October 2023 ASHRAE Journal

The following pages contain supplementary information for these articles in the October 2023 issue of ASHRAE Journal:

The Intersection of Energy-Efficiency, Cost and Environmental Impact

By Mehrdad Alipour, P.E., Associate Member ASHRAE; Harikrishna Patadiya, member ASHRAE

Operation and Maintenance

The 24/7 monitoring and trending of water quality and chemical treatment ensured the water system was within parameters and reduced the cleaning and maintenance loads for the tower. The sand filters and full stream inline filters keep particles out. Automating the system reduced the operational staff's workload and allows them to monitor the subsystems. Intentionally designed redundancy within the cooling system allows for independent towers to be fully taken offline for maintenance without impacting the data center's concurrent operations.

Cost Effectiveness

Because Colovore was new to the industry, the design approach included a reduction of capital cost along with the cost of the utilities and operations. To achieve a cost-effective facility, the design reduced the capital cost of the equipment by not using the chillers. Instead, a cooling infrastructure consisting of only cooling towers, pumps, and variable frequency drives was incorporated. As a result, the design reduced the need for 2,200 tons (7737 kW) of chiller capacity (inclusive of redundancy) typically required for a 6 MW data center. Additionally, the monthly utility bill was reduced significantly because the cost of utilities is limited to the electrical use by the optimized cooling plant.

The cooling towers currently use city water as the primary source of makeup water and recycled water from the municipality as a backup. The water utility companies charge a high fee for sanitary discharge, assuming the sanitary discharge flow is the same as makeup water flow. Since most makeup water is evaporated through the cooling tower, a water flow meter was installed on the sanitary line to measure the sanitary discharge flow. Sanitary flow metering helped the client receive credit back on their water bill, and its return on the investment was less than eight months. In addition, because the main design was based solely on the cooling tower, there were big savings in real estate by reducing the mechanical yard to only 3,600 ft^2 (335 m^2).

Environmental Impact

The recycled water is used as a backup for makeup water for the cooling tower. Using recycled water for backup instead of well water significantly reduced the project's environmental impact. Since most of the cooling system is designed through the tempered water from the cooling tower, the facility's energy use is significantly reduced, leading to a much smaller annual carbon footprint than other data centers. Colovore's cooling system generates 30% less carbon footprint than a data center with state-of-the-art PUE. At the current critical load of the facility at 4.3 MW, Colovore generates 1,500 tons less carbon compared to data centers with state-of-the- art PUE.

Community Center Deep Carbon Retrofit

By Iram Green, P.Eng., Member ASHRAE

Indoor Air Quality (IAQ) and Thermal Comfort

Ventilation in the community center was controlled with carbon dioxide sensors in air handlers before the project. During our initial investigation, we observed that some air handlers operated with sensors out of range, limiting the air handers' fresh air supply often well below the required rate to maintain air quality To avoid insufficient ventilation rates in the future, we introduced a routine that will determine when the sensor is out of calibration and remove the demand-controlled ventilation sequence for the corresponding air handler and adjust the minimum outdoor damper to ensure the ventilation rate for designed occupancy (as per Standard 62.1.-2009) is achieved.

Air handlers serving the fitness center and other activity rooms' air supply were found to be approximately 20% below Standard 62.1-2009. The air handlers' flows were corrected to exceed Standard 62.1 2009. minimum requirements when occupied and achieve occupant comfort levels to meet ASHRAE Standard 55.

Life safety monitoring systems were also brought to current standards. This includes two-step fan flow (continuous and during leak event) for ammonia plant and chiller plants exhaust, and ammonia and R-410A air concentration alarms.

Innovation

The new heat recovery system was designed to be the primary heating system for both buildings, where the existing rink boilers are reconfigured to provide supplementary low-grade heat to the source side of the heat recovery system in the event the heating load exceeds ice plant heat rejection. In this configuration, the boilers cannot supply heating water to the buildings' heating systems directly, making the heat recovery chillers the primary source of heat that cannot be abandoned in the future. The boilers' dual return ports were used to maximize boiler performance by re-piping the DHW return to the high-temperature port.

Variable flow heat recovery chillers were installed in the building to optimize performance and allow continuous chiller operation at design load, as well as in conditions requiring partial load operation. This is extremely important as heating water supply temperature control is critical for applications such as pool and DHW heating. Due to the relatively limited approach temperature of the heating water versus the load setpoint and temperature swings typical for heat recovery, chillers are problematic. Using variable chillers allow more accurate temperature control, avoiding unnecessary supplemental heating sources such as a boiler.

Thermal storage is sized to store as much heat as possible from a short refrigeration operating cycle. Although the heat rejection from the ice occurs each hour for a relatively short time, the heat rejected is enough to carry nearly all the facility heating loads. To store all the heat, the tank capacity was determined to be 5,000 gallons (18 927 L). Ideally, the thermal storage can be stratified, but considering the structural requirements to hold a vertical tank of that size, we designed it to flow horizontally and reduce the cost of structural reinforcement.

Operation and Maintenance

The project was part of a building system renewal where end-of-life equipment needed replacement. Distributed gas-fired heating systems that required increasing service calls were replaced with an integrated centralized plant that is more reliable and required less maintenance. This new control system made maintenance and operations a lot easier and less time-consuming as it can be reviewed and continuously commissioned by the city engineering department and the consultant on an ongoing basis.

Service access platforms for ammonia heat exchangers were installed to provide safe and effective access for maintenance and emergency work.

Unconventional systems take longer to commission. The greatest challenge in projects with a similar configuration is the control integration between the equipment manufacturer's internal controls and the central building automated system. Detailed specifications and coordination of the control systems integration, including specific settings of integrated controllers, were the key to properly commissioning the system and achieving the expected performance. A "hands-on" approach of the consultant was required to commission the systems as intended. This included researching the installed equipment onboard controllers and providing instructions to the controls and mechanical contractors on appropriate configuration and sequencing of operations, which were unknown at the time of tender.

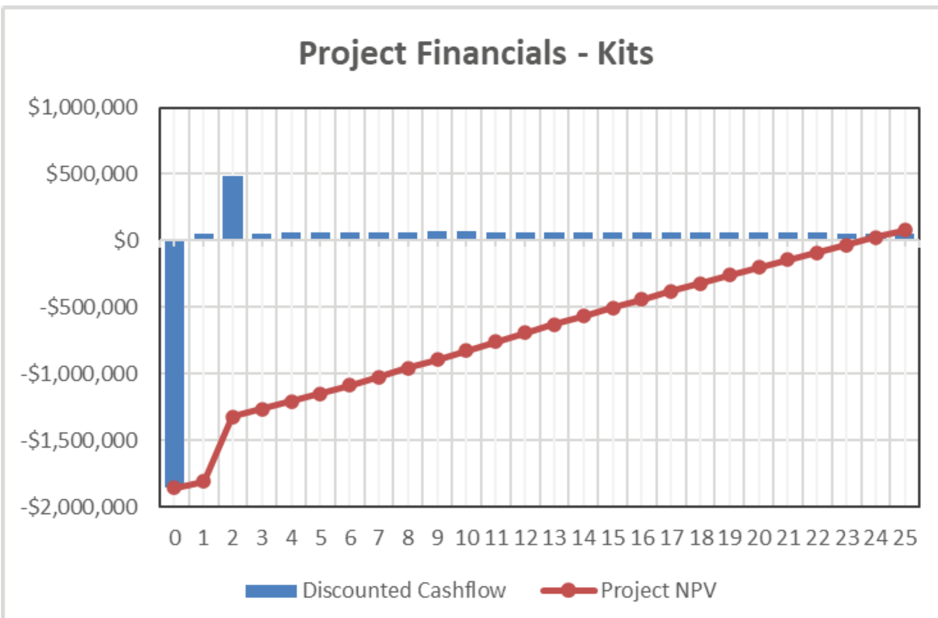
Cost Effectiveness

The following table summarizes the project's financial analysis with updated project costs. Estimated capital costs represent the equipment renewal costs that were avoided. Capital costs were evaluated with future value in year three of the project life.

Measure	Demand Savings (kW)	Electrical Savings (kWh/yr)	Fuel Savings (GJ/yr)	Total Savings ($/yr)	Retrofit Costs ($)	Estimated Capital Costs ($)	GHG Reduction (ton CO_2-e/yr)	NPV ($)	IRR (%)
Ice Rink Heat Recovery	-25	0	4,200	$52,200	$1,860,000	$460,000	210.0	$78,800	3.4%

General notes on financial summary tables:

- Financial metrics are based on a 3% discount rate, 2.5% annual escalation in energy rates and proposed equipment/measure lifespan as noted for the project (25 years).
- The carbon tax levied on natural gas is included in savings calculations. It is based on $45/ton ($2.25/GJ), increasing annually by $15/ton or $0.75/GJ from 2023 until it reaches $170/ton or $8.50/GJ.
- 25-year net present value (NPV) and internal rate of return (IRR).
- Financial analysis is performed based on the incremental cost associated with the difference between base case retrofit and the recommended measure.



General Approach to Energy Use Analysis

Starting from the bottom up, we used an inventory approach of collecting equipment data and assigning load factors and hours of operation based on the audit data. We then determined energy use on an end-use basis. This information provided us with an end-use breakdown that is the source of the savings calculations.

From the top down, we used utility information to determine weather and occupant-related energy use and created a performance model that enabled us to break the energy use into hourly analysis and end-use components. In addition to the utility information, we used load monitoring equipment and ice plant control trends to isolate large buildings and refrigeration plant loads to help improve the accuracy of our calculations.

Energy and Carbon Savings Analysis

Using the information gathered from the site and documentation, we calculated the existing energy use of mechanical equipment and determined the savings from the various HVAC and DHW retrofit options. We used industry best practices and transparent engineering calculations for our savings estimates.

Financial Analysis

We based our retrofit measure costs on real data and experience from previous projects. We also reviewed the measures with contractors before finalizing our pricing. Our pricing shows the required engineering and a contingency amount determined by the city.

Energy modeling was coupled with various financial analyses to determine the cost-effectiveness of each measure. Equity payback and net present value (NPV) calculations were completed. GHG emission savings were presented for the project with escalated emission tax as projected by the City.

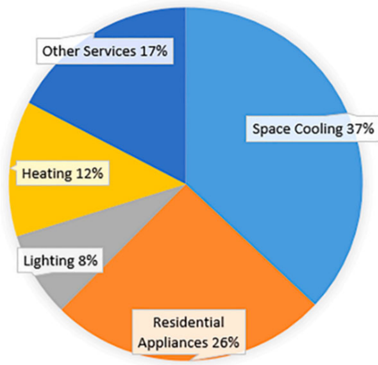
A detailed life-cycle cost analysis was completed for each project, evaluating the future value of related equipment replacement. For the replacement of equipment near the end of life, we presented measure costs based on the incremental upgrade costs. NPV calculations were performed using utility rates escalation, expected carbon tax increase and future replacement value.

Environmental Impact

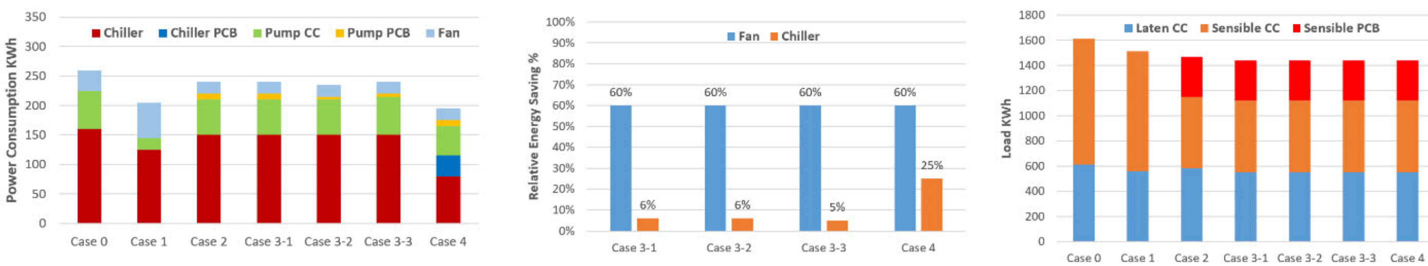
The project had a significant emphasis on reducing carbon emissions for the site.
Considerations were also made for embedded carbon impact, and equipment and piping were reused where possible. Most fan systems were in good condition, even though some were more than 20 years old. Components that needed replacement were mainly gas-fired heating sections, heating coils, DX coils and condensing units. To limit material waste and associated embedded GHG emissions, the system integration approach was to take advantage of existing equipment as much as possible and field retrofit to accommodate the change needed.

Energy Saving Potential of Active Chilled Beam System for Buildings in Dry Climates

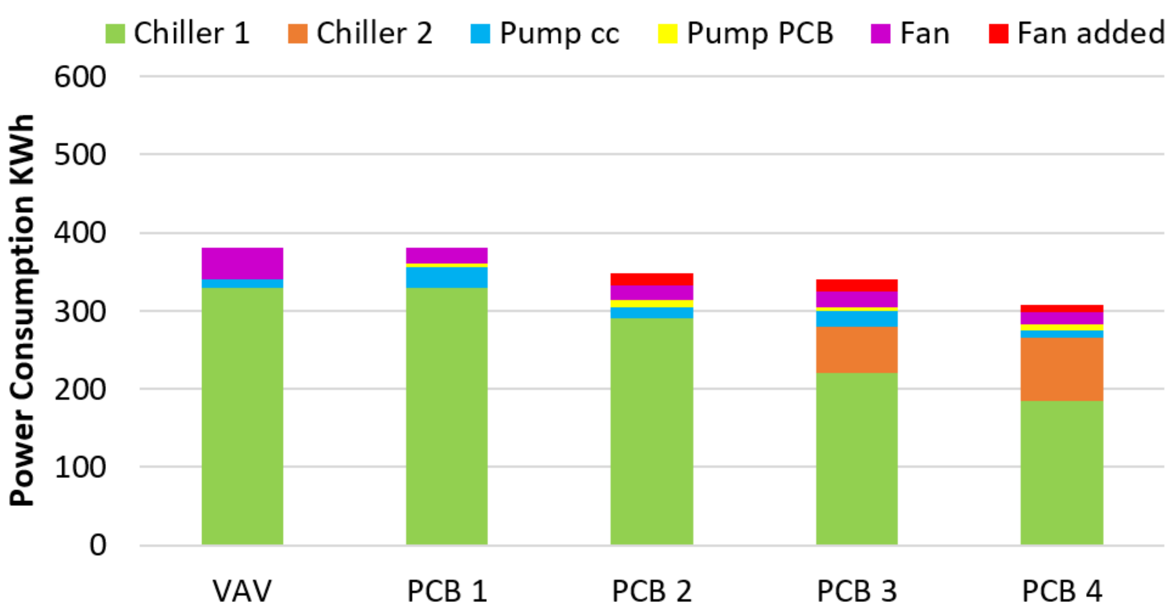
By Ibrahim M. Hasan; Mohamed Yehia, Member ASHRAE; Gamal El-Hariry; Omar Huzayyin, Member ASHRAE



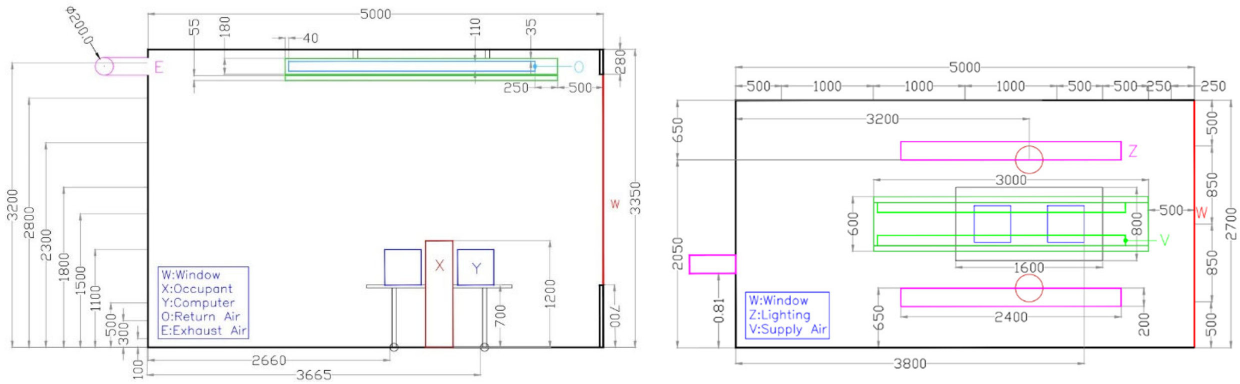
Online Figure 1. Share of global electricity demand growth until 2050.[11]



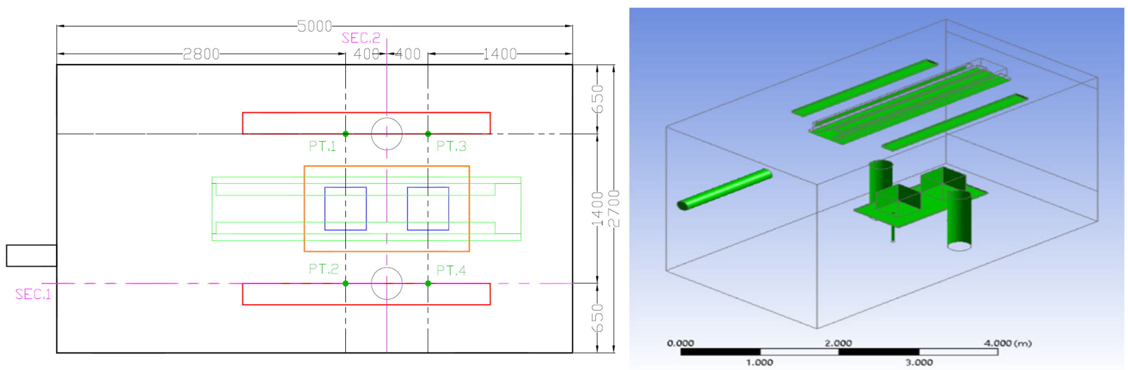
Online Figure 2 Energy savings of passive chilled beam system.[33]



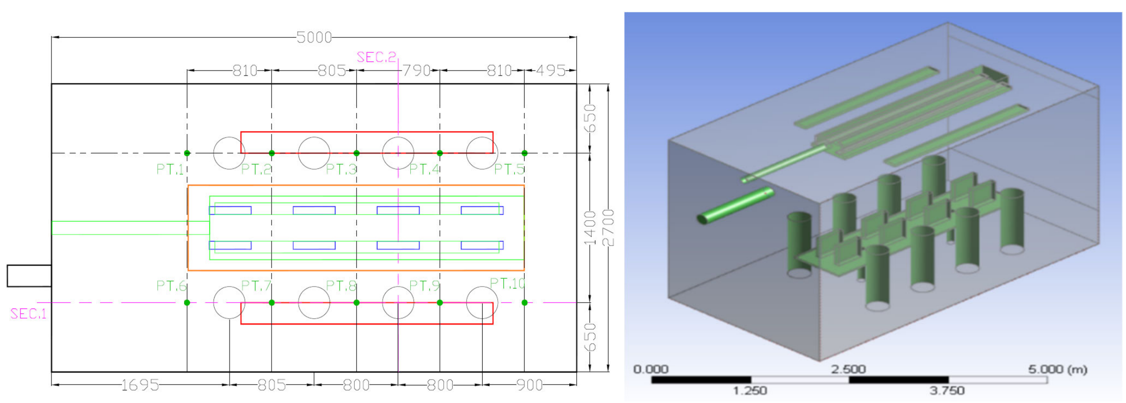
Online Figure 3: Energy consumption results for each configuration in Phoenix, AZ.[34]



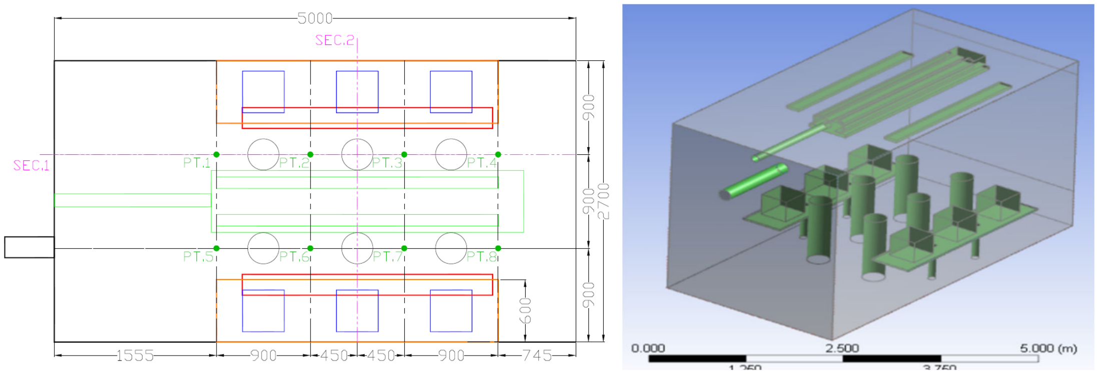
Online Figure 4: Elevation and Plan view for simulated office.



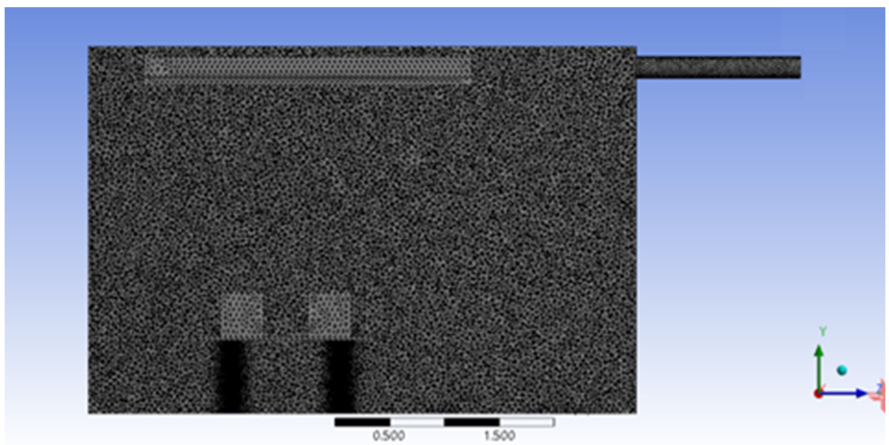
Online Figure 5: Plan view and 3D for simulated office room.



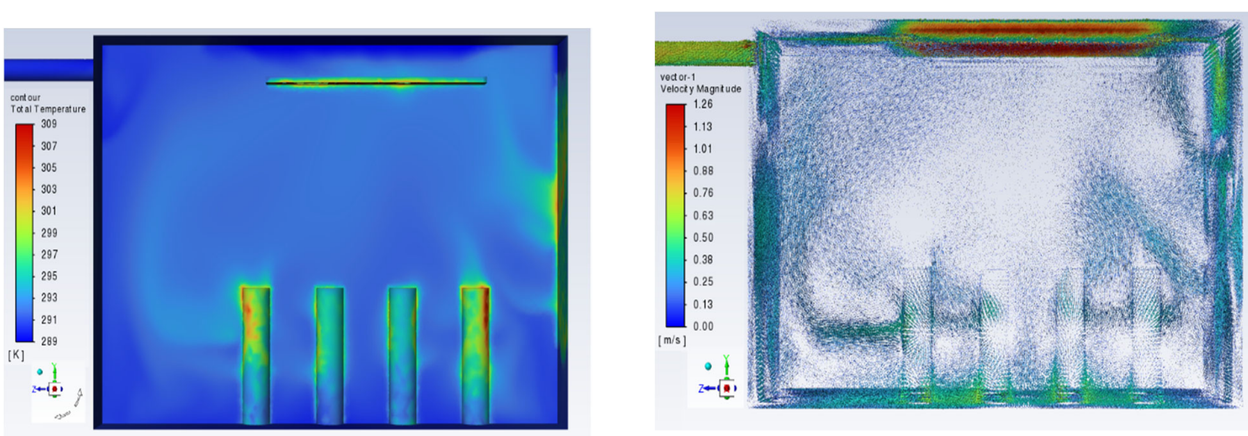
Online Figure 6: Plan view and 3D for simulated meeting room



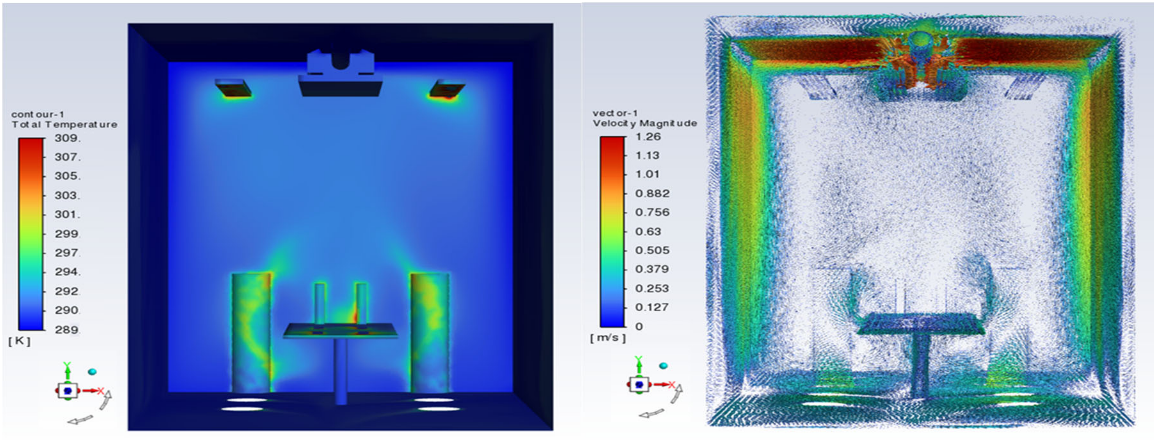
Online Figure 7: Plan view and 3D for simulated control room.



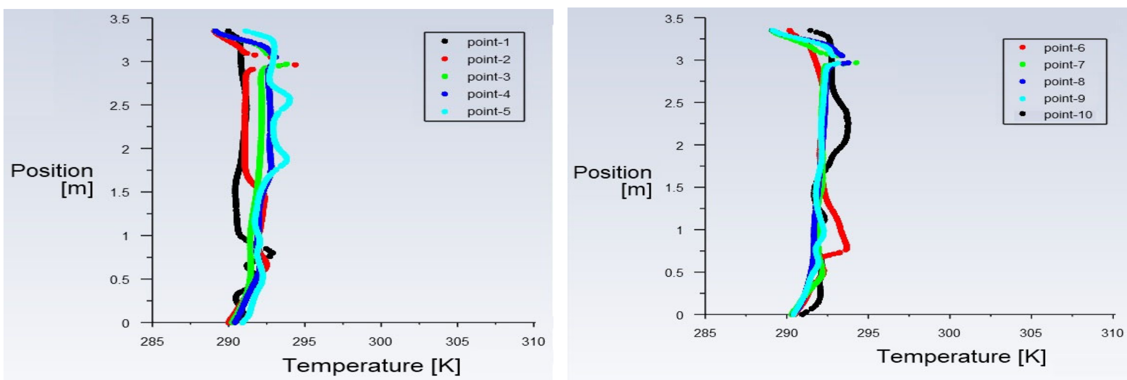
Online Figure 8: The meshed control volume for simulated office.



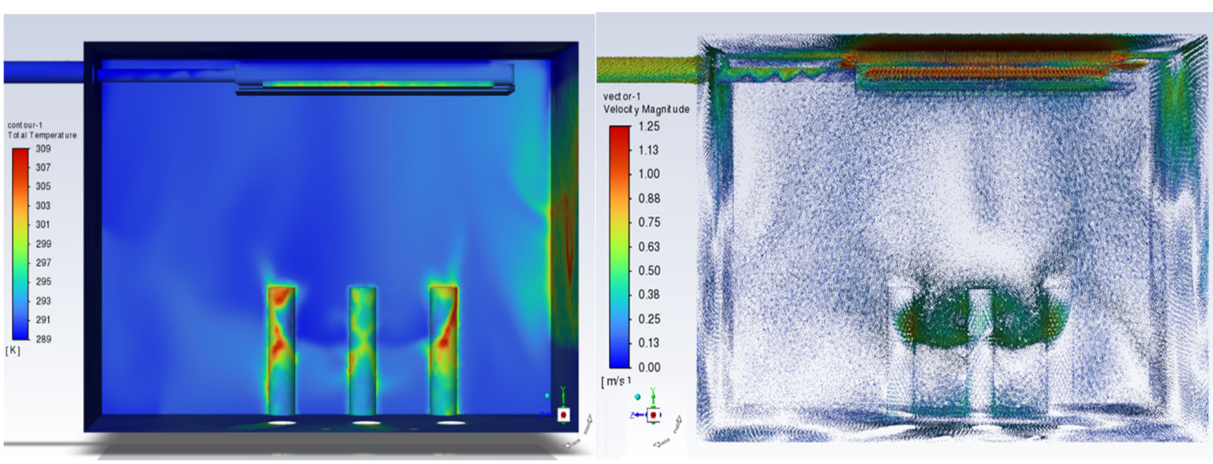
Online Figure 9: Temperature distribution and velocity vectors.



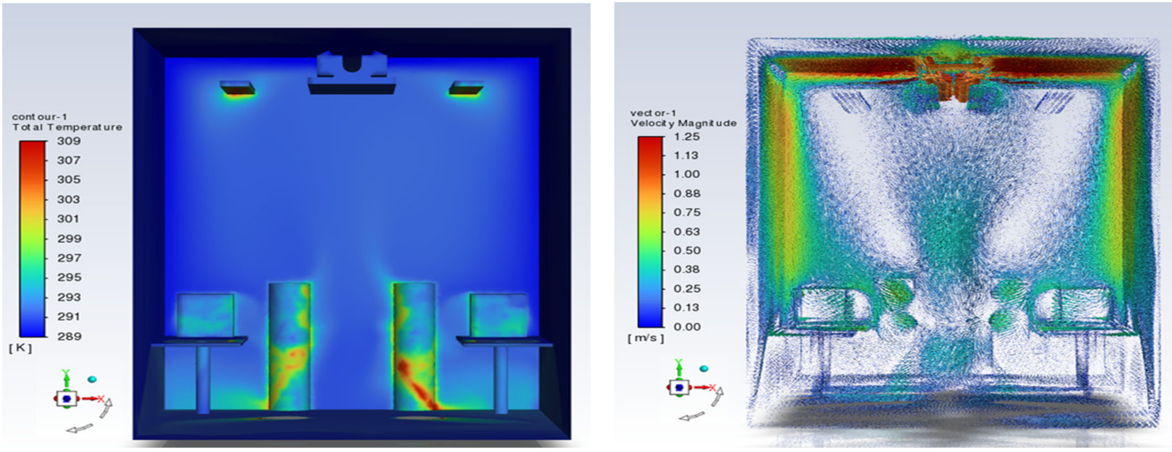
Online Figure 10: Temperature distribution and velocity vectors



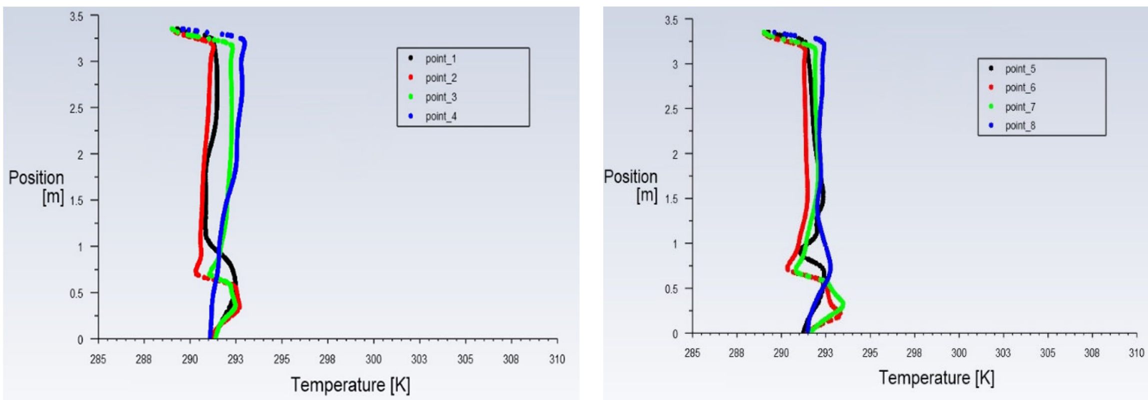
Online Figure 11: Vertical temperature stratification (Point 1–10 refer to Online Figure 6.)



Online Figure 12: Temperature distribution and velocity vectors.



Online Figure 13: Temperature distribution and velocity vectors.



Online Figure 14: Vertical temperature stratification (Point 1–8 refer to Online Figure 7).