre with a typical room temperature of over 24ºC, more than 95% of the year can be spent with free cooling active.



Having pioneered free cooling performance improvements in data centres for many years, we are highly experienced in this field. Nevertheless, despite already market-leading performance, taking free cooling to the next level has always been an important focus for our R&D engineers. We were able to maximise part load efficiencies and reduce the total cost of ownership by implementing design changes to the chiller and optimising the cooling system as a whole. This delivers dramatic reductions in energy use, providing more free cooling for longer.

Free cooling relies heavily on heat exchange performance. Parameters such as depth, fin pitch and pressure drop – on both the air and water side – can be tweaked to perfect the balance between heat exchange, pressure drop and material costs. Virtual technologies including computational flow dynamics (CFD), meanwhile, can help to assess the optimal heat exchanger angle.

Airedale's Enhanced Free Cooling chillers feature additional rows in the free cooling coil, which are accommodated by adjusting the pitch of the coil within our V-block condenser structure.

Increasing air flow across the heat exchanger is the other key variable determining free cooling performance. By increasing the diameter of the EC fans, we can deliver more air across the heat exchangers and improve free cooling capabilities. This has effects on fan power input, which must be balanced in order to deliver improved energy performance.

Another key factor impacting on fan power is design ambient. Therefore, in DX mode our patented optimised head pressure control feature manages fan speed so as to balance fan and compressor power, ensuring an efficient system.

As the enhancements made as part of Enhanced Free Cooling are not tied to a specific compressor or pump technology, they can be applied across chiller portfolios. By increasing free cooling and reducing mechanical cooling hours, we can both reduce running costs and ensure that data centres are more environmentally friendly.

There are also important secondary energy benefits from Enhanced Free Cooling. For example, primary and secondary pumps can run at lower speeds, while lower flow rates within the system can provide pipework savings as smaller diameters can be deployed.

Location	Increased full free cooling hours	Increase vs. baseline	% of year additional
London	4168	2.6x	47.6%
Frankurt	2973	1.8x	33.9%
Amsterdam	3812	2.2x	43.5%
Paris	3543	2.3x	40.4%
Madrid	3047	2.5x	34.8%
Virginia	1946	1.6x	22.2%

Software

Cooling system optimiser

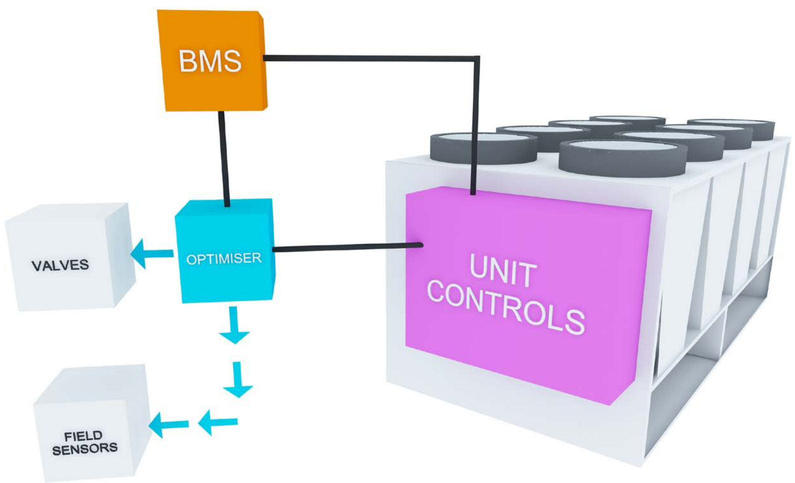
Any cooling system needs control. As data centre cooling systems become more complex and fine tuned, the need for a dedicated controls platform becomes extremely important.

Many data centres use the site building management system (BMS) to mange the cooling system. One core issue with this is that a BMS, whilst still needed for overall monitoring, is not designed for something so precise. It isn't designed to optimise, and mostly pushes data.

With a BMS, redundancy is not built in. As chillers get larger, and more numerous, this is key to ensuring that cooling requirements are met, and the load is evenly balanced across the system.

Complex systems require precise control on a number of levels, transforming them into dynamic systems that can adapt and balance themselves, flexing to required loads.

The Cooling System Optimiser sits above the unit controls and under the BMS, monitoring data from units and field sensors place at critical points in the system. Cooling is staged through temperature sensors and sequencer controls, enabling a smooth transition from mechanical cooling to free cooling.



The Optimiser enables chillers to operate on a reduced water flow rate during free cooling operation, sensibly increasing the efficiency of water coils and pumps.

For CRAHs, the Optimiser's networking strategy achieves the optimum energy efficiency by distributing the cooling demand to all of the operating units if required and thermally shifting the load to avoid hotspots, while also reducing energy consumption in unused areas of data halls. This works as follows:

- Ambient temperature is monitored intelligently, optimising free cooling.
- Live water volumetric flow requirement from the CRAHs is used to automatically adjust water flow through the chillers, reducing use of the bypass valves. The optimiser automatically calculates and adjusts the chiller's pumps speed to achieve the required water flow.

This has a number of benefits. In particular, it further optimises the opportunities for free cooling, over and above the enhancements made to the units, while also delivering other sustainability and resilience benefits:

- A fully-integrated control strategy enables the chillers to run on a reduced water flow rate during free cooling operation, enhancing the efficiency of heat exchangers and pumps.
- Compressors and pumps are modulated according to demand seen at the servers, ensuring only the temperature and flow required are delivered to the CRAH units.
- Free cooling is maximised, reducing energy consumption and helping to achieve sustainability targets.
- Modulation of rotating machinery reduces number of on/off operations, extending equipment life.
- Total ownership cost can be reduced, with lower running and maintenance costs.

By combining the application of enhanced free cooling chillers and computer room air handlers, along with the Cooling System Optimiser, measurable and tangible efficiency and sustainability benefits are attainable. These include:

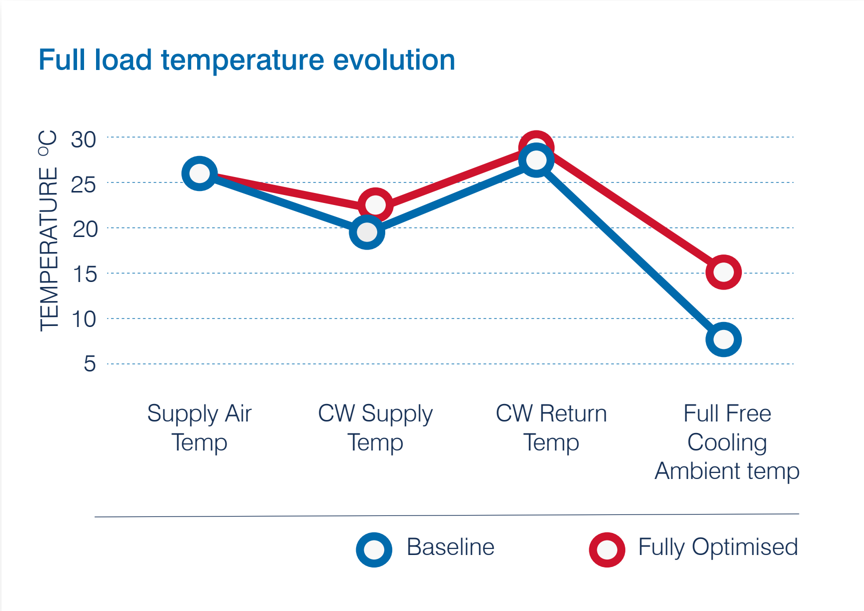
- Substantial reductions in energy consumption.
- Less mechanical cooling stress on components such as compressors.
- Less maintenance.
- Less material waste due to increased lifespan.
- Lower energy consumption, lower approach temperatures and wider Delta T, resulting in reduced PUEs in high capacity situations.

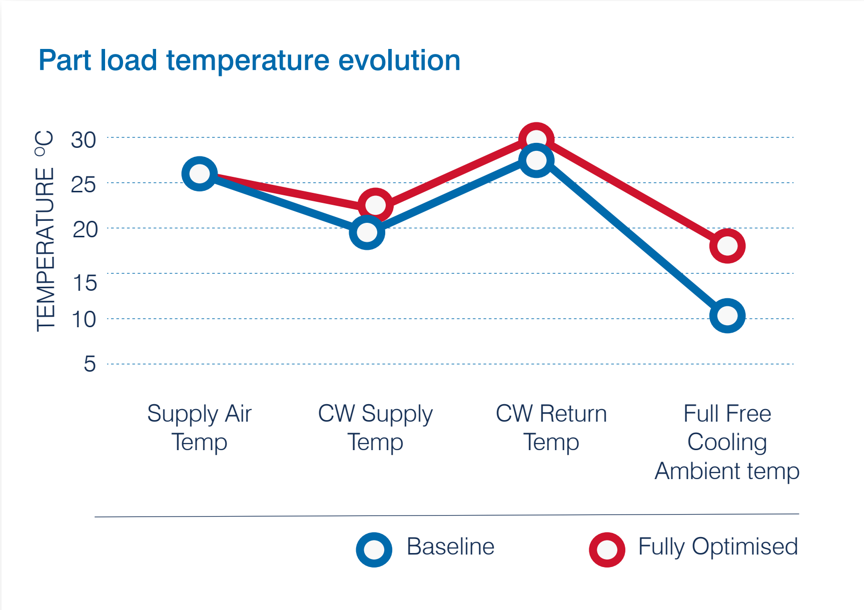
Temperature Evolution

The charts below show the evolutions in full and part load system temperature from the baseline to the fully optimised system.

The major improvement in energy saving results from increasing the temperature at which full free cooling can be initiated. In full load operation, free cooling is initiated at 15ºC – an increase of 7.5ºC over the baseline.

The extra free cooling results from the chiller's enhanced features, namely deeper coils and increased airflow.





Cost/Benefit

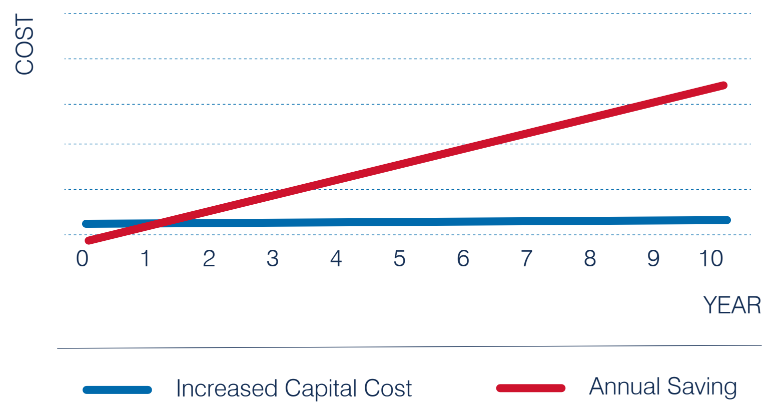
It is important to note that any improvements to a cooling system – whether mechanical or software improvements – will have cost implications. Therefore, any energy performance benefit must be offset against this cost in order to ascertain whether the investment is justified.

The enhanced CRAH contains extra copper and steel (more coil rows and a deeper case), as does the enhanced free cooling chiller (larger coil and fans). The Optimiser software system also involves deploying additional controllers and sensors.

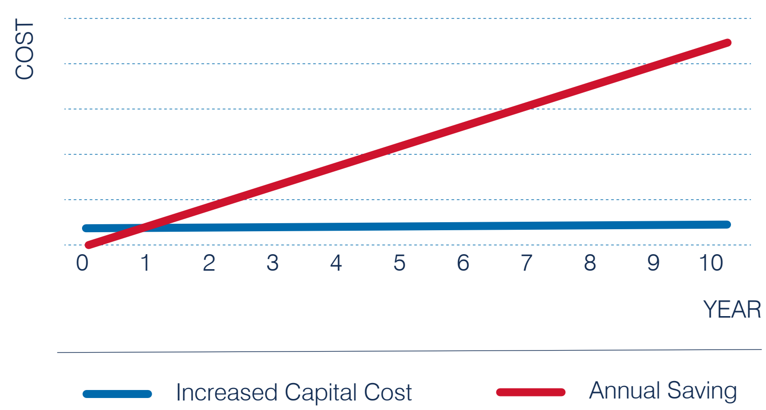
We have calculated the additional capital spend for the enhanced CRAHs, chillers and the Optimiser controls, and plotted it on cost benefit charts for both full and part load, which you can see below.

At part load, the break-even point occurs in year two, while at full load, the break-even point comes in year one. By year 10, savings amount to around £3.8m at part load and around £8.5m at full load.

Cost benefit - Part load



Cost benefit - Full load



Conclusions

Survival of the fittest

The discussion around data centre cooling in trade media tends to focus an apparent mass migration to liquid/immersion, as server densities supposedly rise and sustainability requirements become increasingly stringent.

The authors of this white paper – and, indeed, much of the wider industry – believe that chilled water cooling systems, drawing on CRAHs and chillers, are here to stay. As chilled water systems are proven to deliver in what is a highly demanding sector, the vast majority of digital workloads will continue to utilise them.

This does not mean, however, that providers of chilled water cooling systems should rest on their laurels. There is still a great deal of headroom for energy efficiency, even in technology that is far along the innovation curve, as demonstrated by the findings of this white paper.

Data centres value uptime above all else, which is why proven technologies will remain difficult to shift. Even so, operators are seeking to adjust as they anticipate further sustainability legislation; therefore, getting the job done at the lowest possible environmental cost is moving from aspiration to reality, taking concrete form in specifications.

Chilled water system providers must themselves evolve. Although the PUE metric is viewed by some observers as outdated, the energy consumed by support systems as against that consumed by IT remains a valuable area of focus. At Airedale, we have long believed that free cooling is the key to ensuring that chilled water remains the technology of choice in the data centre sector – but it is clear to us that many operators, consultants and manufacturers are not using it to its full potential.

Raising supply air temperatures in the white space is the first step on the free cooling journey, and it is a step that many have already taken. However, air is only one half of the equation – and optimising both air and water conditions is crucial to ensure that the chiller doesn't have to work as hard to provide the necessary cooling.

Fine tuning comes at a cost. Continuous monitoring and optimisation require robust controls protocols. Human operators and traditional building management systems, meanwhile, are not really qualified to deliver on the cooling system's full energy saving potential. Nonetheless, investing in such a system delivers savings that both justify the initial capital expenditure and deliver benefits beyond sustainability – as vital as this is to the future of our world.

Final comment

Data centres are at a crossroads between technological advance and environmental sustainability.

Climate change now poses an existential threat. What's more, this threat is rising just as information technology enters a new and unprecedented third age, following the internet of people and the internet of things. Artificial intelligence is set to prompt a new surge in data creation, dwarfing the levels we are currently accustomed to.

Likewise, data centres are also on the cusp of a new and momentous era. Scale is the watchword as migration to the cloud continues, leaving the industry scrambling to keep up. Just three years ago, 100MW sites would have raised eyebrows – whereas now, they are the norm. With data continuing to be centralised in these data hypermarkets, new applications are also seeing a parallel decentralisation to the edge.

Data centres are pressing the acceleration pedal firmly to the floor, just as the climate change cliff looms into view.

The new era of data centre expansion will be dominated by debate on cooling technologies. This debate is a worthy one, although we will not go into the whys and wherefores here. What we at Airedale do believe is that chilled water cooling systems, CRAHs and chillers will continue to account for the largest chunk of the large data centre market up to 2030 and beyond.

We also believe that, while chilled water cooling technologies are mature and the room for further mechanical innovation is therefore relatively limited, there remains significant room for improvement in the energy efficiency of these systems.

Mechanical tweaks, system optimisation and software intervention can deliver huge energy savings when compared to current designs. Increasing supply air temperatures is simply one aspect of the equation, which needs to be optimised on both sides to deliver complete system optimisation, delivering the required cooling and redundancy at the lowest possible energy input.

In many climates, free cooling will be crucial if we are to cool the internet without warming the planet. We believe that our findings in this study provide ample proof; although this work can and will be expanded to include more territories and technologies – such as fan walls – the concepts we have introduced in this white paper can form a blueprint for the wider industry to follow.

Appendix

Data Tables Full Load

			Energy Usage				Metrics		
Scenario	Description	IT Load kW	IT kWh	CRAH kWh	Chiller kWh	Total Cooling kWh	Annualised pPUE	Carbon Usage tCO_2	Free Cooling Ambient °C
Baseline	6row, 800mm, 3row, Std	10000	87600000	3777312	6291636	10958088	1.13	2191.6	7.5
2	10row, 800mm, 3row, Std	10000	87600000	3115056	5207233	9211429	1.11	1842.3	9.5
3	10row, 910mm, 3row, Std	10000	87600000	3115056	4782575	8786771	1.10	1757.4	11.5
4	10row, 910mm, 5row, Std	10000	87600000	3115056	3016958	7021154	1.08	1404.2	15.5

	FULL LOAD ANALYSIS			@ N+1 - 142kW per CRAH / 1542kW per chiller (771kW per half)										
String	CRAH								Chiller					
	Air On Temp	Water Inlet	Water Outlet	Airflow	Air Off Temp	Capacity	Power Input	Qty (N+1)	Ambient Temp	Water Inlet	Water Outlet	Capacity	Power Input	Qty
6row, 800mm, 3row, Std	36	19	27	10.8	24.5	142.4	6.16	77	40	27	19	1700.6	509.8	7
8row, 800mm, 3row, Std	36	20	28	10.5	24.5	139.1	7.77	77	40	28	20	1744.9	514.1	7
10row, 800mm, 3row, Std	36	21	29	10.5	24.3	140.8	5.08	77	40	29	21	1789.9	518.5	7
10row, 910mm, 3row, Std	36	21	29	10.5	24.3	140.8	5.08	77	40	29	21	1829.2	508.2	7
10row, 910mm, 5row, Std	36	21	29	10.5	24.3	140.8	5.08	77	40	29	21	1813.5	519.6	7
10row, 910mm, 5row, Opt	36	21	29	10.5	24.3	140.8	5.08	77	40	29	21	1813.5	519.6	7
6row, 910mm, 3row, Std	36	19	27	10.8	24.5	142.4	6.16	77	40	27	19	1733.2	499.3	7
6row, 910mm, 5row, Std	36	19	27	10.8	24.5	142.4	6.16	77	40	27	19	1718.8	510.4	7
6row, 910mm, 5row, Opt	36	19	27	10.8	24.5	142.4	6.16	77	40	27	19	1718.8	510.4	7
8row, 910mm, 3row, Std	36	20	28	10.5	24.5	139.1	7.77	77	40	28	20	1780.7	503.7	7
8row, 910mm, 5row, Std	36	20	28	10.5	24.5	139.1	7.77	77	40	28	20	1765.7	514.9	7
8row, 910mm, 5row, Opt	36	20	28	10.5	24.5	139.1	7.77	77	40	28	20	1765.7	514.9	7

Data Tables Full Load

String	Unit Annual Energy Consumption			Total Annual Energy Consumption					
	CRAH	Chiller @ N+1	Pump	CRAHs	Chillers	Pumps	Total	Annualised pPUE	Tonnes CO_2
6row, 800mm, 3row, Std	53961.6	898805.2	127020	3777312	6291636	889140	10958088	1.13	2191.62
8row, 800mm, 3row, Std	68065.2	820409.2	127020	4764564	5742864	889140	11396568	1.13	2279.31
10row, 800mm, 3row, Std	44500.8	743890.5	127020	3115056	5207233	889140	9211429	1.11	1842.29
10row, 910mm, 3row, Std	44500.8	683225.0	127020	3115056	4782575	889140	8786771	1.10	1757.35
10row, 910mm, 5row, Std	44500.8	430994.1	127020	3115056	3016958	889140	7021154	1.08	1404.23
10row, 910mm, 5row, Opt	44500.8	430994.1	127020	3115056	3016958	889140	7021154	1.08	1404.23
6row, 910mm, 3row, Std	53961.6	846101.2	127020	3777312	5922708	889140	10589160	1.12	2117.83
6row, 910mm, 5row, Std	53961.6	572809.6	127020	3777312	4009667	889140	8676119	1.10	1735.22
6row, 910mm, 5row, Opt	53961.6	572809.6	127020	3777312	4009667	889140	8676119	1.10	1735.22
8row, 910mm, 3row, Std	68065.2	762645.8	127020	4764564	5338520	889140	10992224	1.13	2198.44
8row, 910mm, 5row, Std	68065.2	498635.2	127020	4764564	3490446	889140	9144150	1.10	1828.83
8row, 910mm, 5row, Opt	68065.2	498635.2	127020	4764564	3490446	889140	9144150	1.10	1828.83

Appendix

Data Tables Part Load

Scenario	Description	IT Load	Energy Usage				Metrics		
			IT	CRAH	Chiller	Total Cooling	Annualised pPUE	Carbon Usage	Free Cooling Ambient
		kW	kWh	kWh	kWh	kWh		tCO_2	°C
Baseline	6row, 800mm, 3row, Std	7000	61320000	1355172	3977247	6221559.2	1.10	1244.3	10.5
2	10row, 800mm, 3row, Std	7000	61320000	1275456	3092874	5257470	1.09	1051.5	12.5
3	10row, 910mm, 3row, Std	7000	61320000	1275456	2864886	5029482.2	1.08	1005.9	14.5
4	10row, 910mm, 5row, Std	7000	61320000	1275456	1933210	4097805.7	1.07	819.6	16.5
5	10row, 910mm, 5row, Opt	7000	61320000	1275456	1773589	3484416.7	1.06	696.9	17.5

FULL LOAD ANALYSIS

@ N+1 - 142kW per CRAH / 1542kW per chiller (771kW per half)

String	CRAH								Chiller					
	Air On Temp	Water Inlet	Water Outlet	Airflow	Air Off Temp	Capacity	Power Input	Qty (N+1)	Ambient Temp	Water Inlet	Water Outlet	Capacity	Power Input	Qty
6row, 800mm, 3row, Std	36	19	27	7.5	24.1	102.6	2.21	77	40	27	19			7
8row, 800mm, 3row, Std	36	20	28	7.5	24.3	101	2.97	77	40	28	20			7
10row, 800mm, 3row, Std	36	21	29	7.5	24.4	100	2.08	77	40	29	21			7
10row, 910mm, 3row, Std	36	21	29	7.5	24.4	100	2.08	77	40	29	21			7
10row, 910mm, 5row, Std	36	21	29	7.5	24.4	100	2.08	77	40	29	21			7
10row, 910mm, 5row, Opt	36	21.5	29.5	7.5	24.4	100	2.08	77	40	29.5	21.5			7
6row, 910mm, 3row, Std	36	19	27	7.5	24.1	102.6	2.21	77	40	27	19			7
6row, 910mm, 5row, Std	36	19	27	7.5	24.1	102.6	2.21	77	40	27	19			7
6row, 910mm, 5row, Opt	36	19.5	27.5	7.5	24.1	102.6	2.21	77	40	27.5	19.5			7
8row, 910mm, 3row, Std	36	20	28	7.5	24.3	101	2.97	77	40	28	20			7
8row, 910mm, 5row, Std	36	20	28	7.5	24.3	101	2.97	77	40	28	20			7
8row, 910mm, 5row, Opt	36	20.5	28.5	7.5	24.3	101	2.97	77	40	28.5	20.5			7

Data Tables Part Load

String	Unit Annual Energy Consumption			Total Annual Energy Consumption					
	CRAH	Chiller @ 70% N+1	Pump	CRAHs	Chillers	Pumps	Total	Annualised pPUE	Tonnes CO_2
6row, 800mm, 3row, Std	19359.6	568178.2	127020	1355172	3977247	889140	6221559	1.07	1244.31
8row, 800mm, 3row, Std	26017.2	502967.8	127020	1821204	3520774	889140	6231118	1.07	1246.22
10row, 800mm, 3row, Std	18220.8	441839.1	127020	1275456	3092874	889140	5257470	1.06	1051.49
10row, 910mm, 3row, Std	18220.8	409269.5	127020	1275456	2864886	889140	5029482	1.06	1005.90
10row, 910mm, 5row, Std	18220.8	276172.8	127020	1275456	1933210	889140	4097806	1.05	819.56
10row, 910mm, 5row, Opt	18220.8	253369.8	127020	1275456	1773589	435372	3484417	1.04	696.88
6row, 910mm, 3row, Std	19359.6	548332.6	127020	1355172	3838329	889140	6082641	1.07	1216.53
6row, 910mm, 5row, Std	19359.6	398448.5	127020	1355172	2789139	889140	5033451	1.06	1006.69
6row, 910mm, 5row, Opt	19359.6	356647.3	127020	1355172	2496531	435372	4287075	1.05	857.41
8row, 910mm, 3row, Std	26017.2	472166.4	127020	1821204	3305165	889140	6015509	1.07	1203.10
8row, 910mm, 5row, Std	26017.2	327651.7	127020	1821204	2293562	889140	5003906	1.06	1000.78
8row, 910mm, 5row, Opt	26017.2	302017.1	127020	1821204	2114120	435372	4370696	1.05	874.14

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