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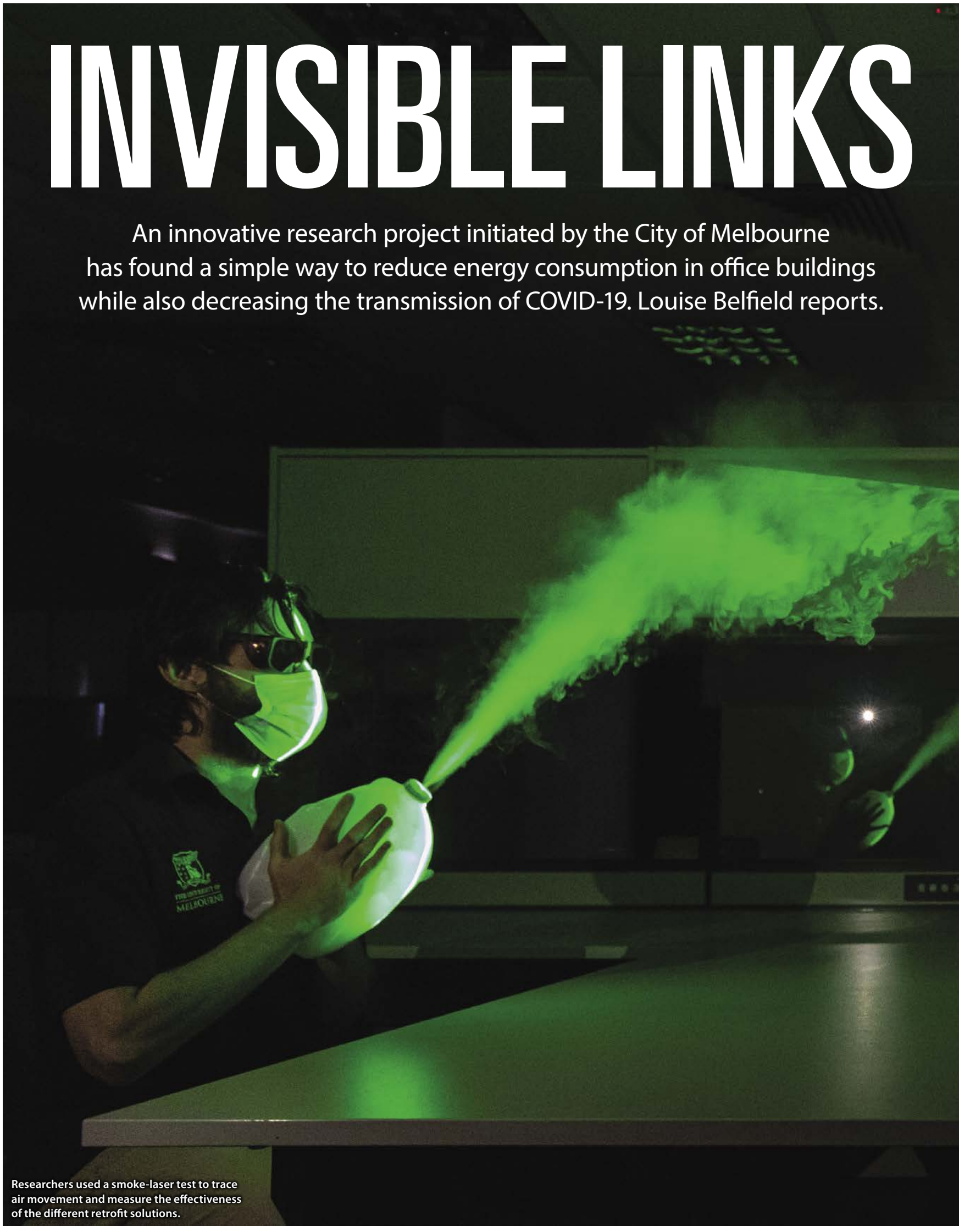
INVISIBLE LINKS

An innovative research project initiated by the City of Melbourne has found a simple way to reduce energy consumption in office buildings while also decreasing the transmission of COVID-19. Louise Belfield reports.



Researchers used a smoke-laser test to trace air movement and measure the effectiveness of the different retrofit solutions.

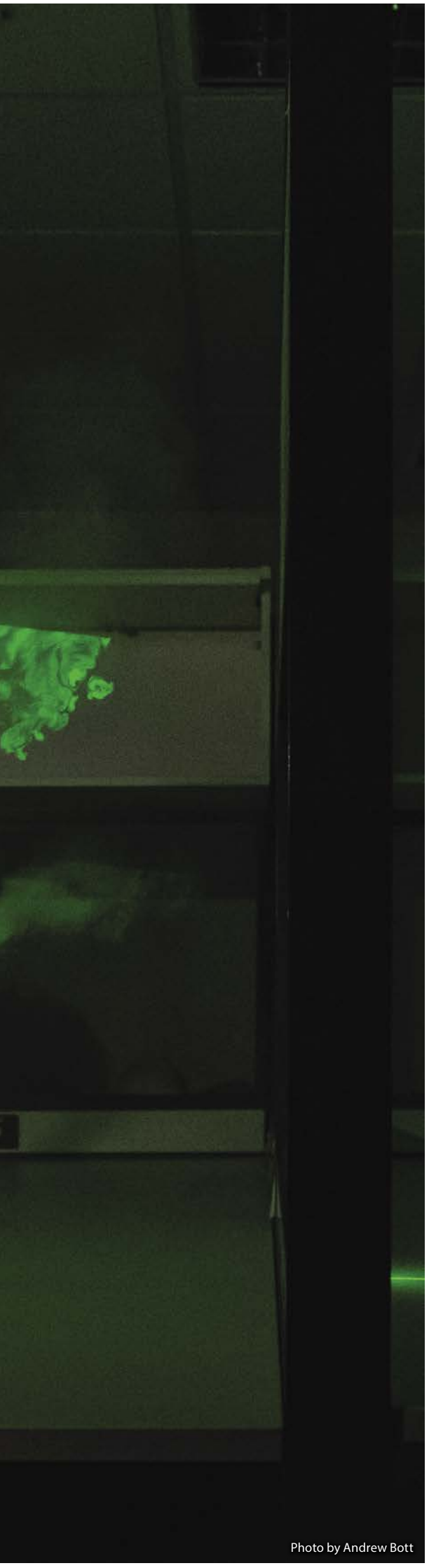


Photo by Andrew Bott

The City of Melbourne is facing a twofold challenge. The first is to achieve zero carbon emissions by 2040. The second is to help save small businesses by attracting up to 40,000 office workers back to the CBD following COVID-19 disruptions. At first glance, one seems incompatible with the other.

Data from the Property Council of Australia shows Melbourne's CBD occupancy rate dropped from 49 per cent to 38 per cent in July 2022. This was far lower than in all other capital cities, with Perth being the top performer at 71 per cent.

Understandably, retailers in Melbourne's CBD are desperate for more workers to return to offices to help boost trade. Melbourne Lord Mayor Sally Capp says unless the return-to-office rate improves, business owners are "running out of choices" with many "on their last legs, trying desperately to stay alive".

But how to convince workers that it's safe to go back into the water?

A BREATH OF FRESH AIR

Enter the Building Retrofit for Efficiency, Air Quality, Thermal Comfort and Health (BREATH) project – a research pilot project initiated by the City of Melbourne in collaboration with Cbus Property, the University of Melbourne, A.G. Coombs engineering, SEED engineering, Aurecon, Cundall, and Westaflex Australia. Designed to bring workers back to the city while reducing carbon emissions, the project has been lauded as an outstanding success by all involved.

"BREATH is a world-first collaboration between local government, industry and academics, and has given us the knowledge to predict the best type of retrofit to simultaneously reduce carbon footprint and infectious disease transmission," says Jason Monty, Professor of Fluid Mechanics and Head of Mechanical Engineering at the University of Melbourne.

"Since the majority of city energy cost goes to ventilation of our buildings, the outcomes from BREATH will improve our ability to reach net zero carbon faster."

That's good news for Melbourne's Deputy Lord Mayor Nicholas Reece. "Bringing people back to the [CBD] safely is a key priority for us," he says.

"This industry-leading research has identified simple but effective changes that can be implemented in office buildings to help workers feel safe, comfortable and protected … We encourage building owners, tenants and partners to take [these findings] on board, and to help us create more healthy and sustainable workspaces in the CBD."

PROJECT OBJECTIVES

The primary aim of the BREATH project was to test different air conditioning and ventilation rapid retrofit options that could be used to reduce the risk of aerosolised viral spread, particularly within a post-COVID return-to-offices context, while also considering the energy, cost and thermal comfort impacts of the proposed solutions.

"We worked closely with clients, industry and government during the pandemic to highlight the role that ventilation in buildings can play in mitigating the transmission of aerosol-borne diseases," says Andrew Nagarajah, Senior Engineer of Sustainability at building services and HVAC specialists A.G. Coombs.

"Our participation in the BREATH project is a natural extension of that. Post COVID it is essential that building owners, occupiers and HVAC designers and service providers have an enhanced understanding of air distribution in the built environment and how this can be better configured to significantly reduce aerosol spread of disease."

The project involved a group of industry experts in a community of practice to review and test assumptions and to discuss outcomes. This included sustainable engineering firm Cundall, with its track record of building retrofits and creation of high-performance buildings. Amin Azarmi, M.AIRAH, a Cundall associate, says the BREATH project aimed to establish data and evidence on how HVAC solutions could provide a healthier workplace in an energy-efficient manner.

Studies focused on improving the filtration of the air conditioning system, using installed equipment in an office space donated by Cbus specifically for the project.

"This office space enabled Melbourne University, Melbourne City Council and the HVAC industry experts to come together to develop and test energy-efficient solutions and ensure proposed retrofits to effectively reduce the virus transmission," Azarmi says.

The pilot test evaluated three different ventilation systems on the first floor of the vacant CBD building over three months. These were:

- Displacement ventilation air conditioning
- In-ceiling HEPA air filters
- Natural airflow through open windows.

A.G. Coombs was responsible for the design, installation and commissioning of the displacement ventilation air conditioning. The other retrofit design, the in-ceiling HEPA filtered air conditioning, was by Westaflex.

KEY TAKEAWAYS

When comparing each of the two retrofit solutions against the base-case scenario of openable windows operating in conjunction with the base-building's conventional mixed-air overhead air conditioning system, Andrew Nagarajah, Senior Engineer of Sustainability at A.G. Coombs says:

1. In-ceiling filtration was essentially the more cost-effective, practical retrofit solution. With an installation cost of approximately $28/m², it had comparable aerosol transmission reduction to the open-window scenario (in the order of a 50 per cent reduction in modelled aerosol spread) while using 10–20 per cent less energy than the open-window scenario.
2. The column-based displacement ventilation solution, at an installation cost of approximately $170/m², reduced aerosol spread by more than 80 per cent, while using 20–40 per cent less energy than the open-window scenario. The superior results of this retrofit solution need to be weighed carefully against its higher installation costs, retrofit practicality, and increased engineering design considerations, when compared to the relatively simpler in-ceiling filtration solution. ■

> It is possible to retrofit improvements to ventilation systems that will improve worker safety and indoor air quality while also ensuring energy efficiency

"Both retrofit solutions were compared against the baseline scenario of utilising openable windows in conjunction with the base building's conventional mixed-air overhead air conditioning system," A. G. Coombs' Nagarajah explains.

"Here, the openable windows were operated in accordance with ASHRAE recommendations as the 'conventional' solution (in the context of the project) to minimising aerosolised viral spread."

PROJECT FINDINGS

Cundall's Azarmi says all three options "demonstrated improvements for reducing airborne virus spread compared to business as usual".

"The key finding was that it is possible to retrofit improvements to ventilation systems that will improve worker safety and indoor air quality while also ensuring energy efficiency," he says. "The research also showed the assumption that opening windows would be a suitable solution counter-intuitively increases energy consumption by between 10 and 20 per cent, as the HVAC system needs to address resulting thermal comfort issues."

In summary, the project found:

- All three ventilation systems reduced the potential transmission of airborne viruses when compared to standard ceiling-based air conditioning, improving safety for office workers
- Displacement ventilation air conditioning – which supplies air from floor level – was the most effective and energy-efficient system tested, reducing COVID-19 transmission by 83 per cent, while also reducing energy consumption by 20 per cent
- Displacement ventilation is the most expensive to install, but there are no additional ongoing maintenance costs
- In-ceiling air filters reduced virus transmission by 49 per cent but resulted in a minor increase in energy consumption
- Opening windows reduced virus transmission by 53 per cent, but increased energy use by up to 20 per cent with seasonal temperature variations
- Opening windows is not available to all office buildings and is not always a viable solution due to Melbourne's climate.

Nagarajah says the project successfully demonstrated that "rapid retrofit ventilation solutions can create healthier office environments by minimising the recirculation of air and thereby reducing the potential for airborne virus transmission, while simultaneously reducing HVAC energy consumption against conventional increased ventilation strategies".

A critical part of the project was the peer review carried out by international engineering, management, design, planning, project management, consulting and advisory company Aurecon. Peter Mathieson, F.AIRAH, Aurecon Australasia's Technical Director of the Built Environment, says that Aurecon gave feedback on the research project assumptions and trial set-up including testing. Aurecon also reviewed the team's approach onsite, and the final report.

"Understanding the science of ventilation effectiveness and how air delivery and exhaust works to improve indoor air quality and minimise occupant exposure to airborne contaminants is a foundation of mechanical engineering design of air conditioning and ventilation systems," Mathieson says.

"Yet many [HVAC personnel] demonstrate only a passing understanding. So, research such as this in real built settings is important to affirm industry design guidance and knowledge. It is not surprising that the displacement air system provided better air quality outcomes as this is well established. Similarly, the fan filtration units that simply increased the clean air delivery rate to the test space is also a well-established approach to achieve improved indoor air quality.

"Aurecon has a history of delivering specific design solutions to manage indoor air contaminant for a range of Australian and international clients, including both of these principles in the design solution. BREATH is therefore a great affirmation of this previous work."

IMPROVING WORKING LIVES

Cundall's Azarmi says post-pandemic, tenants are looking for healthy spaces that reduce the opportunities for infection spread.

"They also want workplaces that increase collaboration between people and improve their social life in the office," he says. "This makes managing how air moves between people and within spaces critical.

"At the same time, the property market is prioritising spaces that have lower energy consumption as part of the broader net zero shift and ESG [environmental, social and governance] appetite. This is why the impact

PROJECT SNAPSHOT

A *baseline vacant operation* was used to determine the baseline power usage of the vacant space as well as the equivalent air change per hour (ACH) value of the space before retrofit modifications were made. The numerous days in the baseline conditions helped to determine a correlation between chiller power usage and average high temperature.

For all operations, 1,600W of heaters in buckets of water were distributed throughout the space (on chairs to simulate seated person height) to replicate the heat load modelled by A.G. Coombs with the displacement ventilation system (100W per person with 60W worth of laptop/monitor, set up for 10 people).

Specifically, the 1,600W of heat was generated through two 300W and five 200W aquarium heaters. These heaters were set to their maximum temperature, which they were not able to achieve with the volume of water they were submerged in. Hence, they were constantly outputting their rated maximum wattage.

OPEN-WINDOW OPERATION

This examined the impact of opening windows while leaving the HVAC running in its standard operating mode (19–21 per cent outdoor air and the remainder recycled indoor air). Only every other window on the east-facing wall was opened (resulting in eight 1.0m x 1.6m windows being opened), to both prevent cross-flow and minimise the chance for incoming wind to affect the measurements. While it was possible to open windows in this building, operable windows are not available for all high-rise offices.

IN-CEILING FILTERED OPERATION

The study used three fan-driven HEPA filter-equipped, locally made ceiling-mounted units to filter the air. The in-ceiling HEPA units are low power devices (measured at 60W), equivalent to the fan/filter power of portable HEPA filters but that allow for BMS integration, making them an industrial solution to the problem of increasing the ACH.

DISPLACEMENT VENTILATION OPERATION

A.G. Coombs used nine columns to retrofit slightly less than half the space for displacement ventilation. The floor was divided with floor-to-ceiling construction plastic. After some testing it was determined that the air exiting the displacement column needed to be 20°C, which is 2°C higher than the standard mixing operating temperature of 18°C.

AIR CHANGEOVER MEASUREMENTS

Ideally, the first period of measurements (where the building is not isolated) consisted of approximately four days of experimentation with three readings per day. Some deviations from this had to be taken. In these ideal conditions, the readings are taken in the nominal morning, midday, and close-of-business (understanding that these times are nominal and can shift depending on the day). During these readings the team was taking an ACH reading as well as temperature readings of the space.

The purpose of these three readings was to capture any changes in the space as the outside temperature changed. Because of the short duration of the experimental campaign, it was hoped to capture different weather conditions over the four days. The study therefore used meteorological measurements of temperature as the source of "true" outdoor conditions. However, the reality of the full-scale tests and the problems associated with both supply chain constraints and HVAC shutdowns following fire alarms meant that only the open-window and baseline measurements were taken sequentially over four days. The other conditions – displacement ventilation and in-ceiling HEPA – were taken as the space was available/possible. ■

of ventilation strategies on NABERS [National Australian Built Environment Rating System] ratings was one of the outputs of the research, because NABERS is the standard most potential investors, tenants or asset purchasers look to in making decisions about commercial space."

One of the important attributes of the BREATH project was the ability to visualise the air movement patterns in a space, says Aurecon's Mathieson.

"The challenge with understanding that infection is airborne is that it cannot be seen and so is forgotten or ignored," he says. "BREATH provided a visual appreciation of infection movement in a space and a comparison of the effectiveness of its removal, building on an important body of previous research work. This visualisation is a vehicle to improve our understanding of the science of successful space air delivery and exhaust systems. Funding of further research is an important opportunity for education of the HVAC industry," he says.

Azarmi says the project provides the necessary evidence that base contractors, consultants and HVAC professionals can use to improve the quality and performance of air conditioning and ventilation in cost-effective ways.

"By giving clear metrics on the relationship between equipment type, equipment configuration, energy requirements, indoor air quality and operational costs, technicians and consultants can present clients with stronger business cases for retrofits."

Nagarajah says HVAC&R technicians, engineers, consultants and contractors should be willing to question directives for conventional indoor air quality improvement solutions – such as simply increasing outside air rates, improving filtration arrestance or retrofitting air disinfection devices.

"They should also feel confident to cite research such as the BREATH project to landlords and facility managers," he says, "for their consideration of alternative air distribution solutions that could also reduce operational energy consumption.".

RESOLVING REAL-LIFE ISSUES

Cundall partner and Australian Managing Director Garrit Schot says the results of this project demonstrate how integrated approaches hold enormous value in ensuring we achieve optimum air quality from both a thermal and a health perspective, while also delivering on energy efficiency.

"It shows how cross-sector partnerships can advance practices," he says.

Azarmi also highlights the spirit of the BREATH community of practice.

"The manner in which Melbourne University, Melbourne City Council and HVAC industry experts collaborated to share knowledge and experience has been inspiring," he says. "Unlocking the most energy-efficient retrofit methods for mechanical services upgrades to increase workplace indoor air quality and indoor air safety is contributing to high-performance buildings.

"Using a smoke-laser test to trace air movement and prove the effectiveness of the retrofit solutions was one of the fascinating testing methods. I am looking forward to seeing ongoing collaboration between the university and industry experts to resolve real-life issues in the built environment."

BREATH PROJECT KEY OUTCOMES

System	Impact on transmission	Installation cost per m^2	Energy use - cost per m^2	Changes to energy use and NABERS
Opening windows, standard heating, ventilation and air conditioning operations	Approximately 53 per cent less infections	Nil	Costs $6/$m^2$ per year	10–20 per cent increase in energy use, loss of up to ½ NABERS star
In-ceiling air cleaner, HEPA filtration units	Approximately 49 per cent less infections	$28/$m^2$ with maintenance costs of $1.5–3/$m^2$ per year	Saves $4.21/$m^2$ per year	2 per cent increase in energy use, no impact on NABERS
Displacement ventilation air conditioning	Approximately 83 per cent less infections	$170/$m^2$ with no additional ongoing maintenance costs	Saves $10.67/$m^2$ per year	10–20 per cent reduction in energy use, addition of up to ½ NABERS star

* NABERS is a simple, reliable sustainability rating for the built environment, which measures buildings' efficiency across energy, water, waste and the indoor environment. NABERS provides a rating from one (making a start) to six (market leading) stars.

Retrofitting displacement ventilation proved to be the most effective – and energy efficient – way of reducing the spread of aerosols.