MODERN GREEN HOMES

Sanctuary

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EXPERTS EXPLORE:

Andy Marlow on indoor air quality in increasingly airtight homes

WORDS Andy Marlow

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My family's Sydney terrace house has been extensively draught-proofed, but is still fairly leaky with an airtightness rating of 10 air changes per hour (ACH50). Despite this, air quality monitoring shows carbon dioxide levels higher than ideal for healthy living, so I decided to experiment to improve the situation.

Airtightness is great for energy efficiency and thermal comfort, and cross ventilation is terrific for fresh air when you're happy to have your windows open – but what can you do to ensure a healthy indoor environment all the time? Architect Andy Marlow explains the experimenting he's done at his place.

In recent years, as part of the movement to improve energy efficiency, there has been an increasing push to make Australian homes more airtight. Reducing the leakiness of our homes allows for greater control of our indoor environment, whether that be holding on to daytime solar gains into the evening in a cool climate winter or trapping the air-conditioned 'coolth' in a summer heatwave.

While increasing airtightness can certainly be good for energy efficiency, especially when paired with insulation and effective solar control, it brings some increased risks, condensation being the most commonly cited one. As air leakage is reduced, the humidity levels inside a home increase due to a lack of balancing with the (generally) less humid outdoor air. If that warm, moist air can find a cool surface, such as single-glazed windows or standard aluminium window frames, condensation will form. Mould growth is also a very real possibility if indoor humidity is high for a prolonged period of time. Sustained levels above 80 per cent relative humidity are of concern, although lower humidity levels can still cause issues.

Condensation and mould risk are now identified in the National Construction Code as issues required to be addressed and, in competent hands, are easily mitigated. However, these are not the only factors affecting the health of our indoor environments.

INDOOR AIR QUALITY

Good indoor air quality matters, as it is the air we breathe for a very large proportion of our lives, and ensuring it is fresh and free of pollutants is critical for our health. The 2019-2020 bushfires demonstrated the repercussions of leaky homes, with unhealthy levels of indoor pollution in many areas even well away from the fire fronts. While airtight homes still required effective filtration, they fared much better than their more tent-like counterparts and could often be adapted easily with additional filters to mechanical ventilation systems to mitigate the health risks [*Ed note:* see 'Where there's smoke: Protecting yourself from air pollution at home' in *Sanctuary 51* for more on this]. Even when conditions are not so extreme, it can be surprising how often indoor air quality is less than ideal in the average home.

Monitoring indoor air quality

The level of carbon dioxide present is an important metric for indoor air quality. Peer-reviewed journal articles suggest that up to 1,500 parts per million (ppm) of carbon dioxide can be acceptable but beyond that, cognitive functions, such as learning in children, begin to decline. Higher carbon dioxide levels can also affect our sleeping patterns as there is less oxygen available to our bodies. That 'stuffy' feeling of my childhood winters turns out to have been likely due to poor indoor air quality.

Good quality sensors that reliably measure temperature, humidity and carbon dioxide are now available and affordable. Benchmarks of 18 degrees Celsius minimum temperature, a maximum of 70 per cent relative humidity and 1,000ppm of carbon dioxide will deliver a healthy and comfortable home.

There are many other factors affecting indoor air quality. For example, volatile organic compounds (VOCs) or 'off-gassing' from paints, furniture and a multitude of household items can be significant, as can any unflued gas appliances. These can be complex to measure, so an approach of reducing or eliminating their use is a good start, combined with using good ventilation to remove the toxins from the home as swiftly as possible.

WINDOWS, NOT A FAN?

When writing as far back as 1894 about ventilating buildings, English medical professor Ernest Jacob wrote "the architect usually thinks this object has been attained if some of the windows can be opened … We may as well attempt to supply a house with water by making a trap door in the roof to admit the rain" (Ernest H. Jacob, 'Notes on the ventilation and warming of houses, churches, schools, and other buildings', 1894).

Most Australian homes do rely on ventilation from open windows to provide outdoor air. Generally, this functions as free cooling in summer, while also providing fresh air that lowers carbon dioxide levels and removes those other pollutants. This strategy is core to passive solar design and serves many homes well for a portion of the year; it will always have benefits. However, as Ernest implies, this aspect of passive design relies on active users and clement weather: in the depths of winter or the heat of summer, it's not very attractive to open your windows enough to keep the indoor air truly fresh.

So, if opening windows is not enough on its own, how can we ensure good indoor air quality without the hit to energy efficiency and comfort?

RELIABLE VENTILATION

Mechanical ventilation with heat recovery (MVHR) systems offer a neat solution. They provide filtered outdoor air, pre-warmed in winter and pre-cooled in summer using heat transfer with the outgoing air, without the two air streams mixing. (As allergy sufferers know, and as very many of us experienced during the bushfires, the outdoor air is not always as fresh as we wish; filtration can be a necessary thing.)

A good MVHR unit can be over 90 per cent efficient for heat recovery, which delivers a considerable energy saving compared to an open window for ventilation paired with a space heating or cooling device. Centralised systems have one unit that feeds small-diameter ducts to each room, pulling moist air from bathrooms, kitchen and laundry while delivering fresh, tempered air to living rooms and bedrooms. These can be tricky to retrofit into existing homes; decentralised units installed in external walls and that operate individually or as pairs can be a good alternative.

It is often said that MVHR is needed for homes with an airtightness rating of below 3-7 ACH50, although these numbers are hotly debated and focused on moisture management more than air quality. So, as architects do, I have been experimenting on my family to test some of those 'rules of thumb' and find a way to retrofit better air quality at our place.

MEASURING AIRTIGHTNESS

Airtightness is measured using a blower door test. During the test, a fan pressurises and then de-pressurises the building, measuring the air flow at 50 pascals of difference in air pressure. This measured flow is then compared to the volume of the home and reported back as a figure for the number of 'air changes per hour' at 50 pascals that can be expected for the house: ACH50. The lower the number, the more airtight the house. A 2015 CSIRO study identified the average airtightness of new Australian homes (sample size 129) to be 15.4 ACH50. In comparison, the Passive House standard requires no more than 0.6 ACH50, a 25-fold improvement.

CASE STUDY: FRESH AIR WITHOUT FREEZING

We live in a 100-year-old terrace house in Sydney, which has had various draught sealing measures implemented and currently has an airtightness of 10 ACH50.

In an effort to improve the indoor air quality, we have installed a Lunos decentralised MVHR system: a pair of fans located in separate rooms, working in tandem and alternating between pushing and pulling air through them at around 70-second intervals. This provides fresh, filtered air to bedroom 1 and the living room (see floor plan on p.78) with minimal loss of heat. Undercuts to the internal doors allow for some airflow through the house even when the doors are closed. We have also installed monitoring devices for temperature, humidity, carbon dioxide and particulate matter in bedrooms 1 and 3 and the living room.

These MVHR units bring in 38 cubic metres per hour (m^3/h) of outdoor air. By comparison, the Passive House standard requires $30m^3/h$ per person. We are a household of three, so these units were always going to be imperfect, but a lack of conveniently located external walls was a limiting factor. (*Note:* there are now various decentralised MVHR options that deliver $60m^3/h$.)

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Our decentralised MVHR system consists of two of these fans installed in external walls. They alternate between pulling external air in and pushing stale internal air out, and contain a heat exchange unit (ceramic core) to maximise thermal efficiency. Image: Lunos

The data in Figure 1 show that even with two adults sleeping in bedroom 1 with closed windows, the fans can deliver enough fresh air to keep carbon dioxide levels within acceptable limits. In contrast, bedroom 3 has carbon dioxide levels well above what is desirable, peaking above 1,500ppm every night and getting close to 2,500ppm at times.

How to tackle this problem? Leaving internal doors open overnight does help in reducing carbon dioxide levels in certain rooms by better balancing with other spaces, although we find this impractical with a small child. It is no surprise that with the windows open in bedroom 3 the carbon dioxide levels are very similar to those outside. However, even in Sydney's mild climate, average night-time temperatures are below 18 degrees Celsius for eight months of the year, too cold for an optimum sleeping environment for the daughter of this relatively recent and protective father!

Installing an additional decentralised MVHR was an option to improve her situation, but keen to experiment, instead we chose an 'air transfer system'. A small 18-watt fan pulls air from the living room into bedroom 3 via insulated ductwork in the roof space. It runs on a schedule of 10 minutes every half hour during my daughter's sleeping hours, and does a great job of keeping the carbon dioxide level within my target range of under 1,000ppm.

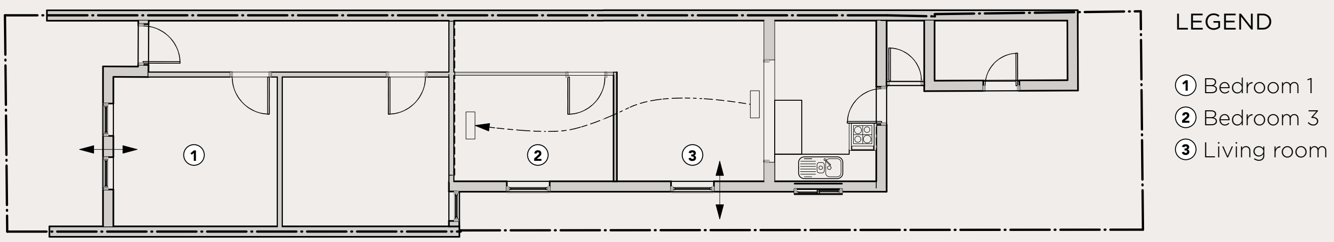
The data clearly show the carbon dioxide level rising and falling as the fan switches on and off overnight, demonstrating the air transfer system's effectiveness. You can also identify the peaks from the midday nap when the fan is not set to run.

Our house is only a little better than the average new Australian home for airtightness: still quite leaky. Despite this, the carbon dioxide level inside can be significantly higher than is considered 'good'. Our undersized MVHR systems do a good job in the rooms where they are installed, and the addition of improved internal air distribution (via the air transfer system) is sufficient to keep other rooms within a comfortable range for carbon dioxide. The air is noticeably fresher; we can detect a difference in air quality, manifesting as a smell, if the fans are turned down for half a day or more. And from a quality-of-life perspective the system is a win too: my partner particularly enjoys the closed bedroom windows on Friday and Saturday nights when the passing foot traffic and boisterous conversations can be loud.

TAKEAWAYS

While it is possible to achieve good indoor air quality with operable windows only, it does require active users willing to open windows regularly regardless of outdoor conditions. In many parts of Australia this is not practical, desirable or healthy during the winter months, especially at night; the data above imply fresh air is required once every 30 to 60 minutes to maintain carbon dioxide levels below 1,000ppm.

At a societal level, the benchmark for design needs to cater to the whole population. I believe there is a compelling argument that reliable ventilation should be mandated to ensure air quality that provides an acceptable minimum level



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I installed a decentralised MVHR system consisting of a pair of fans in bedroom 1 and the living room, supplemented later by an air transfer system using insulated ducting and a small fan between the living room and bedroom 3 where my young daughter sleeps.

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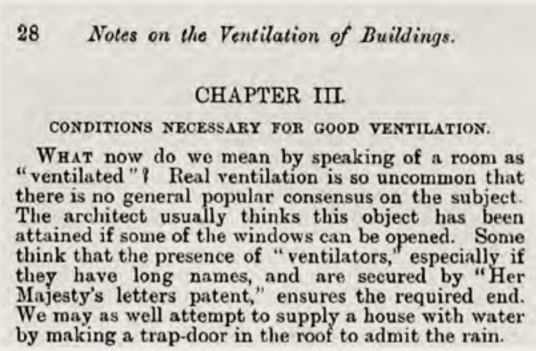
In his 1894 treatise 'Notes on the ventilation and warming of houses, churches, schools, and other buildings', English professor of pathology Ernest Jacob posited that the presence of openable windows wasn't sufficient to ensure good ventilation in buildings.



28 *Notes on the Ventilation of Buildings.*

CHAPTER III.

CONDITIONS NECESSARY FOR GOOD VENTILATION.

WHAT now do we mean by speaking of a room as "ventilated"? Real ventilation is so uncommon that there is no general popular consensus on the subject. The architect usually thinks this object has been attained if some of the windows can be opened. Some think that the presence of "ventilators," especially if they have long names, and are secured by "Her Majesty's letters patent," ensures the required end. We may as well attempt to supply a house with water by making a trap-door in the roof to admit the rain.

of health and comfort for all occupants regardless of their behaviour.

Our experience suggests that even at an airtightness of 10 ACH50 some mechanical ventilation is needed for a healthy home. Various fan systems could be used to deliver this fresh air but, without heat recovery, they would need to be paired (at the regulation level) with a heating system if the World Health Organisation's recommendation of minimum indoor air temperatures of 18 degrees Celsius are to be met.

Our research and data show that small decentralised MVHR systems and additional fans can adequately ventilate a small house for a capital cost of less than $2,000. In the context of the cost of a new home or renovation, this is a drop in the ocean: only a quarter of a granite benchtop! If we as a nation are to continue to invest so much in housing then should we not, as a bare minimum, ensure these buildings are healthy and comfortable as well as efficient? What price for health? S

Andy Marlow is an architect, certified Passive House Designer and director at Envirotecture. He believes passionately in healthy, efficient buildings for people and planet. www.envirotecture.com.au

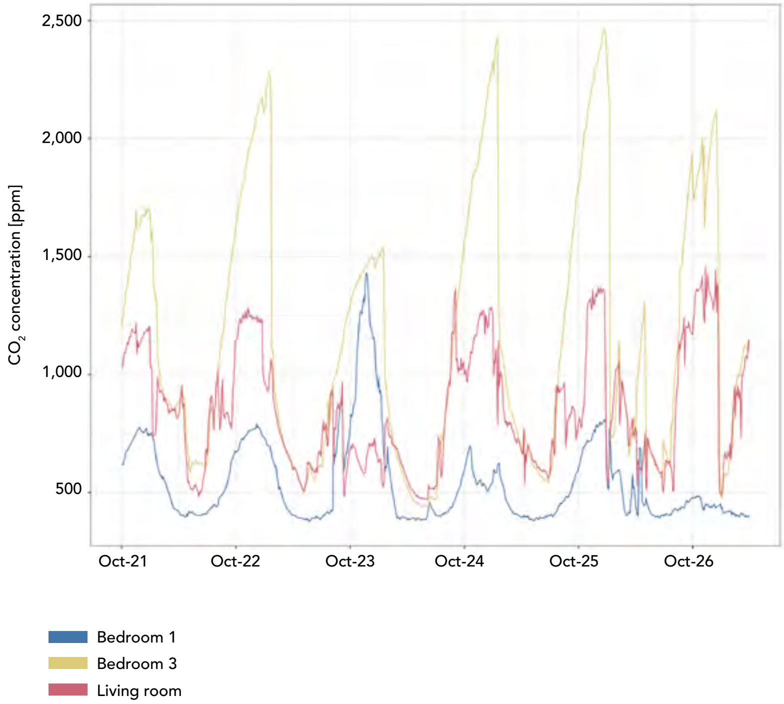


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Figure 1: Carbon dioxide levels over one week with the decentralised MVHR system running, measured in bedroom 1 (main bedroom), bedroom 3 (my daughter's room) and the living room.

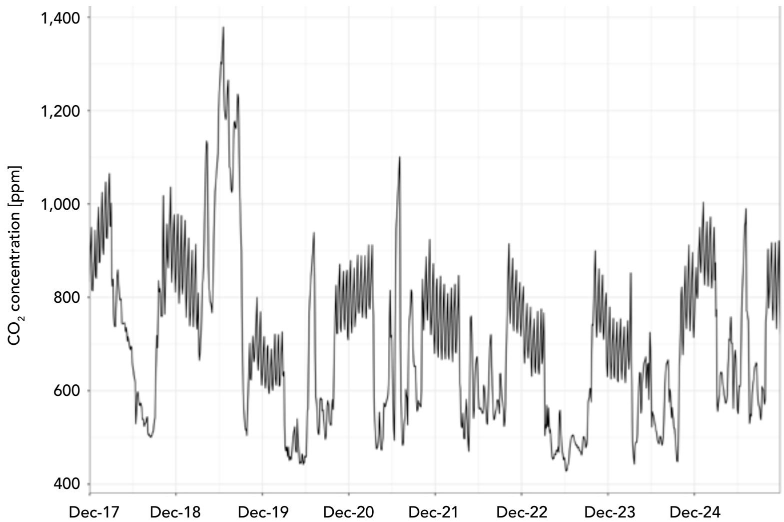

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Figure 2: Bedroom 3 carbon dioxide levels over one week, with the air transfer system operating.