ELEVATE
Future Faster

WHITEPAPER - AIRFLOW MANAGEMENT

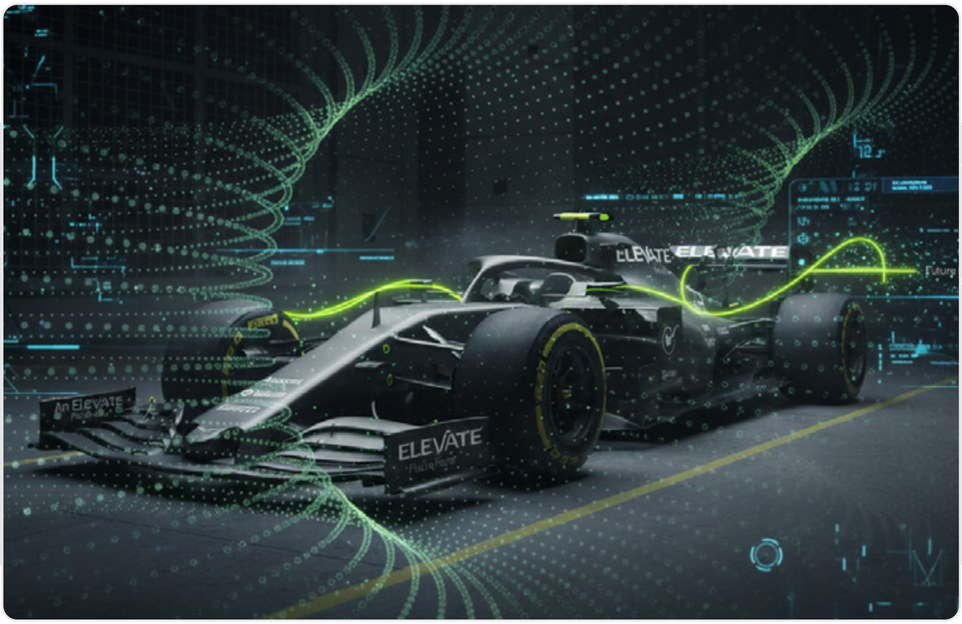
The Five Levers of Optimisation

OPTIMISING AIRFLOW MANAGEMENT: A FOUNDATIONAL STRATEGY FOR DATA CENTRE EFFICIENCY AND RESILIENCE

Table of Contents

Executive Summary

The relentless growth of digital services, artificial intelligence and high-performance computing has exponentially increased the power density and thermal load of modern data centres. Consequently, the cost and complexity of cooling these mission-critical environments have become a primary concern for operators. While advanced liquid cooling solutions are gaining traction for extreme densities, air cooling remains the dominant method for the vast majority of data centre white space.



Achieving maximum efficiency hinges on mastering a first principle: airflow. Just as in elite motor racing, superior airflow management in data centre operations ensures winning performance and efficiency.

This white paper presents a structured framework for optimisation: The Five Levers. The first four levers establish mastery over airflow management (AFM)—from foundational containment to advanced control. The fifth lever, temperature setpoint optimisation, then unlocks the full efficiency potential of the cooling system. We argue that this progression is the most cost-effective first step toward significant gains in efficiency, resilience and capacity,

Introduction: The Imperative for Efficiency

Data centres are among the largest consumers of global electricity, with cooling infrastructure accounting for 30% to 40% of total facility energy usage. Inefficient cooling directly translates to:

High Operational Expenditure (OPEX):

Excessive energy consumption drives up utility costs.

Reduced Capacity:

Inefficient cooling wastes valuable cooling capacity, limiting the number of servers a data centre can support.

Over Cooling:

Mixed air temperatures resulting from poor air flow management, reduces the potential to raise the supply air temperature. Thereby limiting the opportunity to expand free cooling periods and enhance the cooling systems Coefficient of Performance (COP).

Increased Carbon Footprint:

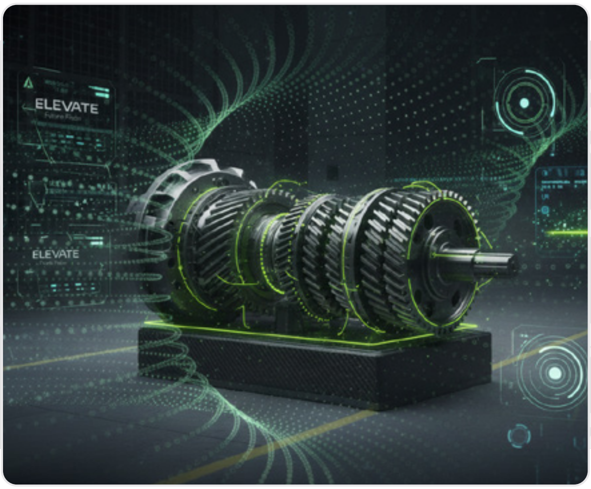
Higher energy use contributes to Scope 1 and 2 emissions (As per Streamlined Energy and Carbon Reporting framework) conflicting with corporate sustainability goals.

Operational Risk:

Hot spots and temperature fluctuations can lead to hardware failures, reduced hardware lifespan and unplanned downtime.

Air optimisation addresses these issues at their root by ensuring that cold / supply air is delivered precisely to where it is needed, with minimal waste and mixing.

Achieving maximum efficiency requires systematically applying each of the five levers, much like progressing through a gearbox to reach optimal performance. The following white paper will guide us carefully through these five crucial stages.



The Fundamentals of Data Centre Airflow

At its core, data centre cooling is a simple thermodynamic process: remove heat generated by IT equipment. However, the path the air takes is often complex and inefficient.

The Ideal Airflow Cycle:

The Traditional Cooling Topology

Supply:

Computer Room Air Handlers (CRAHs) or Air Conditioners (CRACs) deliver cold / supply air, generally through a raised floor plenum.

Delivery:

Cold / Supply air is directed into the cold aisles of server racks.

Intake:

IT equipment intakes the cold air, using it to cool internal components.

Exhaust:

Heated / return air is expelled from the rear of the equipment into the hot aisles.

Return:

The hot air travels back to the CRAH/CRAC/ Heat Exchange units to be cooled and recirculated, completing the cycle.

Popular Alternative Topology

The implementation of “Fan Walls” is becoming an increasingly popular system, where cold supply air is introduced to flood the entire room. The resulting heated air is then directed back to the heat exchange mechanism through a contained hot aisle which exhausts the air into a return air plenum. Despite this specific configuration, the fundamental principles governing the airflow cycle remain consistent with traditional cooling methods.

Emerging HPC Topology

Additionally, particularly for High Performance Computing (HPC) environments, the use of Rear Door Heat Exchangers (RDHx) is expected to increase. The fundamental airflow cycle remains the same, but the heat exchange process is localised much closer to the source, effectively containing the return air plenum within the rear of the server cabinet.

In this setup, the RDHx supplies the cooling air, which then floods the room with the same volume of air the cabinet has processed and exhausted. A key advantage of this approach is that it negates the necessity for arranging cabinets in traditional hot and cold aisle configurations and eliminates the need for contained aisles. Regardless of this altered layout, however, effective airflow management remains equally as important for optimal efficiency and performance.

Common Airflow Challenges (The “Enemies of Efficiency”):

Bypass Airflow:

Cold air escapes from the cold aisle without passing through any IT equipment, mixing directly with the hot return air. This is often caused by cable cut-outs, gaps in blanking panels, or misaligned tiles.

Recirculation:

Hot exhaust air from the rear of a server is sucked back into the intake of the same or a nearby server. This creates “hot spots,” forces the cooling system to work harder, and can trigger temperature alarms.

Mixed Air:

The combination of bypass and recirculation leads to a mixed-temperature environment, nullifying the designed temperature differential and drastically reducing cooling unit efficiency.

A Framework for Air Optimisation: From Basic to Advanced (The Four Levers)

Achieving optimal airflow is a systematic process. The following framework outlines a maturity model for implementation.

In this section we will review the four key levers that must be applied in order to achieve and maintain optimal performance, Foundational Containment, Sealing the Environment, Intelligent Air Distribution and finally Advanced Monitoring and Control. The “Fifth lever” can only be applied later, having mastered the above.

Foundational Containment - Lever 1

The single most effective step is to physically separate the cold supply air from the hot exhaust air.

Hot Aisle/Cold Aisle (HACA) Layout:

The foundational layout where server racks are arranged so that intakes face each other (cold aisle) and exhausts face each other (hot aisle).

Aisle Containment:

Cold Aisle Containment (CAC):

Encloses the cold aisle, ensuring that cold air from the floor plenum can only enter through server intakes. This is highly effective at preventing bypass airflow.

Hot Aisle Containment (HAC):

Encloses the hot aisle, capturing all exhaust air and directing it back towards the heat exchange within the cooling units, via a return air plenum. This allows for a higher cold aisle temperature, often improving chiller efficiency.

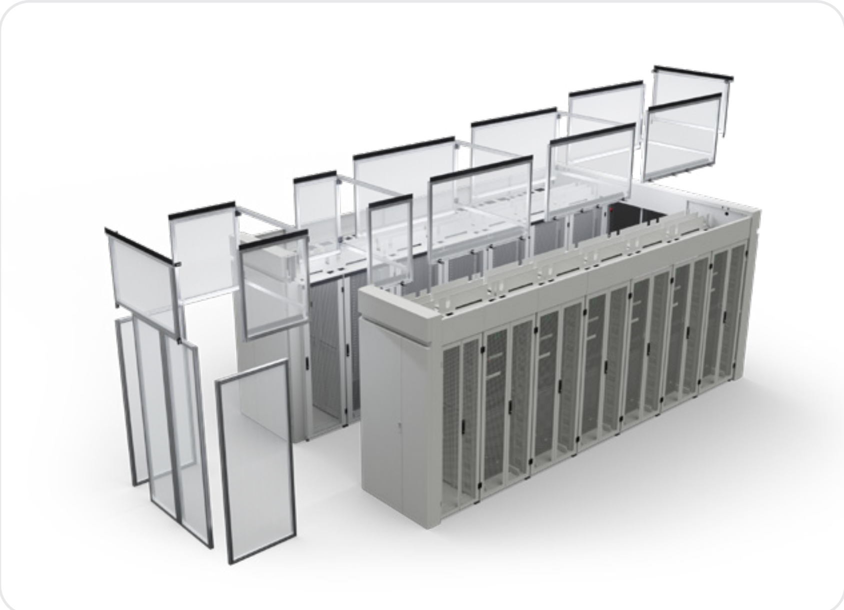
Sealing the Environment - Lever 2

Containment is only effective if the aisles are properly sealed. This section is where we can achieve the most significant gains in the optimisation of AFM, by directly tackling head on the “Enemies of Efficiency”.

However, many facilities fail to progress beyond this stage because these sealing challenges are not addressed comprehensively.

CAC / HAC:

Air loss can occur where the enclosed aisles come in contact with the cabinets they enclose, the floor or slab, in the case of the end of aisle doors and the ceiling plenum in the case of HAC’s.



Corrective Action

- **Seal around the aisle containment where the containment makes contact with the Racks and in the case of HAC’s where it makes contact with the ceiling / return air plenum. Seal around the end of aisle doors.**
- **Where penetration of the CAC/HAC is necessary seal with gasket or brush strips.**

The Rack

This is potentially the most contentious area in some respects, as the Server and Network cabinets deployed, might sit in the IT or your customers sphere of control, depending on the nature of the Data Centre. However, if we are to address the fundamentals of airflow optimisation, we must consider the Rack itself as an extension of the “White Space” infrastructure and an essential component of the Data Centre echo system.

To illustrate the significance of this, the White Paper will use the Elevate DCR range of cabinets as a reference for effective Airflow Management using evidence-based data from an independent research laboratory. The supportive data will illustrate the difference between non-airflow optimised racks and effective airflow optimisation, highlighting the key areas that must be addressed.

In-between 19” profiles

This is the easiest, low cost, and most impactful corrective action that can be taken in addressing the “Enemies of Efficiency”. Despite this fact it is still the most common area where good AFM is consistently undermined through poor and inconsistent application of appropriate blanking panels.

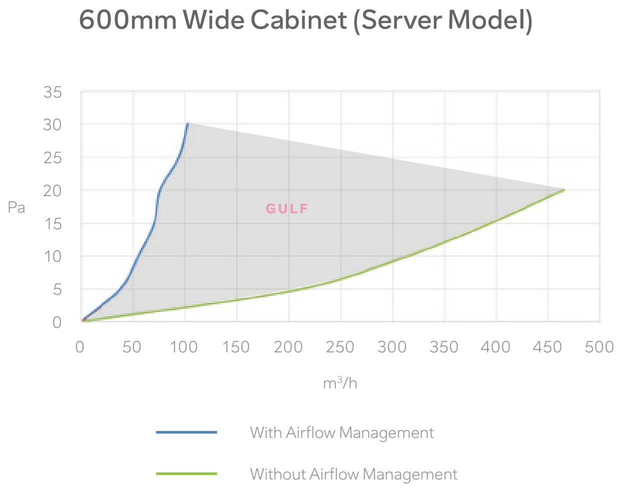
Corrective Action

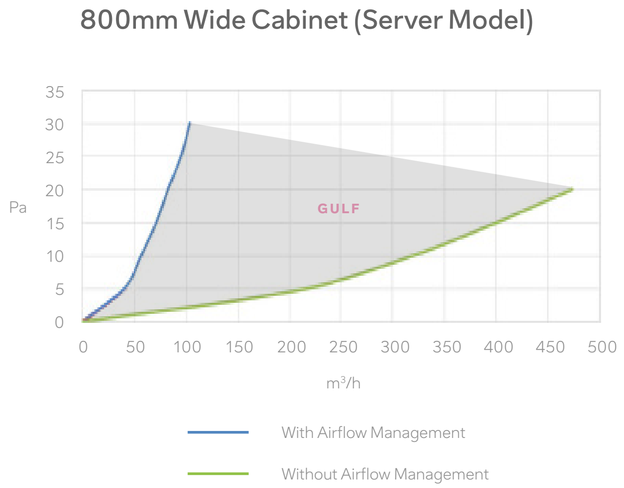
Blanking Panels:

- **Install panels in all unused U-spaces in server racks to prevent hot air from recirculating to the cold aisle and cold supply air bypassing the equipment altogether.**

Around 19" profiles

It is in this area that we will provide a more detailed focus on how to prevent the mixing of supply and return air flows at the cabinet level. With the use of specifically targeted air optimisation tool sets, we can demonstrate how taking the appropriate corrective action in some key areas around the 19" profiles, can provide an evidence-based air optimised solution.





The two graphs presented illustrate the performance difference between an Elevate DCR Server Rack that has been optimised for airflow and one without airflow management.

This performance gap, or **"gulf"**, substantially increases with higher air pressure, which mimics the escalating cooling demands associated with rising IT loads.

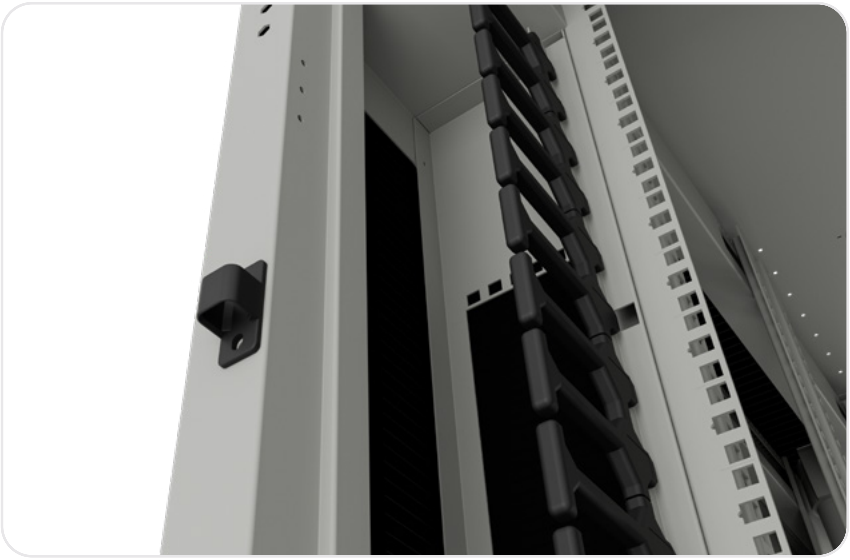
The relationship between pressure and leakage is not linear; it is exponential. A small increase in pressure can cause a significant increase in leakage. Consequently, as the demand for cooling air intensifies, the benefits of the optimised airflow management become significantly more pronounced.

It's important to state upfront that manufacturers rarely publish specific, standardised leakage rates in m^3/h for their cabinets. However, some data does exist and from the market intelligence we have been able to obtain, the Elevate DCR Server Cabinet performs very favourably with other leading "Performance" brands using air optimisation, by either exceeding performance, or in some cases / conditions matching it.

Corrective Action

The following details how the Elevate DCR Server Rack has been engineered to addresses the various challenges that have to be overcome before it can be fully air optimised.

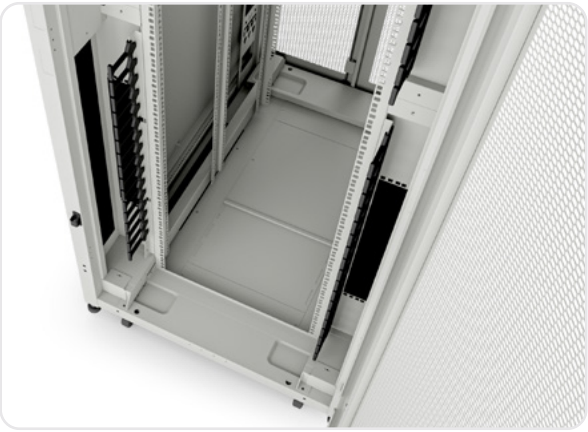
Top and Bottom:



At the front face of the rack above and below the 19” profiles it is necessary to seal the rack. In the illustration above you can see a steel plate is inserted to close the gap between both ends of the 19” profiles and the underside of the cabinet roof as well as the base plate of the cabinet.

This prevents bypass and re-circulation of air at both the top and bottom, whilst at the same time giving flexibility to adjust the profiles without having to fit an alternative number of different combinations of complex air baffles.

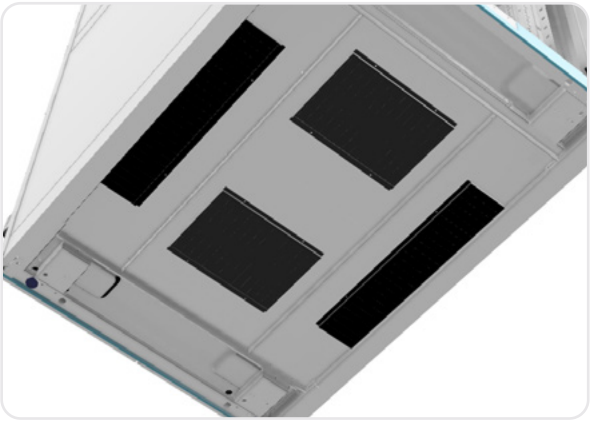
Outside Edge of the 19” Profiles:



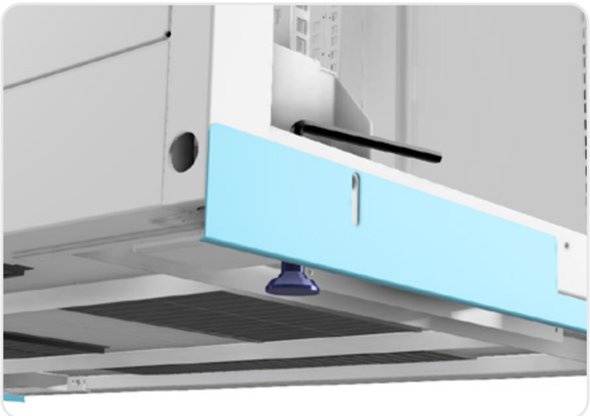
In the above illustration you can see that the gap between the cabinet side panel and the edge of the 19” profile in an 800mm wide rack is sealed using a full cabinet height baffle plate or “side skirt”.

These have potential access holes on the 800mm wide cabinets to pass network cables from front to rear; these can then be sealed with overlapping brushes. Alternatively, these cut outs can also be used to mount both passive and active 19” mountable equipment, increasing the IT equipment U space capacity of the rack without increasing the height and surface area of the rack, thereby reducing the inevitable additional air loss associated with taller racks.

Sealing to the floor or slab:



The above illustration shows how the Elevate DCR base of the rack seals directly to a typical raised Data Centre floor. This prevents air both bypassing and recirculating at the base of the cabinet. In this scenario cabinets delivered with transport castors, have the castors removed prior to being placed in its final position.



In the next illustration above you can see the Elevate DCR cabinet fitted with levelling feet. Typically, with Data Centres using "Fan Walls" along with Hot Aisle Containment the cabinets are fitted directly on to the slab. In this scenario it is necessary to have levelling feet fitted to handle the slight fluctuations in the floor level. The Elevate DCR series have integral levelling feet fitted within the base plate, these are adjusted individually by using an allen key allowing fast, easy levelling once racks are in position. Once adjustment is complete the simple built in adjustable plinth 'draft exclusion' plate is also moved to close the gap between base and slab. Consequently, a front plinth is fitted to ensure the gap is closed between base frame and the slab.

In the example shown, since we have levelling feet to take the load it is also possible to leave the transport castors on and still seal to the floor with the plinth. This might be required where pre-populated racks need to be deployed.

Sealing the Top of Rack:

It is important to remember this is only a requirement for Hot Aisle contained aisles where the edge of the containment sits on the rear edge of the cabinet roof.

For Cold Aisle containment, any roof penetrations aft of the front 19” profiles, require no air seals at all.

The above illustrations show how the top of the Elevate rack is configured for cable entry/exit, on the left we see full depth front to rear cable entry points which are sealed with heavy duty overlapping brush strips, on the right we show how blanking plates can be installed across areas where cables will not be routed providing enhanced sealing.

There are also two rear access points with overlapping brush strips providing an effective seal for a variety of potential cable entries but specifically for Three Phase 63Amp + PDU’s inlet plugs.

Under-Floor Sealing (Floor Plenums):

Where a raised floor plenum is used to direct the supply air to the cold aisle through vented floor tiles, we need to ensure air is neither drawn into the plenum or leaked outside through poorly sealed gaps.

This is particularly challenging as the plenum is pressurised, the shorter the plenum the greater the pressure, rather like squeezing a hose pipe. As the demand for more air is required due to increased IT load this will in turn increase the fan speed of the CRAH/CRAC which will increase the pressure further.

Corrective Action

Air Drawn In:

- In areas generally up to 1200mm from the edge of the CRAH / CRAC, due to the "Venturi effect" we can expect return air (the ambient temperature of the room) to be drawn into the floor plenum through even the smallest gap.
- We need to ensure that the floor tiles are sealed to each other and all gaps, particularly around the floor edge are adequately sealed.

Escaped Supply Air:

- Use foam or seals to block all other gaps in the raised floor, ensuring cold air is directed only through perforated tiles in the cold aisles. Areas of particular focus should be any floor penetration for cable entries. These will generally occur within the cabinet but on the return air side of the cabinet, so they must be adequately sealed given the floor penetrations will be subject to significant air pressure. There are numerous products available on the market, those that extend a sock that is tied around the cable bunch provide very effective seals.

Sealing Return Air Plenums:

Due to its greater cubic volume, a ceiling return air plenum typically operates at a lower pressure than a floor plenum, which mitigates issues slightly and the potential for a "Venturi effect" is also less significant. However, this does not negate the critical need for vigilant and effective air sealing.

Intelligent Air Distribution - Lever 3

Moving beyond passive sealing to active management.

Perforated Tile Management:

Ensure perforated tiles are only in cold aisles and that their porosity (25% vs. 60%) matches the airflow requirements of the racks they serve.

Variable Speed Fans (VSFs) in CRAHs:

Utilise CRAH units with VSFs that can modulate their speed based on real-time temperature or pressure feedback, reducing fan energy consumption.

Data-Driven Vent Tiles:

Implement dynamically adjustable vent tiles that can open or close based on sensor data to provide precise cooling where needed.

Advanced Monitoring and Control (DCIM & BMS) – Lever 4

Optimisation requires measurement and control.

Sensor Networks:

Deploy a dense network of temperature and humidity sensors at the inlet of IT equipment to monitor for hot spots and recirculation. Such sensor networks are typically connected to intelligent power distribution units - iPDU - within the rack.

Computational Fluid Dynamics (CFD):

Use CFD software to create a digital twin of the data hall. This allows for "what-if" scenario modelling before making physical changes, predicting the impact of new equipment, or changes to cooling setpoints.

Integration with DCIM/BMS:

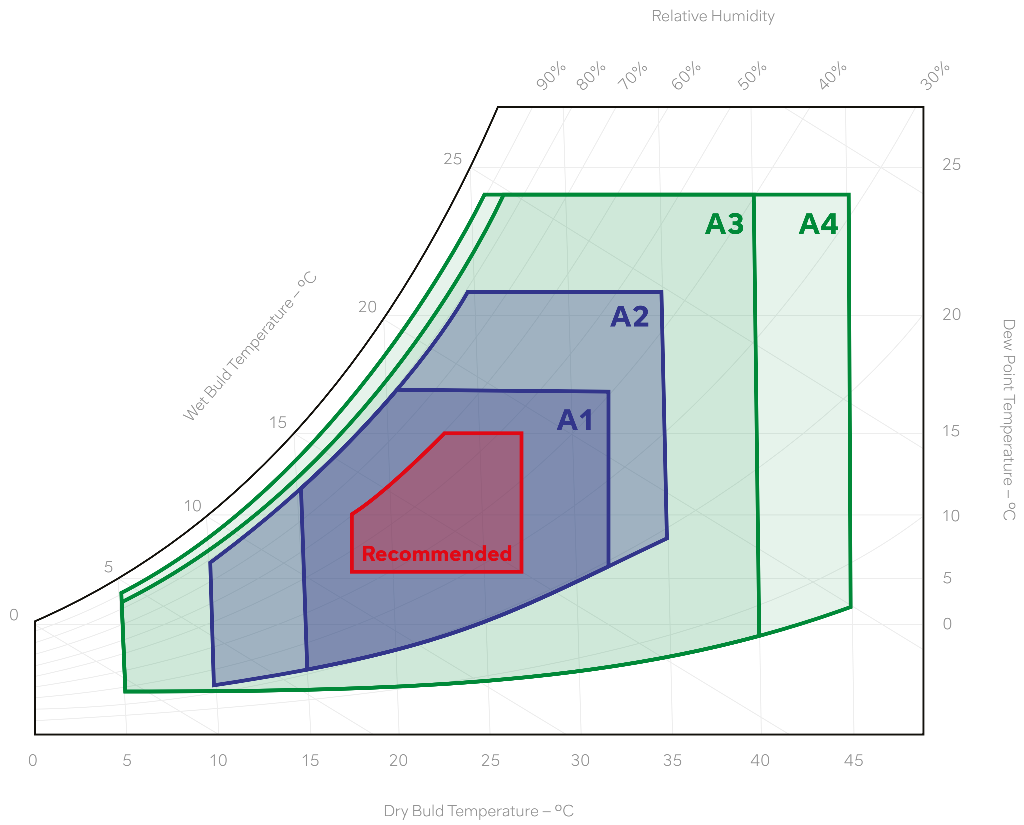
Integrate sensor data and CFD models with Data Centre Infrastructure Management (DCIM) or Building Management Systems (BMS) to enable predictive and automated control of the cooling infrastructure.

Temperature Optimisation (The Fifth Lever)

Having achieved an optimal airflow, we can now apply the final fifth lever for optimising the cooling within the "White Space", Temperature Optimisation.

As with a motor car we can only apply the Fifth gear having worked our way through the lower gears allowing us to now achieve our ultimate goal of optimal performance.

ASHRAE Server and IT Equipment Classifications A1, A2, A3 and A4 can safely operate with inlet temperatures up to 27°C (80.6°F) per ASHRAE TC 9.9 guidelines.



Raising the supply air temperature to the outer recommended limit but inside the safe operating temperature of each classification:

- **Reduces chiller energy use**
- **Expands opportunities for free cooling (economisation)**
- **Enhances system COP (Coefficient of Performance)**

High Performance Computing

Whilst A1-A4 cover the vast majority of standard enterprise equipment, in the ASHRAE TC 9.9 – Thermal Guidelines for Data Processing Environments, a new classification for specialised HPC/AI workloads was introduced; H1.

- **Recommended air temperature: 18°C to 22°C (64.4°F to 71.6°F)**
- **Dew point temperature: 3°C to 18°C (37.4°F to 64.4°F)**

The H1 class was specifically introduced for these new high-density systems that tightly integrate high-powered components (like the NVIDIA H100 SXM5 or B200, some of which are designed for liquid cooling) that simply cannot be air-cooled effectively within the broader A-class ranges.

Whilst some cooling topologies can be adapted to accommodate HPC, it is generally more effective to set aside a separate cooling zone where a different cooling topology such as RDHX or a Hybrid model that incorporates Direct liquid Cooling is adopted. Either way this will enable the use of independent controls to maintain the necessary environment and prevent other, less dense equipment from being inefficiently overcooled.

Quantifying the Benefits: The Return on Investment

A well-executed air optimisation project delivers a compelling ROI.

Energy Efficiency

Reduced Fan Power:

Proper sealing and containment allow for higher return air temperatures, enabling CRAH fans to slow down. A 20% reduction in fan speed can save approximately 50% of the fan power (Affinity Laws).

Improved Chiller Efficiency:

Raising the cold aisle setpoint (enabled by AFM) can significantly improve chiller Coefficient of Performance (COP), leading to substantial energy savings.

PUE Improvement:

It is common to achieve a PUE improvement of between 0.1 and 0.3 through comprehensive AFM.

What would this mean in terms of potential energy savings.

Let us assume a facility has a 1MW IT energy consumption with a starting PUE position of 2.0. This would equate to a total facility energy consumption of 2MW.

- **2MW Total Facility Load ÷ 1MW IT Load = PUE 2.0**

If we can improve the PUE by 0.3 e.g. See Case Study: *A study of a federal data centre implementing hot aisle containment. Then we have a new PUE of 1.7

- **PUE 1.7 x 1MW IT Load = Total facility Load 1.7MW**

This equates to an energy saving of 300kW. There are 8760kWh in a year, so:

- **8760 x 300kW = 2,628,000kWh annual energy saving**
- **2,628,000kWh x ** £0.22 = total annual OPEX saving of £578,160.00**

Therefore a 0.1 PUE improvement would have provided an OPEX saving of **£192,720.00** and a 0.2 PUE improvement **£385,440.00**.

*(source: "Best Practices Guide for Energy-Efficient Data Centre Design" by U.S. Department of Energy, Lawrence Berkeley National Laboratory)

** (example of a local UK kWh rate)

Of course, this is merely an example there are so many variables involved such as the heat capacity of air, the temperature difference that must be removed (ΔT) and the efficiencies of fans and cooling plant all come into play.

Even the electrical unit rate will vary enormously depending on the size and the unique status of each facility and in the UK, in this example, any rate would be subject to a **Climate Change Levy**. Similarly in Europe the **EU Emissions Trading System (ETS)** would apply.

The conclusion is unequivocal: every cubic metre of air leaked per hour (m^3/h) represents wasted energy (kWh), incurring a direct and avoidable financial cost.

The evidence for action is clear and continual improvement in efficiency is both a business imperative and a statutory requirement for large data centres (see references).

As well as statutory requirements there are business incentives such as the UK's **Climate Change Agreements (CCAs)**: Data centres can voluntarily enter a CCA in exchange for a significant discount (currently 90%) on the Climate Change Levy (CCL) tax on electricity and fuel.

Increased Resilience and Uptime

- **Elimination of hot spots reduces the risk of thermal-related hardware failures.**
- **Predictable and stable temperatures extend the operational life of IT assets.**

Increased Capacity and Density

- **By eliminating wasted cooling, existing infrastructure can support more servers, deferring capital expenditure on new cooling units.**

Sustainability

- **Direct reduction in kWh consumption lowers the data centres carbon footprint, supporting ESG (Environmental, Social and Governance) reporting and goals.**

Conclusion and Call to Action

Summary

Air optimisation is not a one-time project but an ongoing discipline. It forms the foundational layer of any holistic data centre efficiency strategy. Before investing in expensive new cooling technologies, operators must first ensure their existing air-based systems are operating as intended.

A recommended path forward:

Assess:

Conduct a thorough audit of the current state. While Computational Fluid Dynamics (CFD) modelling can be valuable, a physical walk-through to identify bypass airflow, recirculation and hot spots is essential.

Contain:

Implement hot or cold aisle containment as the highest-priority capital project.

Seal:

Systematically seal all gaps in the raised floor, racks and containment systems.

Monitor:

Deploy a sensor network to establish a baseline and continuously monitor conditions.

Optimize:

Use the collected data to fine-tune cooling setpoints, fan speeds and air distribution.

By mastering the flow of air, data centre operators can unlock significant operational savings, enhance system reliability and build a more sustainable and scalable infrastructure for the future.

Final Thoughts

While operational savings are a welcome outcome, the genuine benefit is performance enhancement. The motor racing comparison highlights this: perfecting a car's airflow is not just about saving fuel (though it does), it is about achieving greater speed from the same engine. For data centres, this means more cooling capacity from the same "grey space" and more available power (kW) to support increasing compute demands. Maintaining this path to success demands continual adherence to these core principles, despite the distractions of day-to-day operations. Vigilance is essential to never compromise on sound airflow management.

Disclaimer: The information contained in this document is for general guidance only. It is recommended to consult with qualified data centre engineering professionals before implementing any significant changes to your facilities infrastructure.

References

- ASHRAE TC 9.9 – Equipment Thermal Guidelines for Data Processing Environments, 5th Edition (2021)
- Uptime Institute – Data Centre Cooling Best Practices
- The Green Grid – PUE: A Comprehensive Examination of the Metric
- Lawrence Berkeley National Laboratory – Data Centre Energy Efficiency Strategies in particular the LBNL Study on Data Centre Airflow Management and the Best Practices Guide for Energy-Efficient Data Centre Design
- EU Energy Efficiency Directive (EED) (EU) 2023/1791, which Member States are required to transpose into national law
- Streamlined Energy and Carbon Reporting (SECR) framework: UK
- ESOS (Energy Savings Opportunity Scheme): This is a mandatory energy assessment and savings program for large businesses in the UK.
- Climate Change Agreements (CCAs): UK
- EU Code of Conduct for Data Centre Energy Efficiency
- EN 50600 Series / ISO/IEC 30134: These are the core European (EN) and International (ISO/IEC) standards for data centre facilities and infrastructures.
- ISO 50001: This international standard specifies requirements for an energy management system (EnMS) and a continuous improvement process, which many data centres use to manage and improve their energy performance.
- CIBSE (Chartered Institution of Building Services Engineers): Provides guidelines and codes of practice relevant to building services in the UK, including efficient cooling system design and operation for data centres.

rev 1.0 - 18/02/26

ELEVATE

Future Faster

elevate@excel-networking.com

elevate.excel-networking.com

an excel solution