future facilities

Using Simulation to Validate Cooling Design

CASE STUDY

KAO DATA

Challenge:

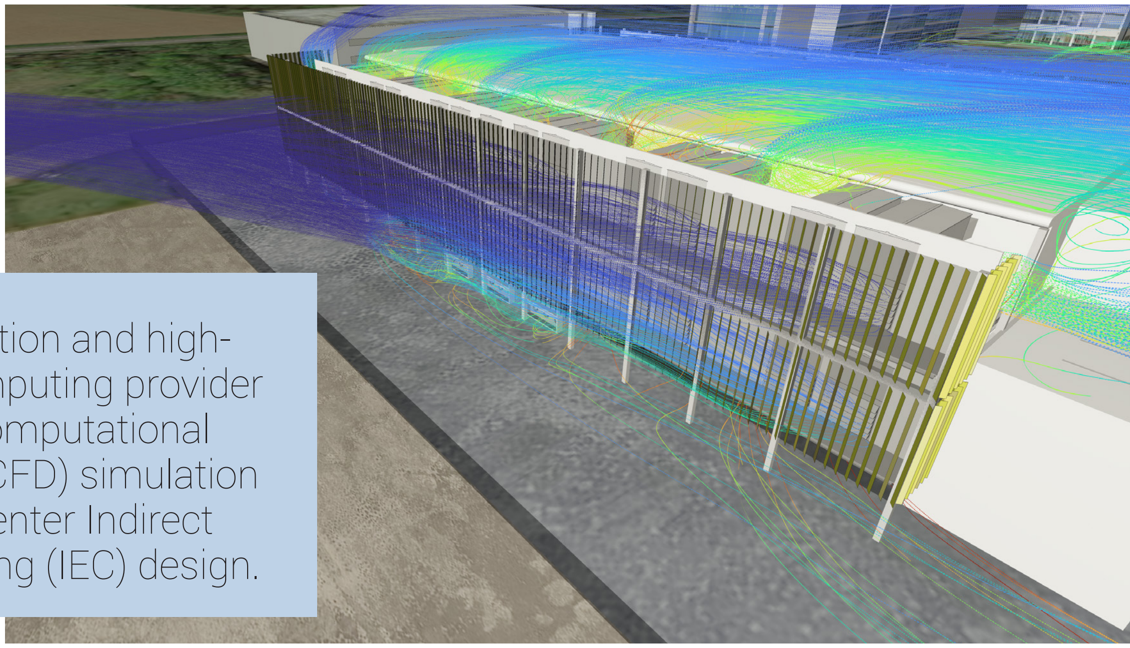
To implement a cutting edge wholesale colocation and high-performance computing data center with environmental performance at the heart of its design.

Process:

Explore the viability of Indirect Evaporative Cooling (IEC) design concept through external modeling using CFD simulation.

Solution:

Refine data center design to maximize operational efficiency and use the 6SigmaDC Digital Twin to ensure informed decision making using CFD simulation both in design and operations.



Wholesale colocation and high-performance computing provider Kao Data uses Computational Fluid Dynamics (CFD) simulation to validate data center Indirect Evaporative Cooling (IEC) design.

In 2018, when Kao Data launched KDL1, the first of four planned data centers on a 36-acre campus, it was the UK's first 100% free-cooling wholesale colocation facility. Located within the iconic London-Stansted-Cambridge "UK Innovation Corridor", the data center campus is designed to be cutting edge in terms of supporting high performance computing (HPC) and intensive artificial intelligence (AI) requirements, but crucially, not at the expense of the environment.

In fact, environmental performance was put at the very heart of the data center's design with a brief to ensure the campus was as energy efficient as possible. To cater for this, an Indirect Evaporative Cooling (IEC) system – using water evaporation in place of mechanical systems to cool the air – was considered and later adopted to create a data center that was greener, as well as more efficient and cost-effective to run.

Future Facilities worked alongside JCA Engineering and Kao Data throughout this project, providing CFD simulations of both the external and internal environments of the data center campus to help make informed decisions around design, implementation and operations.

"The success of data center energy efficiency is governed by two key factors: the relationship between the infrastructure engineering and the applications operating on the compute, storage and networking equipment," said Paul Finch, Chief Operating Officer (COO), Kao Data. ***"Energy efficiency has always been one of the key pillars of our data center strategy, and with a PUE of 1.2 at both high and low IT utilization, it remains one of the primary differentiators of our campus. We chose to work with Future Facilities due to their industry-leading reputation for CFD analysis, which was pivotal in helping us to design and build one of the most sustainable and energy efficient facilities in the UK."***

The Data Center Specifications

With ambitions to cater for the increasingly high-density deployments characterized by machine learning and deep learning workloads and offering the ultimate in Open Compute-Ready (OCP) infrastructure, the Kao Data campus will be split into four halls totaling around 150,000 square feet of technical space. This space is engineered from the ground-up to specifically cater for advanced, GPU-powered supercomputing with Technology Suites incorporating slab-flooring, no column data halls and wide access corridors. Each data center will offer a total technical load of 8.8MW, accommodating rack densities of 20kW and beyond, in line with customer expectations.

Kao Data boasts an impressive 100% uptime track record ensuring power resiliency via an on-site substation. This uses 43.5MVA supplied by UK Power Networks (UKPN) national grid via a dual feed to the data center facilities. When needed, back-up power generation is provided by generators configured with N+1 redundancy to satisfy the toughest client SLAs.

Under normal running conditions the whole campus is powered by 100% certified, renewable energy and their architecture has received the Building Research Establishment's (BRE) BREEAM excellence certification in construction for building energy efficiency, environmental and sustainability competency. IT operations boasts a PUE of 1.2, even at partial loads, and its non-mechanical cooling design eliminates the need for harmful refrigerant-based systems, ensuring it meets the ASHRAE TC 9.9 environmental guidelines.

"From inception, Kao Data was precision-engineered for industrial scale computing; those found in high performance computing (HPC), artificial intelligence (AI) and supercomputing environments," continues Paul Finch, COO, Kao Data. ***"Due to the demanding power and cooling requirements of these GPU-powered systems, it's essential that they're as sustainable as possible, which requires pinpoint operational efficiency, alongside an ultra-efficient design and use of renewables. Future Facilities' CFD analysis played a crucial role in helping us achieve this."***

Aims of Working with Future Facilities on this Project

With such ambitious design specifications, Kao Data and its data center design engineering firm JCA Engineering decided to work alongside Future Facilities to validate the proposed design and troubleshoot any potential problems. A Digital Twin of the data center campus was created and CFD simulation was used to:

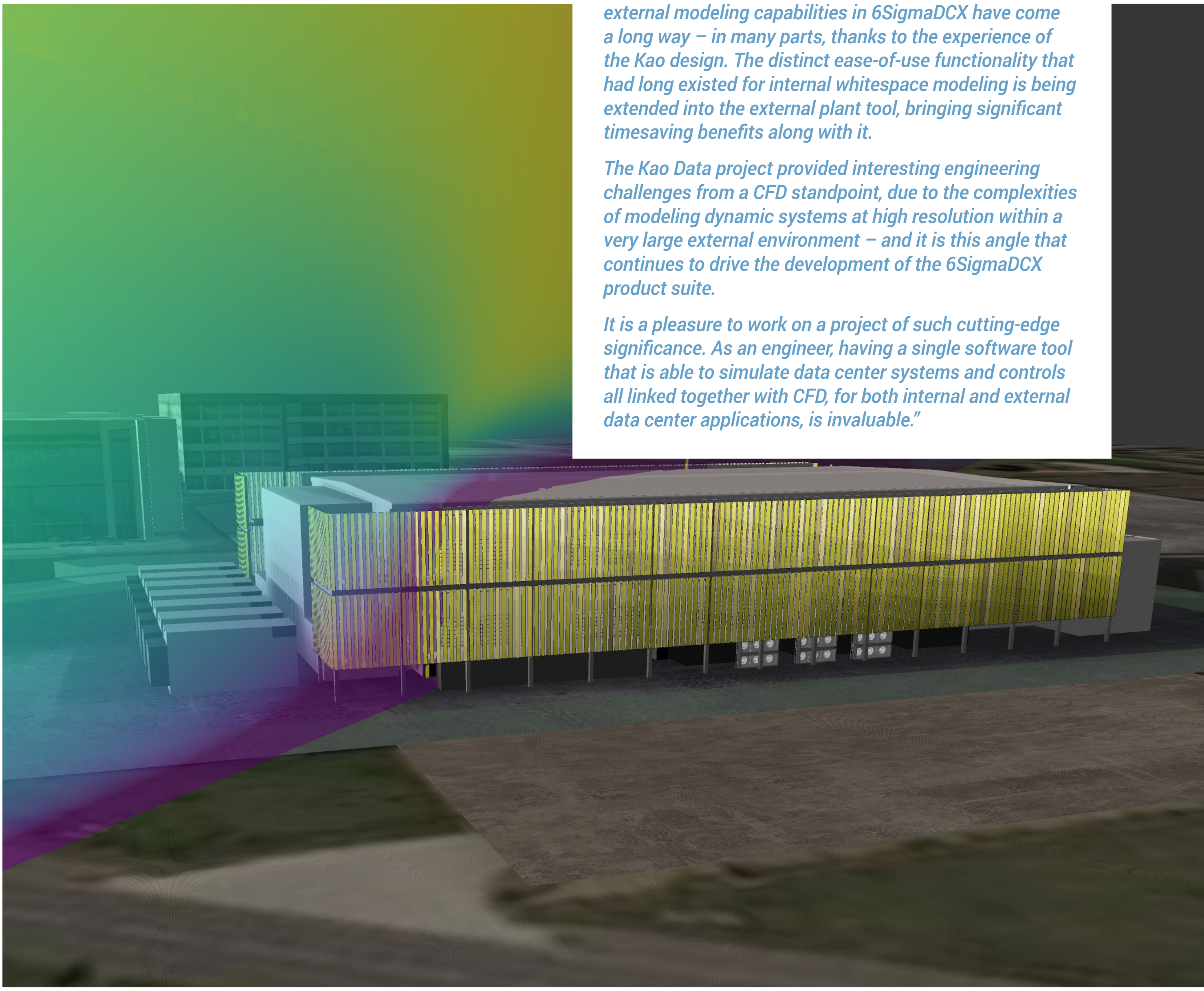
- Evaluate the viability and performance of the proposed IEC design concept
- Confirm satisfactory cooling performance of each of the proposed build-out stages
- Demonstrate the effect of potential varying and extreme environmental conditions
- Verify that predicted IEC inlet conditions for a variety of external conditions were acceptable and should not compromise IEC performance.

In making a data center Digital Twin of the Kao Data environment using the 6SigmaDCX product suite, Future Facilities' initial task was to use external modeling to evaluate cooling performance under different weather scenarios using a range of configurations.

Talking about the project, Maira Bana, Senior Consultant Engineer at Future Facilities says, *"Since our first consultancy engagement with Kao Data & JCA, external modeling capabilities in 6SigmaDCX have come a long way – in many parts, thanks to the experience of the Kao design. The distinct ease-of-use functionality that had long existed for internal whitespace modeling is being extended into the external plant tool, bringing significant timesaving benefits along with it.*

The Kao Data project provided interesting engineering challenges from a CFD standpoint, due to the complexities of modeling dynamic systems at high resolution within a very large external environment – and it is this angle that continues to drive the development of the 6SigmaDCX product suite.

It is a pleasure to work on a project of such cutting-edge significance. As an engineer, having a single software tool that is able to simulate data center systems and controls all linked together with CFD, for both internal and external data center applications, is invaluable."



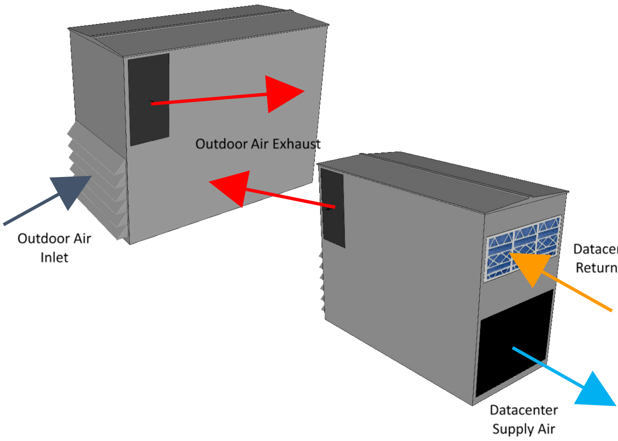
Choosing Indirect Evaporative Cooling (IEC)

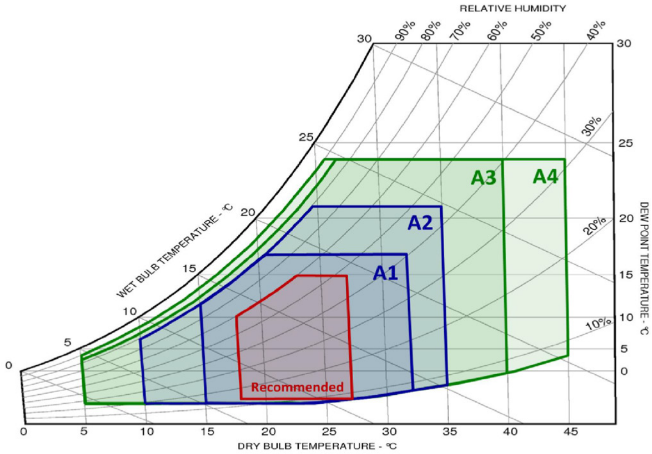
Kao Data opted to use Indirect Evaporative Cooling (IEC) Units at its facility. These units are designed specifically for the data center environment and are based on the principle that evaporating water removes heat from its surroundings. IECs use external air to cool the facility, without allowing external and internal airstreams to directly mix. External air is drawn through a heat exchanger and then immediately exhausted, while internal air is drawn from the room and circulated through the other side of the heat exchanger before being re-introduced to the space.

By humidifying the outside air during the process, its temperature is economically reduced, which makes this an essential step when external temperatures are high and need to be reduced to provide cooling.

Using Indirect Evaporative Cooling ensures that humidity levels aren't affected in the data center environment because the two airstreams pass through opposite sides of the hermetically sealed heat exchanger. As a result, hot IT server exhaust air is drawn away from IT equipment in the data center and expelled without any risk of outside air entering the building, maintaining the internal environmental conditions of the ASHRAE recommended range of Class A1.

It is important to recognize in the case of evaporative cooling, that the air that exhausts back out to the environment is much more humid due to the water addition. This means that a critical component of the IEC design is adequate segregation of the intake and exhaust of the external air path to avoid moist air being drawn back in.





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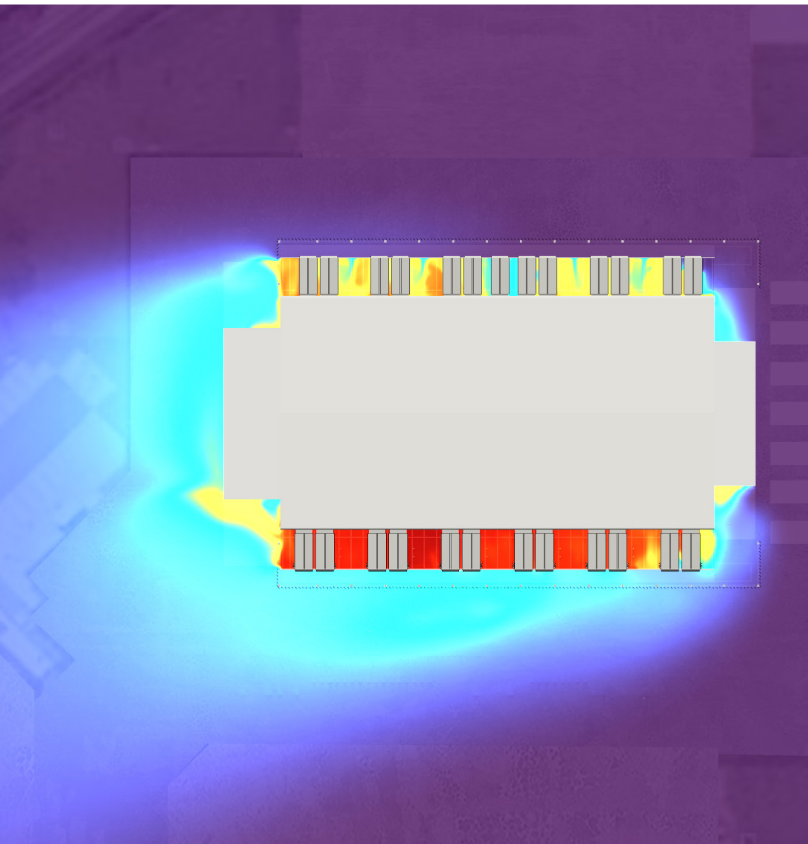

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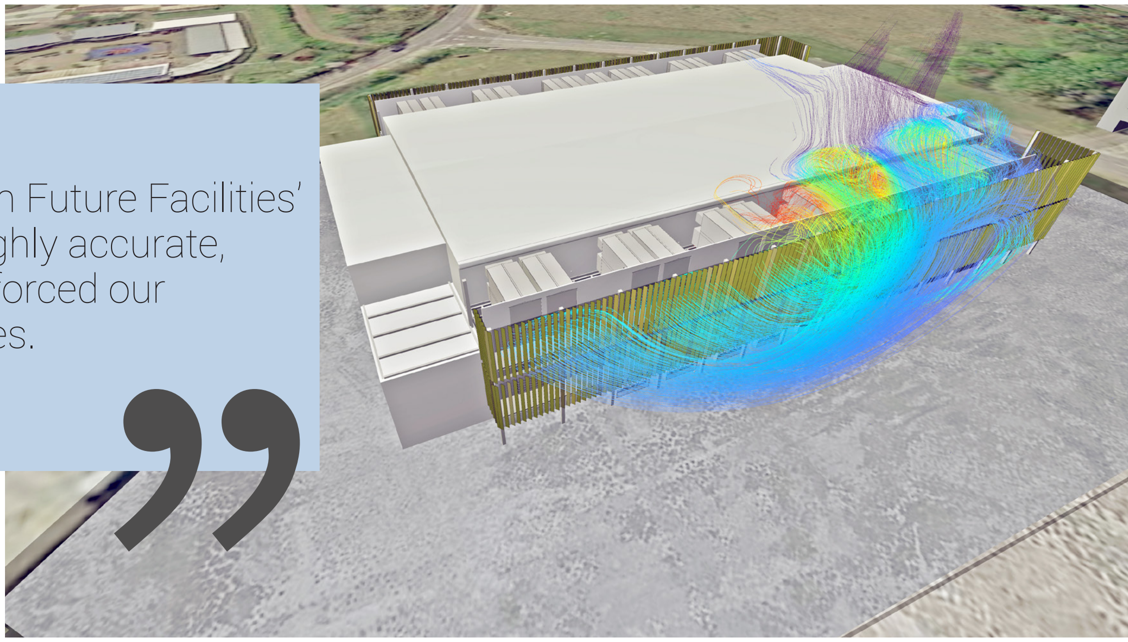


Why Use CFD Simulation for External Modeling?

Having established the IEC performance is potentially susceptible to humidity at the intake, and that the IECs in evaporative mode will output humid air, it was important to assess the risk of recirculation between the exhausts and intakes. This is where the power of CFD could be utilized.

A CFD simulation study of the external site would allow Kao Data to understand:

- The thermal impact of the overall design
- How this could be affected by different weather conditions
- How the different stages of site build-out could affect performance.

The goal was to ensure optimal operation throughout the different stages of the project and flag up any areas of concern.

Once build-out of KDL1 is completed, four data halls will operate on the first and second floors of the building. On both floors, IECs will be placed on the north and south facing sides of the facility, with the IEC inlet louvers facing north and south and the outlet louvers facing east and west.

Kao Data decided to simulate a number of wind speed/direction conditions to understand the air flow behavior around the building in different circumstances. The aim was to understand which wind directions caused the worst recirculation of air and how best to optimize set-up to avoid moisture getting trapped around the building and drawn back into the IECs. It was also necessary to consider what happened in still wind conditions – this can be the worst scenario as higher wind speeds can often help carry away the humid expelled air.

Engineers at JCA and Future Facilities assessed historical ASHRAE weather data for the area to establish conditions that were most likely to be risky. This allowed for a clear project definition involving the simulation of a reasonable number of scenarios. Initially 6SigmaDCX was used to map different external environmental scenarios, taking into account the effect of building obstructions on air intake and any potential difficulties such as exhaust air mixing and raising the intake wet bulb (WB) temperature above the specified limits for the IEC units. The simulations were used to identify and reduce the risks, enabling the final design to take into consideration the placement of cooling chillers and how airflow might be restricted by placing them too close together or by issues such as aesthetic/cosmetic louvered walls around the units.

As well as assessing the outside environment, CFD modeling played an important part in whitespace configuration. For the whitespace, Kao Data's Digital Twin was used to verify the cooling system worked effectively at the design supply air temperature. It was crucial that airflow was distributed evenly throughout the data center, and IT cooling availability was unaffected by location.

As well as validating thermal performance under normal operating conditions, CFD simulation was used to verify that the design would cope in a failure scenario – especially in terms of the IT equipment located near the failed cooling unit.

"Engineering requires comprehensive due-diligence, it's critical to ground your decision-making in fact. Data is a fundamental component of that process," commented Paul Finch, COO, Kao Data. ***"Being able to rely on Future Facilities' next-generation, highly accurate, CFD modeling reinforced our technical capabilities, and gave us the confidence that both our facilities design and choice of power and HVAC infrastructure were operating as optimally as possible. This helped to manage risk prior to the commitment of a multimillion-pound capital project."***

Looking Forward

Whilst KDL1's first Technology Suites TS01 and TS02 are now fully operational, the need for CFD simulation continues as build-out of the remaining future two Technology Suites TS03 and TS04 progresses. Simulation was important to appreciate the changes in recirculated air volume with the increase in IEC units and evaluate the unique risk profile associated with each operational stage of build-out.

The 6SigmaDCX data center CFD simulation model was updated to incorporate operational TS02, TS03 and TS04 Technology Suites with results demonstrating the mechanisms of recirculation in four different scenarios. The key objective was to establish the intake air conditions at all the installed IECs. The wind speed of 3.0m/s at 10 m was used in accordance with the prevailing wind condition at the Kao Data campus. Park buildings that surrounded the data center were modeled as blockages with no heat loads and ground floor obstructions like water tanks and plantrooms were included where relevant. Wet bulb temperature limits of the IEC cooling duties were taken into consideration and it was presumed that operation below these limits would ensure a data center supply temperature of 26 °C.

The effectiveness of design features – such as partitioning and louvers – as well as the impact of the SW wind direction and nearby condensers were investigated. Through use of simulation, Kao Data could consider any necessary adjustments to the order in which IECs and partitioning were installed and make adjustments for any concerns regarding recirculation.

Why is All of This So Impressive?

JCA and Kao Data were able to design a high-performance data center which didn't use any mechanical refrigeration. This was unprecedented at the time that TS01 became operational.

The result was a high efficiency, industrial scale data center (PUE of 1.2) even at low IT utilization, which gives long-term OPEX savings for both Kao Data and their customers and allows them to operate with the highest sustainability credentials for their cooling operation. The design also allowed them to be flexible with how they fill the space. Unlike most conventional data centers, at 50% load the PUE was only 1.14, and for a wholesale colocation data hall this is very impressive.

Recommendations Resulting from CFD Simulation

"CFD modeling helped us refine our decision making process around the design and provision of cooling infrastructure at both facility and data hall levels. This includes the deployment of NVIDIA's Cambridge-1 supercomputer and the unique technical considerations that accompany such implementations," said Paul Finch, COO, Kao Data. *"Gaining data driven insight into the operating densities of critical customer environments is essential to our capabilities, and further reinforces our position as the UK's leading provider of high performance colocation for industrial scale, intensive computing."*

The main aims of the project were to settle on an effective IEC arrangement, analyze the air segregation solution, and assess whether suitable IEC air intake conditions were expected.

During initial simulations, at full load occupancy and with a prevailing south westerly wind condition, it was found that humidity at the external air stream intakes was raised, particularly for IECs on the North elevation. The wet bulb temperature was simulated to be above acceptable limits. This impact on performance was identified because of the CFD study and improvements to the design were able to be made in advance of construction.

Extra design features were analyzed, including a partial canopy above the exhaust areas and blanking to reduce recirculation under units. Such features were simulated and found to prevent the mixing of the humid exhaust stream with the drier ambient air.

Engineers were also able to recommend the installation of an additional IEC at TS01 in order to ensure added resilience.

All these design changes meant that even in worst-case scenario inlet conditions, recommended supplier specifications should not be compromised. Use of ongoing simulation throughout the project has informed the order of the build-out sequence to keep operational risks at a minimum.

Ongoing Simulation

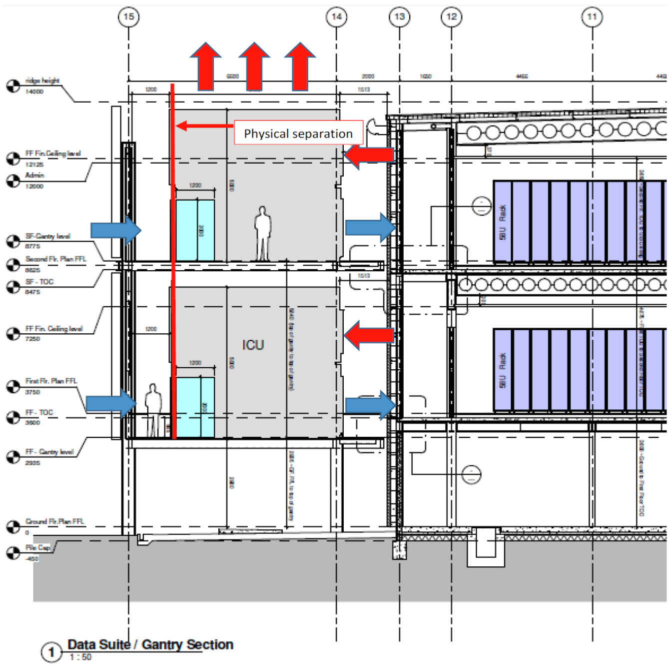
Future Facilities has been proud to be involved in Kao Data's ground-breaking project and continues to work alongside Kao Data to help support decision making on both external and internal data center configurations.

Recently, CFD simulations have been performed to demonstrate how Kao Data can meet stringent SLAs of clients, such as NVIDIA, who recently deployed their DGX SuperPOD architecture in the form of their Cambridge-1 supercomputer within the data center.

Through the CFD simulation of a wide range of what-if scenarios, the data center Digital Twin remains key for colocation operators to make informed decisions, reduce risk and increase efficiency for both themselves and their clients.

Mark Seymour, CTO at Future Facilities comments on working with Kao Data:

"This was a fantastic opportunity to work with an experienced data center colocation professional, Paul Finch, who, along with the Kao Data team wanted to produce not only an exceptional wholesale colocation environment but also set a new standard for environmental sustainability for such data centers in the UK. Importantly, while understanding the value of the Digital Twin, Kao Data also realized the importance that as a model, the value of the Digital Twin depends on the quality of the information provided to create it, the choice of scenarios to study and the expertise required to interpret the predictions. Working with the design contractor JCA and Kao Data on this carefully thought-out, prestigious project has been a privilege for Future Facilities."



CFD modeling helped us refine our decision making process

Paul Finch, COO, Kao Data

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