

Clean Air Spaces Prototype Guidance Project

A technical review of ASHRAE Guideline 44
Protecting Building Occupants from Smoke During
Wildfire and Prescribed Burn Events

Provided by AIRAH for the Air Policy Team, NSW Department of
Climate Change, Energy, the Environment and Water

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Title	A technical review of ASHRAE Guideline 44 – Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events	
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Created by	AIRAH	
Primary author	Brad Prezant, Prezant Environmental	
Primary reviewer	Dr Amanda Wheeler, CSIRO	
Additional reviewers	<ul style="list-style-type: none"> • Dr Claire Bird, LITMAS, Associate Director of AIRAH IAQ STG • Derek Shearer, A.G. Coombs, Chair of AIRAH IAQ STG • Daniel McCaffrey, AFPRO Filters Australia • Dr Dino Pisaniello, University of Adelaide 	
Additional contributors	<ul style="list-style-type: none"> • Abdel Darwich, Guttman & Blaevoet Consulting Engineers • Steven Emmerich, National Institute of Standards and Technology 	
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Introduction

In December 2024, ASHRAE (the American Society of Heating, Refrigerating, and Air Conditioning Engineers) published Guideline 44, Protecting Building Occupants From Smoke During Wildfire and Burn Events. The purpose of this document is to determine the applicability and feasibility of applying this Guideline to buildings in New South Wales.

There are differences between Australia and the countries covered by ASHRAE in terms of building design and codes, building operations, public policy, and guidance during periods of poor air quality resulting from wildfires. This document responds to several questions raised by NSW DCCEEW on the potential application of the ASHRAE Guideline 44 to the Australian setting. This document is a gap analysis designed to support discussions around future actions to reduce the negative impacts on health from bushfire smoke emissions. It is intended to address bushfire smoke exposures in public, commercial, hospital/health care, multifamily residential, and other indoor non-residential occupancies.

As devastating as a bushfire can be to the persons and communities in the immediate vicinity of the fire, the smoke from such an event can travel many hundreds of kilometres downwind and impact an even larger population, particularly when it impacts a large metropolitan area. Smoke from such an event can persist for days, weeks, and occasionally months, and is known to have a significant negative impact on both acute health outcomes and more generally on public health.

Increasing use of prescribed burns for the management of fuel loads has the potential to reduce catastrophic bushfires and the associated economic damage. However, careful planning is needed to ensure that these do not result in more extended, more clustered, or socially inequitable exposures to bushfire smoke, due to the unpredictability of smoke movements, or possibly due to compelling reasons to increase the frequency of such burns.

In this document, the term 'landscape fire smoke' will be utilised to cover resulting smoke from both bushfires and prescribed burns.

Landscape fire smoke emissions are extremely complex chemically and physically due to the uncontrolled nature of the combustion process. In addition to solid particulate matter (PM_{2.5}) consisting of burned, partially burned, and unburned plant material, bushfire smoke contains gases and vapours, including semi-volatile compounds. There is an extensive body of evidence that outdoor air pollutants infiltrate building envelopes as well as enter buildings via heating and ventilation systems. Unlike large grains of pollen, the small particles of landscape fire smoke can penetrate building envelopes and infiltrate indoors at moderate to high efficiency, depending on building envelope tightness.

Measured indoor levels generally exceed 50% of outdoor levels and can be much greater for certain building types. In Australia, estimates of protection from PM_{2.5} in Victoria during smoke plume events (not limited to bushfires) indicated highly variable reductions of peak PM_{2.5} with windows closed, from 29% to 76%.¹ With proper planning and attention to specific interventions, these indoor exposures can be significantly reduced, with health benefits exceeding their costs.

Potential hazards can extend beyond the immediate impact of visible smoke. Landscape fire smoke pollutants can deposit on indoor surfaces and transition between solid and vapour phase, causing ongoing exposure that extends beyond the initial incident.² Deposited indoor particulate matter has also been shown to re-suspend.³ When anthropogenic structures also burn, additional contaminants may be present in landscape fire smoke, changing its toxicology.

It is estimated that one-third of Australians have a health condition that puts them at elevated risk of developing smoke-associated illness during extreme events.⁴ While the full toxicology of inhalation of landscape fire smoke is not well understood, it is believed that there is no threshold of harm for PM_{2.5}.⁵ Future research will likely identify further health effects from landscape fire smoke than those currently understood, increasing the importance of implementing population-wide measures for reducing exposures to landscape fire smoke, as discussed in this document.

As a result of the extended duration of landscape fire smoke impacts on outdoor and indoor air quality, human exposures can be significant and continuous over a full 24-hour periods. Since exposure is a function of both concentration and time, this extended uninterrupted period can result in a highly elevated dose. The toxicology of this exposure pattern is not yet fully elucidated; what is obvious, however, is that there is no recovery time for the body's detoxification mechanisms during this extended period. This exposure is particularly problematic for the health of priority populations due to their age and/or, their existing health status.

¹ Fabienne Reisen, Jennifer C. Powell, Martine Dennekamp, Fay H. Johnston & Amanda J. Wheeler (2019) Is remaining indoors an effective way of reducing exposure to fine particulate matter during biomass burning events?, *Journal of the Air & Waste Management Association*, 69:5, 611-622, DOI: 10.1080/10962247.2019.1567623

² The persistence of smoke VOCs indoors: Partitioning, surface cleaning, and air cleaning in a smoke-contaminated house. *Sci. Adv.* **9**, eadh8263(2023). DOI: [10.1126/sciadv.adh8263](https://doi.org/10.1126/sciadv.adh8263)
DOI: [10.1126/sciadv.adh8263](https://doi.org/10.1126/sciadv.adh8263) DOI: [10.1126/sciadv.adh8263](https://doi.org/10.1126/sciadv.adh8263)

³ Silberstein, J.M., Mael, L.E., Frischmon, C.R. *et al.* Residual impacts of a wildland urban interface fire on urban particulate matter and dust: a study from the Marshall Fire. *Air Qual Atmos Health* **16**, 1839–1850 (2023). <https://doi.org/10.1007/s11869-023-01376-3>

⁴ Johnston, F.H. Understanding and managing the health impacts of poor air quality from landscape fires. *Med. J. Aust.* **2017**, 207, 229–230.

⁵ Yu W, Xu R, Ye T, Abramson MJ, Morawska L, Jalaludin B, et al. Estimates of global mortality burden associated with short-term exposure to fine particulate matter (PM_{2.5}). *Lancet Planet Health* 2024;8(3):e146–55.

On average, we spend 90% of our time indoors, perhaps more during bushfire events when outdoor air is unhealthy. We are estimated to spend 69% at home, 13% in public buildings and restaurants, and 5% in workplaces.⁶

Because public buildings and workplaces can be used both formally and informally for temporary refuge centres from smoke during landscape fire events, the percentage of time spent in these buildings can be substantially greater than the aggregate time (18% = 13%+ 5%) estimated during “normal” periods. The balance between home and public buildings might be dramatically shifted as a result, increasing the time spent in a public building implementing ASHRAE Guideline 44 recommendations, while reducing the time from the estimated 69% spent at home. This can reduce aggregate exposures and positively impact public health.

Reducing exposure levels in those buildings where people seek refuge (public buildings and workplaces) is therefore good common sense as well as prudent public health practice. Taking the opportunity to reduce overall dose by lowering exposure levels in these non-residential buildings can therefore offer a significant contribution to lowering the overall burden of disease. Such a reduction is possible by providing primary protection to those unable to improve their residential exposures, by providing both primary and supplemental protection to priority populations, and by providing supplemental protection to the general population.

The questions raised by NSW DCCEEW on the potential application of the ASHRAE Guideline 44 to the Australian setting are addressed below.

⁶ KLEPEIS, N., NELSON, W., OTT, W. *et al.* The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *J Expo Sci Environ Epidemiol* **11**, 231–252 (2001). <https://doi.org/10.1038/sj.jea.7500165>

Would ASHRAE 44 be fit for purpose for NSW and/or what would be needed to help adapt and improve this guidance for NSW situations? Would this framework be appropriate or would an alternate framework be needed? What would that alternate framework look like?

ASHRAE Guideline 44-2024 Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events – Overall Framework and Suitability for NSW.

Background and purpose

This ASHRAE guideline was developed following specified protocols by a purpose-formed committee composed of technically qualified individuals in the subject area, including both members and non-members of ASHRAE. Unlike ASHRAE standards, ASHRAE Guidelines do not require consensus, and are not submitted to ANSI (American National Standards Institute) for approval. ASHRAE Standards are often intended to be adopted by ANSI and are written in a form that can be adopted into building codes or other applicable codes or regulations. This Guideline is not presented in this form; however, the Guideline could be adopted in its present form for other uses.

The Guideline also has two informative (non-mandatory) appendices that would not necessarily require conformance to state compliance with the Guideline as published. Informative Appendix A does not include any details for the design of the Smoke Readiness Plan, a key element of the document. Appendix B, Managing Air-Side Economizer and Demand-Control Ventilation for Smoke would be relevant for more sophisticated HVAC systems. The Guideline is scheduled to be updated on a five-year cycle.

The Guideline is explicit that its purpose is to minimise occupant health impacts from both wildfires and prescribed burn smoke events, with an expectation that these events can be prolonged in nature. It is intended to apply to commercial buildings and institutional buildings, including health care facilities and multifamily residential buildings. It addresses buildings expected to be occupied by vulnerable at-risk populations, including children and older adults, though no mention of vulnerabilities is explicit beyond these characterisations. It chooses to focus exclusively on PM_{2.5} as the best indicator of air quality and its known impact on potential health effects.

The health-focused purpose, building applicability, and focus on PM_{2.5} as the best indicator of air quality and its impact on potential health effects are consistent with the Clean Air Spaces Prototype Guidance Project and are considered suitable for utilising the guideline in NSW. While the Guideline does not address dust storms, which likely will result in a different particulate size

distribution, mitigation measures for landscape fire particulate would also protect against the larger particulate characteristics of dust storms.

Key aspects

ASHRAE Guideline 44-2024 suggests that PM_{2.5} be managed based on “as low as reasonably practicable” (ALARP). **This focus is appropriate for NSW.**

ASHRAE Guideline 44-2024 recommends targeting 20% of the outdoor concentration in selecting an indoor design concentration. **This focus is appropriate for NSW, and consistent with what can be achieved in NSW through interventions.**

ASHRAE Guideline 44-2024 recommends that consideration be given to creating a balance between the health risks of overheating, thermal safety, and infectious aerosol exposure, weighed against the health risks of PM_{2.5} exposure, with design engineers and building operators addressing multiple and overlapping health risks. Similar risks of thermal safety and overheating exist in NSW, such that the requirement to address multiple and overlapping health risks is appropriate for the Clean Air Spaces Prototype Guidance Project in NSW. **This focus is appropriate for NSW.**

Within the ASHRAE Guideline 44-2024, Section 5, Design and Commissioning, and Section 6, Operation During a Wildfire Fire Event, are the heart of the document. Section 5 envisions what building design elements to reduce smoke impact are present or could be implemented, whereas Section 6 utilises a Smoke Readiness Plan (SRP) that describes which control measures will be used and how they will be initiated. **This framework is logical, achievable, and applicable to NSW.**

Section 5, Design and Commissioning, applies to initial design of a building, or as retrofit on existing buildings. While some of the recommendations can be integrated during initial design, **implementing them as a retrofit would require significant modifications.** The guidance for new design, both for building envelope tightening, including egress and entry points, and for ventilation system capability, are consistent with architectural practice. **As such, these new design recommendations could be implemented in NSW.**

Section 5 may require some “engineering” input to calculate the design impact of various interventions on the indoor PM_{2.5} concentration.

Section 6, Operation During a Wildfire Fire Event, “provides a general framework and best practices for creating a Smoke Readiness Plan.” A Smoke Readiness Plan (SRP) is a written document, specific to the building. It is unlikely that an SRP written for one building would be applicable to another building, unless they were constructed from very similar plans and equipment. The custom-developed SRP would include the occupancy type, HVAC system,

building envelope, types of doors and windows, and patterns of use. **Development of a building-specific SRP is appropriate for NSW.**

The SRP is intended to be turned “on”, generally because of elevated PM_{2.5} readings from air quality monitors, or potentially as a result of notifications from health departments or other cognisant health authorities, or simply because the building owner or operator makes that choice. The concept of a ventilation guideline that is utilised only during certain periods was introduced by ASHRAE with Standard 241-2023, Control of Infectious Aerosols, and termed Infection Risk Management Mode (IRMM) in that Standard. Because there are equipment, economic, health, and maintenance trade-offs involved in operating in SRP mode, the concept that health authorities can recommend or require an SRP to be utilised, or that a building owner/operator can choose to operate in that mode, addresses these trade-offs. **Utilising a non-permanent approach is appropriate for the Clean Air Spaces Prototype Guidance Project in NSW.**

Elements of the SRP include preseason preparation, activation during smoke episodes, evaluation, deactivation once the smoke has cleared, and periodic assessment of the need for updates. The SRP assumes that HVAC systems are well maintained and working as designed. For new buildings, the Guideline recommends commissioning to confirm operational parameters in the SRP, including demonstrating HVAC control sequences and filter effectiveness, and building envelope commissioning. Table 4 in the Guideline includes elements to consider in the SRP; Table 7 includes a decision matrix for implementation of an SRP and a checklist for placing a building in a smoke-ready mode. **This general outline and specific guidance is appropriate for the Clean Air Spaces Prototype Guidance Project in NSW.**

The technical expertise to implement Section 5 and Section 6 exist among architectural and ventilation engineering consultancies within NSW. **The guidance is appropriate for use in NSW.**

Practicality

For a building engineer in a large building, implementing ASHRAE Guideline 44-2024 is not a trivial undertaking. Simply confirming that an HVAC system is working as designed, a prerequisite of ASHRAE Guideline 44-2024, can be a major undertaking. Designing and programming the Building Management System (BMS) to perform as intended when the SRP is invoked, and verifying operation under the SRP, is also a major undertaking. With the documentation and administrative requirements specified, implementing all the requirements of ASHRAE Guideline 44-2024 could require significant time and expense. In the introduction to Section 6, Operation During a Wildland Fire Event, the Guideline notes, “It is important to realise that this planning and testing process will take considerable time and effort.”

These financial, effort and time commitments could influence whether the Guideline would be voluntary or mandatory in NSW. However, individual elements of the Guideline can be implemented with partial benefits. For example, a study of a public library in Port Macquarie during a local peat fire and nearby bushfires noted that the single intervention of taking shelter indoors in the library resulted in a 70% reduction from outdoor PM_{2.5} in the building. There were additional reductions of up to 83% in a room within the library where the portable air cleaners were installed. These reductions were achieved without the application of the additional interventions set out in ASHRAE Guideline 44-2024.⁷

Studies have indicated that several intervention measures including particle filtration in homes in Southern California during a 10-day bushfire smoke exposure can be cost effective, particularly for the elderly, under specified conditions.⁸ No studies addressing the cost-effectiveness of intervention measures in public buildings were identified.

In conclusion, the overall framework (including the health-based purpose and necessity of recognising overlapping health issues), the inclusion of vulnerable populations, the technical approach (including the necessity of developing a building-specific plan), the ability to turn interventions on and off as needed, and the applicability to dust storms, are consistent with the Clean Air Spaces Prototype Guidance Project, meaning that the Guideline is suitable for use in NSW. The detailed requirements of implementing a SRP in accordance with the Guideline would require significant resources, both financial and effort, by building owners, particularly the documentation and necessary planning.

⁷ Wheeler, A.J.; Allen, R.W.; Lawrence, K.; Roulston, C.T.; Powell, J.; Williamson, G.J.; Jones, P.J.; Reisen, F.; Morgan, G.G.; Johnston, F.H. Can Public Spaces Effectively Be Used as Cleaner Indoor Air Shelters during Extreme Smoke Events? *Int. J. Environ. Res. Public Health* **2021**, *18*, 4085. <https://doi.org/10.3390/ijerph18084085>

⁸ Fisk WJ, Chan WR. Health benefits and costs of filtration interventions that reduce indoor exposure to PM_{2.5} during wildfires. *Indoor Air*. 2017 Jan;27(1):191-204. doi: 10.1111/ina.12285. Epub 2016 Mar 2. PMID: 26843218.

ASHRAE 44 applies to commercial buildings, institutional buildings (including healthcare facilities), and multiunit residential buildings, and dedicated spaces within these buildings for temporary occupancy during bushfires or prescribed burn smoke events. Would these standards and requirements be applicable to similar NSW buildings and other NSW building types, e.g. community and town halls and low-rise residential buildings?

It can be noted that in Section 4.11 Need for This Guideline, ASHRAE Guideline 44 states that “every building is different, but the principles of smoke infiltration are the same across all buildings.” The paragraph goes on to state that smoke can be prevented from entering buildings, and it can be removed if it does enter. These guiding principles would apply equally to NSW as they do to the U.S.

Examples of buildings in NSW that could be used as community cleaner air spaces (CCASs) include libraries, shopping centres, sports facilities, schools and community halls.⁹ None of these buildings were designed or constructed with the aim of protecting human health during poor air quality episodes.

There are two factors that would most influence bushfire smoke infiltration: building envelope design and mechanical ventilation system design. Addressing the impact of these factors is a major focus of ASHRAE Guideline 44. These designs potentially vary between countries and climates, by building height and complexity, and along a rural/urban interface. Additionally, changes to building codes and practices influence construction techniques - older buildings are constructed differently from new buildings.

Building envelope considerations

Preventing smoke from entering is preferable to removing it once it has entered. ASHRAE Guideline 44 discusses the importance of building envelope commissioning, as envelope design plays a key role in determining the potential and magnitude of smoke infiltration. Tightening the building envelope is addressed in detail in Section 5.5.3 Envelope Tightening, and Section 5.6.2

⁹ Campbell SL, Wormworth J, Green D, Goodman N, Vardoulakis S, Johnston FH, Wheeler AJ. Community cleaner air spaces during landscape fire events: What do we know? Aust N Z J Public Health. 2025 Feb;49(1):100222. doi: 10.1016/j.anzjph.2025.100222. Epub 2025 Feb 12. PMID: 39947093.

Envelope Commissioning. The latter section would apply to new buildings and references various ASTM standards for determining air leakage rates and tightening the air barrier.

One major driver of choice of building envelope materials and construction technique is climate. The climate of much of NSW resembles that in the southeastern U.S. or Hawaii. Higher land elevations within NSW such as the Snowy Mountains or cities such as Oberon or Jindabyne may be climatically like more northerly or higher elevation portions of the U.S. There is no climate zone in NSW that does not have a corresponding climate zone in the U.S., which aids in the application of the Guideline to NSW.

Building tightness is also related to its age. Older buildings are leaky, by both design and construction. When energy costs were lower, and climate change was not a consideration, little attention was paid to tightening buildings. Changes in building code requirements and building practice have resulted in more airtight building envelope construction in newer buildings. Efforts to tighten the building envelope for older buildings will likely be more difficult and may not be realistically achievable. This is a consideration in NSW, as many public buildings are historic.

This is particularly the case in rural areas and small regional cities, and particularly for public heritage buildings. Certain construction techniques impacting envelope performance and particulate matter infiltration may differ for example, double brick buildings with venting from the brick cavity to the interior is a construction technique utilised in NSW but not in the U.S. Many historical public buildings in NSW that could be used as CCASs would fall into this category.

Contemporary urban envelope design of large multi-storey buildings, as well as large shopping centres, may be quite similar from one country to another. Thus, the Guideline would be applicable to these building types.

For single-family residential and small multifamily residential, leakiness may be related not to age but to architectural design, with simple boxy buildings or buildings constructed of masonry typically less leaky than more complex designs. It may not be that poorer communities have leakier buildings, as other considerations may dominate. Research within Australia was not identified linking airtightness of buildings with socio-economic conditions of residents.

Ventilation

When considering the impact of ventilation design, there are typically two scenarios found in NSW: naturally ventilated buildings and mechanically ventilated buildings.

For naturally ventilated buildings with operable windows and mechanical exhaust limited to toilet exhaust, which are generally single or several-storey buildings, ventilation design would generally be similar in NSW and those in the U.S. For these buildings, filtration choices may be

limited to portable air cleaners (PACs). An SRP and choice of monitoring measures and interventions would therefore be reasonably consistent from the U.S. to NSW.

Contemporary HVAC design of large multi-storey buildings, as well as large shopping centres, may be quite similar from one country to another. HVAC equipment, controls, and software are concentrated in several large international companies, including but not limited to Johnson Controls, Siemens, Honeywell, Schneider Electric, Mitsubishi Electric, and ABB. Interventions to provide upgraded filtration that would be employed in the U.S. would likely be feasible for application in NSW.

Urban versus rural communities

Information taken from NSW Annual Air Quality Statements for 2024 and several earlier years suggests that areas with air quality exceedances (measured in days) due to landscape fires occur with equal frequency in the Tablelands as well as Sydney and surrounds. The mix of locations most impacted, and whether the cause is bushfire or hazard reduction burning, varies by year, but both highly populated urban areas as well as rural areas are significantly impacted.¹⁰ From a public health perspective, the greatest population health impact would be in the dense urban areas, though localised smoke impacts from hazard reduction burns may be concentrated and repetitive in areas in proximity to bushland reserves, resulting in fewer persons impacted but high concentrations and frequency of exposure for persons in these communities.

It is anticipated that buildings in Sydney and major rural cities of NSW of significant height (five or more storeys) may share many characteristics of buildings within similar climate zones of the U.S. The occupancy type of these buildings would likely be dominated by offices and multifamily residential.

Searching the internet for images of “community and town halls rural NSW” yields a mix of mostly small timber-framed buildings as well as larger brick or stone buildings. Searching for images of “community and town halls urban NSW” yields a mix with very few small timber-framed buildings and mostly larger, historical brick or stone buildings, as well as contemporary buildings. A search for articles addressing differences in construction and architectural styles between NSW and the U.S. was unable to identify any published research. An inquiry was therefore made with the Australian Institute of Architects (AIA), NSW office, for a person(s) familiar with architectural styles and construction techniques between the two countries.

¹⁰ <https://www.environment.nsw.gov.au/topics/air/nsw-air-quality-statements/annual-air-quality-statement-2024/air-quality-summary>

A response was received from Mr. Nigel Bell, of ECOdesign Architects, a NSW architect referred by the AIA who practices in Katoomba. His complete comments are included in Appendix C.

One comment he made was “an increasing number of Australian public buildings now are steel framed with light-weight cladding (aluminium, fibre-cement etc) due primarily to cost concerns (away from labour-intensive brick/blockwork or stone).” This construction technique may be consistent with U.S. construction practices as regards new construction, increasing the applicability of ASHRAE Guideline 44 to new construction in NSW.

Mr. Bell also stated, “Increasing NCC emphasis is now being placed on sarking behind light-weight cladding for all building typologies – no doubt encouraged by Passive House movement and condensation control issues. Smoke control is not mentioned ... but if walls are air-tight, that would minimise infiltration from that source.”

While he was unable to further address the issue of smoke infiltration or management, as he had minimal experience with this issue, he did address the issue of NSW Specification 43 and its subsequent modification, particularly as it applies to primary and secondary school buildings, and particularly as it applies outside of capital cities.

Specification 43 is integral to the National Construction Code (NCC) 2022, and it mandates bushfire protection measures for Class 9 buildings, which includes healthcare facilities, early childhood centres, schools, and residential care buildings. It addresses vegetation distance from buildings, safe external areas, vehicular access, water supply, and fire-resistant materials or construction techniques. It does not address bushfire smoke infiltration.

Based on experience with these mandatory requirements, he emphasised the benefits of guidance and the need for measures to be practical and feasible for users, with their practicality to be tested before they are proposed. He also highlighted the disproportionately high costs and challenges of retrofitting existing buildings, especially for smaller projects and buildings, vs incorporating measures in new construction.

Given the experience of Specification 43, a cautious approach for Guideline 44, balancing public health benefits with practicality of implementation, may be warranted.

Multifamily residential

Differences in multifamily (multiunit) residential ventilation design may exist between the U.S. and NSW, as management of toilet and kitchen exhaust and introduction of make-up air have large variability across different buildings. Some multifamily buildings have central ventilation systems serving all units, while many have independent heating and cooling systems within each unit. Almost all have operable windows or sliding doors. It is unknown if large differences

exist between the two countries, but the general guidance provided in section 6.2.9.5 in ASHRAE Guideline 44, Multiunit Residential Buildings, which includes provision of portable air cleaners, sealing and caulking of cracks to reduce smoke infiltration, and provision of outreach and educational materials to residents, would apply equally to NSW as to U.S. occupancies.

Section 6.2.5 in ASHRAE Guideline 44 addresses Dedicated Cleaner Air Spaces. This section is suggested to apply to older buildings that may not be able to accommodate higher efficiency filters. For these buildings, envelope design becomes less relevant, and the section in Guideline 44 suggests the use of portable air cleaners with a HEPA filter in a closed room may be a more practical solution. This is what was evaluated in the intervention study in Port Macquarie, previously cited.¹¹ Considerations for this application do not appear to differ from the U.S. to NSW, and this section would be equally relevant in the two locations.

¹¹ Wheeler, A.J.; Allen, R.W.; Lawrence, K.; Roulston, C.T.; Powell, J.; Williamson, G.J.; Jones, P.J.; Reisen, F.; Morgan, G.G.; Johnston, F.H. Can Public Spaces Effectively Be Used as Cleaner Indoor Air Shelters during Extreme Smoke Events? *Int. J. Environ. Res. Public Health* 2021, 18, 4085. <https://doi.org/10.3390/ijerph18084085>

What can be learned from the US experience in developing and implementing ASHRAE 44 to make NSW guidance practical and user-friendly to improve its effectiveness? For example, would it be beneficial to separate the guidance into two guidelines: one providing more targeted technical guidance for a range of building types aimed at mechanical ventilation professionals and building managers, and another offering practical and user-friendly guidance for households? What key elements should each include?

The guideline was published in December 2024, so little information exists at present on implementing ASHRAE 44 as it would relate to its practicality, user-friendliness, and effectiveness in both reducing exposure and its effect on public health.

The ASHRAE 44 development process and its applicability to Australia

The process used by ASHRAE for the development of ASHRAE 44 follows a Standards and Guidelines procedure that is formalised and highly structured. The technical committee that develops these documents includes volunteer participants with voting status (between 6 and 18 members) and other participants without voting status, either as corresponding or provisional corresponding members. Non-voting members provide technical expertise during discussions and need not be ASHRAE members but do have to be approved by the Committee Chair. Whereas in the past, meetings were based on attendance at a winter and summer conference, currently most committees meet via remote participation. Once a provisional document is prepared, a structured process for seeking public review is followed, with all written comments required to be considered by the applicable committee, potentially incorporated into a final document, but in all cases provided with a written response in due course.

There are conflict of interest provisions in committee makeup, for example, no more than one voting member of a technical committee may be from the same organisation. Diverse stakeholder groups are represented among voting members, including manufacturers, consultants, researchers, utilities, regulators and contractors. Some ASHRAE Standards require unanimous approval, which can involve extended debate, while ASHRAE Guidelines such as ASHRAE 44 do not require consensus.

While appearing onerous, this process is intended to create effective documents representative of the larger community of stakeholders. In some cases, this may provide a document that

meets ANSI standards for adoption, which is necessary for recommendations to be formally incorporated into building codes. This process ensures that ASHRAE's development efforts are highly effective, however, this highly structured and regulated process is quite time-consuming, often stretching over many years.

The ASHRAE model provides NSW with a good example of a highly robust process that is resource-intensive and requires volunteer participant commitment and organisation, and considerable time from conceiving of a Standard or Guideline to final publishing.

In conclusion, portions of the ASHRAE development protocols may be suitable for the goals of the Clean Air Spaces Prototype Guidance Project.

Dividing the Guideline

There is considerable merit in dividing the Guideline into two documents. The first should be targeted to building and mechanical professionals, building managers and building owners, and the second offers practical and user-friendly guidance for households. ASHRAE Guideline 44 does not address all households, only large multifamily households. "Households", as used below, refers to households not covered by ASHRAE Guideline 44.

Section 5 of the Guideline "is a guide for designers." Implementing its recommendations requires a high level of technical expertise. This point is further elaborated in addressing Question 6, but put simply, applying Section 5 will require engineering expertise. It would neither be user-friendly nor appropriate to include this in a guidance document for households. Section 5 in its entirety may therefore not be appropriate to include in a household guide.

There is much practical and user-friendly guidance that can be offered to households without the technical requirements of Section 5.

In a household guide, some of the theory represented in Section 5 would be a key element to translate into easily accessible actions for the householder. As an example, it would be useful to explain the basic concepts and rationale for controlling the level of PM_{2.5}, but without providing technical calculations or specialised equipment. As a second example, explaining the necessity of minimising infiltration as a first step, and cleaning of infiltrated air as a second step, defined in Section 5 as the design challenge concept, is a basic premise that would be a useful conceptual framework for a householder.

Given that most single-family homes are naturally ventilated, the absence of a mechanical HVAC system that can be modified to provide enhanced filtration means that other methods are required to reduce particulate. Cleaning could typically only be accomplished by utilising portable air cleaners (PACs). A homeowner Guideline should additionally include information on how to evaluate performance of PACs prior to purchase, including the tests expected to have

proven their safety and effectiveness and to ensure they are designed for appropriate room sizing, and noise prevention. ASHRAE 44 discusses Selection of Portable Air Cleaners in Section 6.2.2.3.1. and addresses many of these issues.

A website to assist in choosing locally available PACs is available at <https://cleanairstars.com/filters>.

Further information would include how to position PACs to minimise restricted or obstructed airflow, the importance of purchasing replacement filters ahead of time, and maintenance issues common to all PACs. A comprehensive discussion of PACs is essential for a homeowner guide as it is the most important and most likely intervention to be adopted by homeowners.

ASHRAE 44 discusses do-it-yourself (DIY) air cleaners in section 6.2.2.3.2. For many homeowners, an appropriate DIY cleaner can be an effective intervention at a lower cost than some commercially available PACs. For example, testing of Corsi-Rosenthal boxes has indicated that this design can be both economical and provide high performance.¹² Not all DIY cleaners may be as effective. Including such guidance would be a key element in the document. Several safety issues discussed by ASHRAE 44 would be applicable to householders, including electrical safety and proximity to water that are common to the U.S. and NSW.

Tightening the building envelope would be the intervention most likely to further reduce ambient levels of particulate. Whereas using a PAC may be intuitively obvious to a homeowner, the value of building tightening may not be appreciated.

The key concept of tightening the building envelope to prevent infiltration of outdoor particulate, and the methodology to accomplish that, as discussed in ASHRAE Guideline 44 for use in commercial and multi-residential buildings should also be included in a household guide. Minimising opening of doors and windows, sealing a sliding door not normally used for entry and exit, sealing active or passive exhaust pathways such as kitchen or bathroom exhausts absent effective seals when not operating, that could permit infiltration, are all examples of interventions that would be achievable for homeowners. These measures could be described and could be accomplished by homeowners in a homeowner-focused Guideline.

Most households will not be measuring indoor and outdoor PM_{2.5} as a building performance metric for avoiding incoming smoke, nor will most households be capable of measuring the pressure differential between outdoors and indoors that allows them to understand the likelihood and extent of infiltration of vegetation-combustion derived particulate matter. While

¹² Dal Porto, R., Kunz, M. N., Pistochini, T., Corsi, R. L., & Cappa, C. D. (2022). Characterizing the performance of a do-it-yourself (DIY) box fan air filter. *Aerosol Science and Technology*, 56(6), 564–572. <https://doi.org/10.1080/02786826.2022.2054674>

these performance metrics are important to determine the efficacy of interventions for a professional or in a public or commercial building, it is not reasonable to expect homeowners to assess efficacy via a performance assessment.

For a commercial building, a written SRP facilitates communication to a new employee taking over these responsibilities later and preserves the institutional "memory" and rationale for measures taken. This need is not relevant for homeowners; documentation in the form of a written SRP would therefore not be necessary to include in a homeowner guideline.

Any interventions implemented by a homeowner would be useful, and even if they do not achieve a benchmark such as the 80% reduction ASHRAE 44 targets for a large public building, they will still have value in reducing their exposure.

For a homeowner willing to more diligently address infiltration, quantitatively assessing the potential for infiltration in residences is feasible and is done often for energy efficiency purposes. Members of ATTMA, the Air Tightness Testing and Measurement Association, based in Sydney, assess residential builds for envelope tightness on single-family residential buildings. The ATTMA website lists over 88 entities performing this work across Australia, with a high percentage offering their services in NSW.¹³

For a Guideline for professionals, key elements to include would be to replicate the ASHRAE approach: define the goals, establish the methodology to achieve those goals, measure performance relative to those goals, and then revisit performance periodically.

This approach is described as the design challenge, and is defined in Section 5, which starts by asking the design team to pre-determine and establish targeted representative concentrations for both outdoor and indoor air and then evaluate the extent to which all planned interventions of building tightening and air cleaning would achieve that desired goal. This pre-planning framework should be a key component of a professional guide, and it is wise to plan before implementation to anticipate problems before they occur.

ASHRAE 44 suggests communicating this design analysis to stakeholders in a Basis of Design (BoD), presumed to be a written document. No further elaboration of the BoD is provided. It is not clear what the benefit of this would be, as most stakeholders would have difficulty interpreting or following the required calculations. In a regulatory framework, a BoD could potentially function as a quality control measure. Thus, a BoD may not be a key component of a building professional guide without a regulatory context.

While a target reduction of 80%, in keeping with the ALARA (as low as reasonably achievable) approach as specified in Section 5 - is reasonable, it is somewhat arbitrary. No evidence is

¹³ Retrieved 5/6/2025, <https://www.bcta.group/attma/air-tightness-testers-members/air-tightness-testers/australia/>

provided or referenced in ASHRAE 44 regarding the public health impact of various targets. ASHRAE 44 suggests that this value can be adjusted for “the vulnerability of the intended occupancy and expected activity levels (e.g., usage of the space, occupant age, occupant susceptibility).” The 80% target could be modified based on feasibility or economic considerations in applying ASHRAE 44 to NSW. The concept of including a target, however, should be a key component of a guide for building professionals.

To accomplish this pre-planning framework, it is necessary to establish the operational sequence and performance of the building, particularly the mechanical introduction of outdoor air. It is common that the design intent of a building is not being achieved in practice, so a key element of a professional guide would be a requirement to determine the current performance of the HVAC system in bringing in outdoor air and any existing filtration or other cleaning technology.

Measuring indoor and outdoor PM_{2.5} values and measuring building pressurisation should be a key element of a professional guide. Although these are not realistic expectations of a homeowner, they are reasonable expectations for a public or commercial building that will be occupied by the public, particularly one intended to be used as a community cleaner air space (CCAS)

Understanding how zonal pressure control can minimise smoke migration in the building is important, and a discussion of these issues should be another key component of the guide. It should also cover loading characteristics of filters and when they require changing. There are numerous specific instructions for operating building controls (BAS, known as building automation systems¹⁴) that are useful for designers and should be included in a professional guide. The relationship between fan performance and filters is important information for designers. In summary, all the technical information pertaining to design of HVAC systems, envelope commissioning, and the specific building type information included in ASHRAE 44 is valuable and should be included as key elements of a building professional guide.

In Section 6, Operation During a Wildland Fire Event, Developing a Smoke Readiness Plan (SRP) is crucial and should be retained as a key element in any NSW approach. The SRP should include building-specific design elements, roles and responsibilities, costs, operational testing, implementation, sequence of operations, and returning to normal operation. As in the U.S., building HVAC management personnel change, so the necessity for written documentation that is consistently employed by an organisation is similar in NSW as in the U.S.

¹⁴ A BAS is a computer monitoring and control system that both controls and monitors HVAC systems. Many have alarm and trending functions and serve as the main interface between the building manager and the operation of the HVAC system.

ASHRAE 44 provides some descriptions of operational challenges and potential solutions that could result from reducing outdoor air and maintaining positive pressure. Methods to determine building envelope tightness are described. Managing odours resulting from reduced ventilation is discussed. This information draws from practical experience and can be quite valuable to a building professional in implementing ASHRAE 44. Providing this practical guidance should be a key element of a professional guide, as this information – particularly collated and directly applicable to the smoke intervention measures required – is not easily available elsewhere and vastly simplifies the task of determining how to go about implementing the guide. For a building professional, this may be the most valuable part of the guide.

Section 6.4.2 When to Implement the Smoke Readiness Plan suggests various criteria for implementation. It suggests informative sources on U.S. air quality that might provide information on PM_{2.5} concentrations. Fundamentally, it leaves implementation decisions to either building managers or state and local health departments. What it avoids is defining concentrations of PM_{2.5} that would initiate implementing the SRP. Keeping this flexibility should be a key element of a NSW approach to a building professional guide to allow for different building uses, designs and changing environmental factors.

ASHRAE 44 recommends several mitigation and management approaches, including various types of equipment and treatments with reference to associated standards to help mitigate the impact of smoke on indoor air quality. Are these practicable or the most appropriate and relevant for Australian conditions, building types and performance

With one important exception, discussed below, equipment and treatments available in the U.S. are like equipment and treatments available in NSW. Commercial HVAC equipment and portable air cleaners (PACs) are similar as many are marketed worldwide by large international manufacturers. Several international rating schemes exist for verifying capacity, noise, performance, and safety of PACs or air treatment technologies (i.e., electrical safety and unintentional generation of unwanted contaminants such as ozone). These standards and ratings are appropriate for Australia, and some are already in use here in Australia.

The mitigation and management approaches described in ASHRAE Guideline 44 would be applicable to both residential use and commercial building use for all building types and are applicable for relevant Australian conditions.

As per the exception mentioned above, filtration efficiency rating and filter loading creates additional complication.

Filtration is a key component of Guideline 44 as reflected in the calculations required by equation 1 in Section 5.4.1, where the mass removal at PM_{2.5} needs to be known for the filter, and Section 5.4.3 Filter Loading Calculation. These will be addressed individually, below.

Section 5.4.1, calculations required by equation (1)

Different jurisdictions have historically rated HVAC filter performance differently.

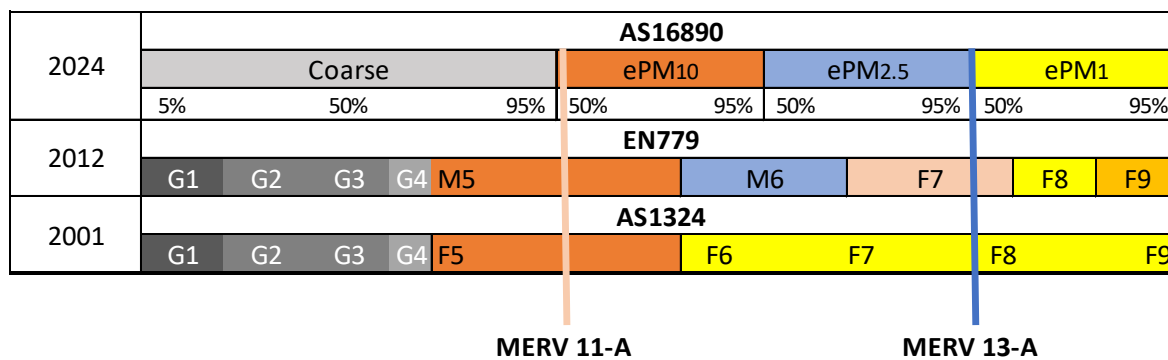
Until last year, Australia operated exclusively in accordance with Standards Australia AS 1324.1 and AS1324.2. Our filters received rating designations of “F” and “G” and numerical designations, such that we had G1-G4 and F5-F9 filter classifications. The U.S. has a different system using the acronym MERV, Minimum Efficiency Reporting Value. These ratings refer to the efficiency of the filter, information required to be input into equation 1, ASHRAE Guideline 44. ASHRAE Guideline 44 adheres to the U.S. rating system, which is not used in Australia. Further complications arise as Australia is in the process of transitioning to a new filter rating system, ISO/ AS16890, discussed further below; however, the old system will still be in operation in Australia until late 2026.

Tables which permit conversion of a given Australian designation filter in the current system (AS 1324) , i.e., F7, to the rating system utilised in the U.S., i.e., MERV 13-14 have been created.¹⁵ In many cases there is not an exact conversion, as the rating systems tested different performance metrics, such that in the example cited above, efficiency for an Australian F7 rated filter falls somewhat between a MERV 13 and a MERV14.¹⁶ In addition to the Australian and U.S. systems, there are also important systems including EU (EN779) and ISO (16890). Sometimes subtly, and sometimes significantly, these multiple classification systems do not align.

This overlap of different classifications can be seen in the illustration below:

Evolution of Filter Classifications – From AS1324 to AS16890

(courtesy Daniel McCaffrey, AFPRO Filtration Group)



Further complicating the issue is that filters can be categorised based on particle count removal efficiency or based on mass removal efficiency. ASHRAE Guideline 44 is clear that mass removal efficiency is most relevant for landscape fire smoke; other ASHRAE Standards such as ASHRAE 241, addressing Control of Infectious Aerosols, use a particle count approach.

To better harmonise with other international filter standards, and better reflect actual performance of filters, Australia adopted ISO/ AS16890 effective at the end of 2024.

To ease the transition, a two-year transition period was instituted such that both standard systems (AS1342 and ISO/AS 16890) are currently active in Australia and manufacturers are providing filters under both systems. The older AS 1324 series will phase out at the end of November 2026. At that time, all filters will be required to correspond to the ISO/AS16890 system.

¹⁵ AIRAH DA15 Air Filters and Cleaning Devices, 2nd edition 2019.

¹⁶ Table 7.2: Filter Classification System Guide in DA15, cited above.

Some filters carry an electrostatic charge as part of the particle capture design. Electrostatic charge influences filter performance, particularly when new. Electrostatic charge can however quickly dissipate, resulting in a decrease of performance, so the rated performance of a filter when new may not reflect its performance during the majority of its service life, changing the assumptions about its performance. The ISO/AS 16890 considers the behaviour of electrostatic filters in the rating by averaging the efficiency across both new and conditioned filters.

In the case of health care, a separate HEPA filter standard (AS4260) exists, and this remains unchanged with the adoption of ISO/AS16890. The EU has also moved from their existing EN779 filter standard to ISO 16890.

Guideline 44 requires input to Equation (1) of the mass removal efficiency of a filter and indicates the approximate performance of MERV filters for PM_{2.5} removal efficiency in Table 2, page 14. The notes from this table in Guideline 44 indicate that there may be variation in removal efficiency across manufacturers for the same MERV rated filter.

ISO/AS 16890 defines ePM_{2.5} as the efficiency of removal of particles with aerodynamic diameter greater than 0.3 µm and less than 2.5 µm. A ePM_{2.5} filter will remove particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 2.5 µm aerodynamic diameter.

Given all of the above, because the new ISO/AS16890 provides information on filter efficiency at both PM_{2.5} and PM₁ for each classified filter, it will be possible to directly use data from ISO/AS16890 in Guideline 44 equation 1. Thus, in Australia we will avoid some of the confusion arising from using the MERV rating system when applying the concepts of ASHRAE 44.

In Section 7.3 Classification, ISO/AS16890 classifies filters into one (and only one) of four groups based on minimum efficiency values. This group is then shown on the filter label.

Table 4, ISO/AS 16890 shows that a filter designated as an ISO ePM_{2.5} filter achieves ≥50 % minimal removal of particles greater than 0.3 µm and less than 2.5 µm. For the next least efficient filter group, the so-called ISO ePM₁₀, no value is provided in the table for the removal efficiency for e which is an input requirement for equation 1 of ASHRAE Guideline 44. The designation therefore may remove the ability to make the required calculations to apply the guidelines.

Section 5.5.4.1 Filters in New Construction, and Section 5.5.4.2 Filters in Retrofits, state that if calculations in equation (1) cannot be performed, the minimum filter efficiency required to meet the guideline requirements is MERV 13, or ePM₁-50% using the ISO 16890 classification. So technically, ASHRAE Guideline 44 does not permit these lower-efficiency filters (ISO ePM₁₀) to be employed. It recommends (in Section 5.5.4.2 Filters in Retrofits) that the “AHU/HVAC system in retrofits of existing buildings should be modified as practicable to accept a minimum of MERV

13 or ePM₁-50% filters.” This can be rather problematic or difficult to achieve, leaving the engineer in a difficult position implementing ASHRAE Guideline 44.

If ASHRAE Guideline 44 were considered for implementation in NSW, it might address this issue slightly differently, given the practicality issues.

The data for performance of a filter with less than 50% efficiency for PM_{2.5} (i.e., ISO ePM₁₀) will typically be available from the manufacturer, though it wouldn't be printed on the ePM₁₀ filter.

Some initial confusion will likely arise in obtaining the input values for Equation 1, however as ISO/AS 16890 comes into greater usage, and as filter representatives become more familiar with any specific landscape fire guidelines within NSW, confusion should be reduced.

Section 5.4.3 Filter Loading Calculation

Guideline 44 Section 5.4.3, “Filter Loading Calculation,” is intended to determine when filter loading reduces efficiency and/or increases flow resistance and is required to be replaced. It permits calculation of the number of days a filter would be usable during a landscape fire event. It uses dust-holding capacity values derived from ASHRAE Standard 52.2 in determining filter life but notes that landscape fire smoke has a different size distribution from the calculations used in Standard 52.2. ISO/AS 16890 uses the ASHRAE Standard 52.2 values without the cotton linters or the carbon content, thus eliminating the sticky and binding effect of these substances in the filter fabric. Thus Guideline 44 and ISO/AS 16890 both adhere to an appropriate approach for landscape fire smoke.

This latter section discusses issues pertaining to how a filter will load, which influences performance efficiency, and how much resistance to flow will result with loading.

Section 5.4.1.1 opens the possibility of using mass removal capacity for PM₁ as a better estimate of landscape fire smoke reduction compared with PM_{2.5}. Replacing PM_{2.5} with PM₁ values would require re-calculation of equation (1), re-evaluation to determine if the 80% desired reduction is going to be achieved with PM₁, and in buildings where interventions have already been accomplished, possible changes in installed equipment. If NSW is intending to implement portions or all of ASHRAE 44, it would be prudent to independently assess the likelihood and desirability of using PM₁ rather than PM_{2.5}.

In summary, there is likely to be confusion as we transition to new filter standards in both using Equation (1) for properly allocating filtration ratings, and in identifying and installing the proper filters when the Smoke Readiness Plan is implemented.

Would these mitigation approaches be readily available and accessible in NSW? Experience in the US highlighted supply difficulty due to demand during extended periods of smoke, and the need therefore for careful risk assessment and planning in preparation for smoke events.

Extended periods of smoke can stress personnel, equipment, and supply resources. For ASHRAE 44 to be meaningfully implemented, all preparations need to be completed prior to such periods. Full preparation includes:

- Availability of engineering expertise.
- Purchase and installation of filters, or portable air cleaning devices.
- Modifications of HVAC systems for temporary recirculation in 100% outdoor air systems such as hospitals.
- Installation of monitoring equipment for PM_{2.5}, and for air pressure differential.

Verification that operational objectives are met, during what is described as the testing phase, also must be conducted prior to an extended period of smoke.

Following this approach allows us to fulfil the phrase “It is important to realize that this planning and testing process will take considerable time and effort.”, which is the first sentence of Section 6, *Operation During a Wildland Fire Event*.

Most of the suitable mitigation approaches are readily available and accessible in NSW, but most tasks must be performed prior to the start of the extended period of smoke to allow the Guideline to function as intended.

Would there be available professional and technical skills in NSW that can be accessed to help design, assess, install, commission, and maintain these mitigation approaches for a range of building types?

The technical approach defined in ASHRAE 44 and the design approach defined in Section 5 are not overly complex and are achievable by HVAC engineers in Australia. There are many HVAC design and installation contractors that could both assess the current HVAC systems and perform the Design Challenge described in Section 5.2 “Definition of the Design Challenge Concepts”, and Section 5.4 “Design Calculations and Processes”.

The goal laid out in Section 5 is for the design team to establish representative concentrations of PM_{2.5} in each of outdoor and indoor air and then build a spreadsheet using a provided equation that calculates the predicted PM_{2.5} values resulting from installing a particular piece of particle-reducing equipment. Alternatively, ASHRAE 44 specifies that one could use a specialised computer program called CONTAM that provides mass balance analysis to predict performance. This program is utilised by Australian professionals; the Clean Air Society of Australia and New Zealand (CASANZ) offers a multi-day training course in the use of CONTAM. The tools required to enable implementation are therefore already being utilised regularly here in Australia. The level of expertise required to use these tools is within the scope of an HVAC professional design engineer but would likely not be able to be accomplished by a building engineer (mechanical services practitioner), the person responsible for the HVAC system for a larger commercial building. Therefore, a range of professionals may be needed for full scale application of the guidelines.

Regarding Section 6, implementation, commissioning agents are another skilled trade that would be able to accomplish the requirements of this section.

To reduce outdoor airflow for the purpose of minimising intake of smoke when using a sophisticated HVAC system, reprogramming of the building control system (BAS) may be required. Specialist application engineers, rather than facility maintenance personnel, or even HVAC design professionals, often perform this function.

AIRAH members include both HVAC design professionals and commissioning agents. Based on the knowledge of their membership base, most of the ASHRAE 44 designated tasks and required professional capabilities exist in NSW for all building types.

Envelope commissioning is perhaps a less common skill. There are specialty architects that review other architect’s work for envelope integrity, both for water and air leakage.

The previous reference to ATTMA and the website address is relevant for testing envelope integrity, as many commercial buildings and high-rise buildings (LCHR) are tested for envelope tightness by members of ATTMA.

While the skills and expertise for designing and implementing an SRP exist within NSW, many of the tasks required are beyond the expertise of non-engineering persons, such as facility managers, who might regularly monitor the HVAC system on a day-to-day basis. Some of the tasks, such as selecting and calibrating a PM_{2.5} sensor, or installation or maintenance of building pressure sensors might be accomplished by these building engineers and not require a professional HVAC engineer.

In summary, the professional skills exist within NSW to conduct the mitigation approaches for all the building types that would be encountered, but it would be unlikely that a building owner could accomplish these tasks without hiring outside professional expertise. Because the design professional would need to be familiar with the current operation of the building, it is unlikely this approach could be accomplished without a site visit to verify the current equipment and operation of the building. For more remote rural areas, costs and time for travel might be a consideration.

What arrangement would we need with ASHRAE to adapt their guidance for use in NSW?

ASHRAE has a memorandum of understanding with AIRAH dating from 2021 that is currently in effect through 10 June 2026, with provision for extension.¹⁷

In the section on Advocacy:

ASHRAE and AIRAH agree to work together on common public affairs goals and ideologies...” Collaborative opportunities to be considered include:

- Joint promotion of codes and standards at the local, state, and federal levels.
- Promoting mutually beneficial positions during the development and passage of state and federal legislation.
- Education of legislators on issues important to the members of each organization.”.

There is therefore a provision for cooperation of promotion of codes and standards that would apply to NSW adopting portions or all of ASHRAE Guideline 44.

AIRAH has previously adapted ASHRAE publications for use in Australia. DA07 - Criteria for Moisture Control Design Analysis in Buildings, is based on ASHRAE 160, and is now called up as a reference document in the National Construction Code.

ASHRAE Standards and Guidelines are routinely adopted by code-making bodies throughout the U.S. The expectations regarding these, based on inquiries made with one former ASHRAE President, are that “there are no restrictions on an authority adopting an ASHRAE standard or guideline. What they cannot do is freely distribute or sell an ASHRAE standard or guideline simply because they adopt it. That is a copyright issue and ASHRAE, of course, wants the revenue that is generated by distribution of its standards. I think that the place to start would be to contact Stephanie Reiniche with your questions.”

AIRAH is currently pursuing this with ASHRAE management and will report the results of those inquiries.

¹⁷ Chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ashrae.org/file%20library/communities/memoranda%20of%20understanding/memorandum-of-understanding-ashrae-airah-2021-fully-executed.pdf

Any additional relevant information including knowledge and experience that could be used to support the development of technical guidance to make it more effective and practical.

Requiring adoption of the Guideline in its entirety across all buildings accessed by the public may not be as effective as publishing it as a voluntary guidance document, due to the significant amount of work and expense necessary to fully implement its requirements. This is particularly true for existing buildings.

It might be more feasible at this stage to require adherence to the Guideline for new construction.

For designated CCASs (Community Cleaner Air Spaces), the path forward may be better positioned as a roadmap with possible funding available to cover the Section 5 engineering personnel expense as an incentive to implement the Guideline.

Many CCASs may be older structures and because of their accessibility to communities for this purpose, a separate Guideline could be developed focusing on these types of buildings and not including the design elements of ASHRAE 44 as it pertains to new construction. For example, ASHRAE Guideline 44 Section 6 addresses the importance of temporary cleaner air spaces within the building in enclosed rooms. A document focusing on this mitigation measure could be included in an initial document as a first step in applying ASHRAE 44 to NSW.

The ASHRAE Guideline 44 only includes large multiunit residences. There are good arguments for a similar guide for single-family and small multiunit residential buildings, as discussed in the section entitled “Dividing the Guideline” in response to question 3. A further review of literature and building codes specific to these types of buildings would be a pre-requisite for extending the Guideline to these types of buildings.

Dividing the Guideline is preferred because the current guidance provided is ad hoc and often incorrect, i.e., public health authorities consistently recommend staying indoors during bushfire events, even though the data indicates that a significant percentage of fine particulate matter penetrates, albeit with a slight time delay. Therefore, the current recommendations are not protective of public health, and further efforts to recommend more effective mitigation measures would be advantageous. There is sufficient information at present to produce an evidence-based household-focused guidance document.

Recommended next steps

As a number of differences between Australia and the countries covered by ASHRAE have been identified in this report, this section summarises the recommendations for future actions in terms of building design and codes, building operations, public policy, and guidance during periods of poor air quality resulting from landscape fire smoke.

While the full toxicology of inhalation of landscape fire smoke is not well understood, it is believed that there is no threshold of harm for PM_{2.5}. Thus, selection of ALARA, which attempts to reduce indoor particulate matter levels to 20% of those found outdoors during air pollution episodes, may not be sufficiently protective of human health. It would be advisable to review the ALARA concept over time as new health research becomes available.

- A review of the state of the science is warranted given advances in research activities related to smoke emissions and associated health outcomes.
- As technology continues to advance, a review of alternative interventions to reduce exposures to non-particulate matter pollutants is warranted.

Taking the opportunity to reduce overall dose by lowering exposure levels in non-residential buildings can offer a significant contribution to lowering the overall burden of disease. The ASHRAE guidance has identified some limitations that require further support:

- Current Australian building codes should be compared with ASHRAE's expectations related to the building envelope and ventilation systems.
- ASHRAE assumptions around ventilation in medical buildings is that they have a two-pass system and are thus protective during shorter-term air pollution events. The Australian situation should be verified prior to adopting the guideline.
- The recommendation to tighten building envelopes relies on an understanding of the building codes as well as which ones will be most effective, both physically and economically. A pilot study to evaluate a range of building envelopes will assist in providing recommendations that are reasonable and effective.
- A review of the infiltration of air pollutants into larger buildings is needed as there is limited data available.
- It will be easier to implement changes to the building envelope and ventilation system in the design of new buildings; retrofitting existing buildings will be more difficult. This is especially true of historic buildings where options may be limited to zonal pressure controls. A trial of currently available options for these buildings would be useful to implement.

ASHRAE Guideline 44 does not include any details for the design of the Smoke Readiness Plan (SRP).

- There is benefit in trialling the development of a SRP in a range of building types and designs to ensure that the plans can be adapted.

Appendix A – Aspects of ASHRAE 44 to consider for local adoption

Aspect	Ease of implementation	Cost	Level of expertise required
Use of PM 2.5 as indicator of air quality	Access to low-cost sensors has increased and is being used more frequently for citizen science projects.	It is possible to measure using low-cost sensors. Understanding when concentrations are high vs low is possible with these sensors.	The general public have been able to utilise low-cost sensors. Note that access to data from low-cost sensors can require a third party to manage, but it depends on the version being used.
Use of ALARA as criteria for interpreting PM2.5 data	This requires an accurate monitoring instrument that does not just track trends in the data as the low-cost sensors tend to do.	Can be expensive if using regulatory instruments.	Requires some understanding of regulations and averaging times.
Balancing other health risks (overheating, infectious aerosol exposure)	Very easy to implement if the system has been designed for this, high difficulty to implement or impossible to implement if not designed for this.	May not impact costs if building engineer is full-time and already accounted for in fixed costs	Ability to adjust the balance between outdoor air intake and recirculated indoor air based on the ability of the HVAC system to manage this transition
Switch concept, SRP is turned on only when necessary	Requires someone with an understanding of the building	May not impact costs if building engineer is full-time and already accounted for in fixed costs.	Requires someone with an understanding of the building.
Use of PM2.5 monitoring instruments indoors and outdoors to calculate efficacy	Feasible to implement.	Low-cost sensors have increased availability, reliability and durability.	Can be done by either building personnel or consulting engineers or HVAC maintenance personnel.
Tightening of building envelope	Feasible to implement.	Will depend on actions to be taken.	Sealing of cracks and some insulation can be completed by homeowner but other more complex changes will require a professional.

Aspect	Ease of implementation	Cost	Level of expertise required
Building of vestibules	Feasible to implement.	Professional fees involved.	Will require a professional and may also require building approvals from council if a historic building.
Calculation of indoor design concentration of PM2.5	Difficult.	Professional fees involved.	Mechanical engineer, if using public software such as CONTAM, specialised expertise required.
Estimation of leakage for new design	Not difficult.	Professional fees involved.	Can be done by mechanical engineer.
Filter loading calculations	Moderate difficulty.	Professional fees involved.	Can be done by mechanical engineer.
Installation of differential pressure sensors to evaluate building pressurisation	Not difficult.	Professional fees involved.	Can be done by mechanical engineer.
Adding of smoke-reducing logic to existing BAS systems	Moderate difficulty.	Professional fees involved.	Can be done by specialty contractor.
Choosing portable air cleaners (PACs)	Not difficult, many consumer guides exist comparing different makes and models; requirements for CADR ratings by AHAM and US EPA creates level playing field for assessment.	Minimal time involved.	Can be done by minimally trained personnel.
Commissioning a control system with integrated monitoring and BAS responses	High difficulty.	Professional fees involved.	Can be done by subcontracted commissioning agents.

Aspect	Ease of implementation	Cost	Level of expertise required
Full envelope commissioning for new buildings	High difficulty.	Professional fees involved.	Can be done by subcontracted specialists, e.g., ATTMA members.
Sealing and caulking cracks on annual basis	Low difficulty.	May not impact costs if building engineer is full-time and already accounted for in fixed costs.	Can be done by existing personnel.
Developing and drafting a SRP	High difficulty.	Professional fees involved.	Can be done by mechanical engineer.
Assessing impact of upgrading filtration for existing systems	High difficulty.	Professional fees involved.	Can be done by mechanical engineer.
Use of DIY air cleaners	Low difficulty.	Minimal fees involved.	Can be done with minimally trained personnel.

Appendix B – Key resources and contacts

ASHRAE Standard 241-2023, Control of Infectious Aerosols

<https://www.ashrae.org/technical-resources/bookstore/ashrae-standard-241-control-of-infectious-aerosols>

ASHRAE Standard 52.2-2017, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

https://store accuristech.com/ashrae/standards/ashrae-52-2-2017?product_id=1942059

ATTMA, the Air Tightness Testing and Measurement Association

<https://www.bcta.group/attma/air-tightness-testers-members/air-tightness-testers/australia/>

Australian filter standard AS16890 – Air filters for general ventilation

<https://www.standards.org.au/standards-catalogue/standard-details?designation=as-16890-1-2024>

Australian HEPA filter standard HEPA filter standard AS4260 – High efficiency particulate air (HEPA) filters

<https://www.standards.org.au/standards-catalogue/standard-details?designation=as-4260-1997>

Australian Institute of Architects (AIA), NSW chapter

<https://www.architecture.com.au/nsw-chapter>

Contact: Nigel Bell, of ECOdesign Architects

Clean Air Society of Australia and New Zealand (CASANZ)

<https://www.casanz.org.au/>

CONTAM – indoor air quality and ventilation analysis computer program

<https://www.nist.gov/services-resources/software/contam>

DA07 – Criteria for Moisture Control Design Analysis

<https://airah.org.au/site/site/shop/product.aspx?iProductCode=DA07>

National Construction Code

<https://ncc.abcb.gov.au/>

Portable air cleaner (PAC) selection tool

<https://cleanairstars.com/filters>

Specification 43 of National Construction Code – Bushfire protection for certain Class 9 buildings

<https://ncc.abcb.gov.au/editions/ncc-2022/adopted/volume-one/g-ancillary-provisions/43-bushfire-protection-certain-class-9-buildings>