Mechanical Engineering
Lighting Design
Sustainable Design
Electrical Engineering

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

MECHANICAL ENGINEERING

STEENSEN VARMING

Consultant Advice Note COVID Guidance for SINSW Classrooms

Sydney, 7th October 2021
Project No. 217164

Mechanical Engineering
Lighting Design
Sustainable Design
Electrical Engineering

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

STEENSEN VARMING

Document Revision and Status

Date	Rev	Issue	Notes	Checked	Approved
7.10.21	3	Final	Peer Review Comments Included	DJM/MAC	CA

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

Table of Contents

1.0 Executive Summary

This guidance note has been prepared to provide School Infrastructure NSW (SINSW) with advice on air quality in schools, in particular naturally ventilated classrooms and measures to achieve this.

Specific advice has been provided around the effectiveness of natural ventilation to achieve internal air quality in line with international health recommendations for COVID-19. In particular the number of air changes and external opening areas required to meet the recommendations.

This advice is required to support the re-opening of NSW public schools from the 25th October. The advice is considered interim guidance as a first step to allow the safe re-opening of schools until if required, more permanent solutions can be provided.

We note that ventilation and air quality will be one of many layers SINSW is addressing to reduce risk of Covid-19 transmission in schools.

The assessment has been based on a typical 65m² classroom, with 26 people (25 students and 1 teacher), with single sided natural ventilation. This is considered the worst case scenario assessment as single sided natural ventilation provides lower air change rates of fresh air than a classroom with cross ventilation.

The World Health Organisation's (WHO) "Roadmap to improve and ensure good indoor ventilation in the context of COVD-19", has been used as the primary reference to base the guidance on. Several other international guidance papers have also been referenced.

The results of the high level assessment undertaken shows the typical classroom satisfies and exceeds the WHO roadmap first strategy approach of providing the nominated fresh air ventilation rate of 10 l/s per person. Additionally, the results also show satisfactory CO_2 levels in the typical classroom.

Single sided ventilation by buoyancy forces alone i.e. no wind

Number of people present	26	
Required flowrate to achieve 10l/s/person	260	l/s
Outside temperature	22.5	°C
Inside temperature	26.0	°C
Opening free area required	2.802	m²
Size of window openings based on minimum 5% free area of floor area to satisfy the National Construction Code.	3.25	m²

Table 1

Based on the assumptions made, the results presented in the table above show that for a single sided natural ventilated 'typical' classroom, 2.8m² of free area of opening is required to provide 260 l/s of fresh air, which is the minimum volume based WHO roadmap guideline. From a statutory compliance perspective the minimum effective free area required is 5% equating to 3.25m² which is greater than that calculated. Under this scenario, the 'typical' classroom is capable of providing a higher volume of fresh air to the classroom due to the greater free area of opening that should be available.

Reworking the calculations using an area of 5% effective free area or 3.25m², then for the conditions modelled the volume of fresh air increases to 300 l/s which would support a class size in theory of 30 people (29 students and 1 teacher).

Cases 2: Single sided ventilation by wind forces alone

Required flowrate	260	l/s
Wind speed at building height	3	m/s
Flow coefficient	0.05	
Opening free area required	1.733	m²
Opening free area based on 5% of Floor Area	3.25	m²

Table 2

As expected with the presence of wind the ventilation rate is higher and the minimum ventilation rate of 260 l/s is easily achieved.

From an indoor air quality perspective, the average CO_2 level during the occupied school day for the typical classroom is 726 ppm based on a supply flow rate of 260 l/s which is below the NCC maximum of 850 ppm as a weighted average. Under the same conditions, for a class size of 30 the ppm of CO_2 rises to 772ppm.

For classrooms with recirculating split air conditioning systems, windows need to be kept open. Air conditioning systems can be turned on if necessary on hot days. The air conditioning will not keep the classrooms as cool as they would be with windows closed, but will provide some cooling effect to improve thermal comfort and still have natural ventilation to keep air movement and supply of fresh air.

Within the scope of this guidance note, the advice provided is generally in line with the OzSage recommendations.

In summary:

1. Adopt roadmap measures as defined in the World Health Organisation – 'Roadmap to improve and ensure good indoor ventilation in the context of COVID-19'.
2. Natural ventilation openings to classrooms should be fully opened before and after school. During lunch and recess periods windows should also be left open.
3. Ensure natural ventilation openings are maintained and in working order and free from obstructions.
4. Were natural ventilation cannot be provided and if the department wish to use the classroom then mechanical ventilation systems should be installed. This could be via ducted systems, wall mounted fans or pedestal fans placed adjacent to natural ventilation openings.

Mechanical Engineering
Lighting Design
Sustainable Design
Electrical Engineering

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

2.0 Introduction

2.1 Objective

The purpose of this guidance note it to provide School Infrastructure NSW (SINSW) with a roadmap outlining a range of measures that need to be considered in preparing both primary and secondary schools for reopening on Monday 25th October 2021.

The focus as outlined in our briefing session with SINSW, is around ventilation and specifically to look at existing classrooms that are naturally ventilated. To bring some science to the discussion we have undertaken some high level assessment on likely air change rates and how they rate against industry/health organisation guidelines to maintain suitable air quality and mitigate risk of transmission of COVID-19.

We understand that an audit of existing schools in NSW is underway to assess the state of classrooms' natural ventilation systems to determine their operational status and to identify instances where natural ventilation/fresh air cannot be provided to classrooms, such as inoperable windows, obstructions blocking air flow and the like. In such instances interventions such as installation of mechanical ventilation systems to classrooms is recommended to ensure adequate air quality is provided.

The roadmap prioritises short term measures for SINSW that are considered temporary until more permanent measures are put in place. This is a result of both time constraints and available funding. Thermal comfort is also an important factor however hasn't been addressed in this report apart from being raised as a potential risk as summer approaches with increasing levels of discomfort likely in leaving windows fully open.

We have referenced a number of international guidelines that specifically address COVID-19 from a ventilation perspective, including some that are specifically relevant for schools.

For the purpose of this guidance note it has been agreed to assume a typical classroom is deemed as:

Floor area	65m^2
Number of students	25
Number of teachers	1
Floor to ceiling height	2.7m
Natural ventilation opening free area*	3.25m^2
Case 1 distance between openings	1.2m
Case 2 opening height	1.2m

Table 3

* Based on 5% of floor area as minimum effective free openable area required by National Construction Code (NCC) F4.6. Refer section 3.2.3.

As a conservative basis we have also assumed natural ventilation is single sided.

2.2 Reference Material

The following reference material has been used for the preparation of this guidance note:

1. NCC 2019
2. AS 1668.2 2012, The of mechanical ventilation and air-conditioning in buildings Part 2 Mechanical ventilation in buildings
3. AS 1668.4-2012, The use of ventilation and air conditioning in buildings - Natural ventilation of buildings
4. Bureau of Meteorology
5. SINSW DG55 - Thermal Comfort and Indoor Air Quality Performance Brief
6. World Health Organisation "Roadmap to improve and ensure good indoor ventilation in the context of COVD-19" 2021 guideline
7. ASHRAE - Reopening Schools and Universities C19 Guidance (14.05.2021)
8. CIBSE COVID-19 Ventilation Ver 5 16th July 2020
9. Risk Reduction Strategies for Reopening Schools, Harvard School of Public Health, Nov 2020
10. John Hopkins Centre for Health Security – School Ventilation a Vital Tool to Reduce Spread. May 2021
11. Guide for Ventilation Towards Healthy Classrooms – European Cooperation in Science and Technology, Dec 2020
12. Room Air Cleaner Guidance for Schools, Department of Education, Ireland, May 2o21
13. COVID Guidance for SINSW Classrooms Peer Review, Arup, 2nd October 2021
14. Safe Indoor Air (Ventilation) Recommendations, OzSage, Ver 1.02, 6th September 2021
15. Australian Health Protection Principal Committee (AHPPC) statement on the role of ventilation in reducing the risk of transmission of COVID-19
16. National Guide for safe workplaces – COVID-19, Safe Work Australia, October 2020

New research and material is becoming available on an ongoing basis, and further reviews can be undertaken at a later date to ensure latest and best practice advice is being followed.

2.3 Limitations

This guidance note has been prepared specifically for School Infrastructure NSW. It is intended to offer guidance regarding best practices regarding the natural ventilation of primary and secondary schools in an effort to reduce the risk of disease transmission, specifically novel coronavirus SARS-CoV-2 and the disease it causes, COVID-19 when schools reopen. Adherence to any information included in this advice note will not ensure successful treatment in every situation, and SINSW acknowledges that there is no "zero risk" scenario. SINSW acknowledges that each school and situation are unique and some of the guidance contained in the report will not apply to all school buildings.

Furthermore, this guidance paper should not be deemed inclusive of all proper methods nor exclusive of other methods reasonably directed to obtaining the same results. The report is in no way intended to override or supersede guidance from government and health organisations. The information contained herein reflects the available information at the time the report was created. SINSW recognises that details and information are changing daily, and new information and/or the results of future studies may require revisions to the report (and the general guidance contained therein) to reflect new data. We do not warrant the accuracy or completeness of the guidance in this report and assume no responsibility for any injury or damage to persons or property arising out of or related to any use of the report, or for any errors or omissions.

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

3.0 Background

3.1 COVID-19 Transmission

There are several reasons why disease outbreaks occur in school environments. Research shows that disease outbreaks can happen when immunization against a disease is not 100% effective, when there is vaccination failure, or when there is an inadequate level of immunity in some of the students. Furthermore, the high degree of interaction of students in schools and the frequency with which children put their hands or objects in their mouths increase the transmission of disease.

Even so, historical disease outbreaks in school environments indicate that implementing adequate intervention strategies can successfully minimise COVID-19 transmission and keep the majority of staff and students safe when reopening schools.

No one control strategy alone can limit the transmission of disease. Schools should approach reopening with a layered defence strategy, where many recognised/effective interventions and strategies are combined, simultaneously. Schools should deploy an 'all in' approach that uses every complementary control feasible.

As referenced from the Harvard Public School of Health, there are three routes of transmission for COVID-19 that are supported by models and case studies of outbreaks as follows:

> ***Close-contact transmission*** *can occur via droplets or aerosols (tiny droplets, also called droplet nuclei). Close contact transmission by droplets refers to close-range transmission of virus by sometimes-visible droplets that are coughed or sneezed by an infectious person directly onto the eyes, mouth, or nose of a nearby person. Droplet transmission can be minimised by, among other things, physical distancing and universal non-medical cloth mask-wearing. Close contact transmission by aerosols refers to transmission of virus in tiny, invisible droplets that are generated when an*
>
> *infectious person exhales, speaks, coughs, sneezes, or sings, and that are then inhaled by another nearby person, allowing the virus to deposit directly on the surfaces of their respiratory tract. This close contact aerosol transmission can also be minimised by, among other things, physical distancing and mask-wearing.*
>
> ***Fomite transmission*** *refers to viral transmission via inanimate objects, like desks, tables, playground equipment, or water fountains that are contaminated with the virus. A surface could become contaminated in many ways, for example, after a person coughs directly onto an object or after they sneeze into their hand and then touch the surface. Individuals who touch the fomite while the virus remains viable, and then touch their eyes, nose, or mouth before washing their hands, could be exposed to the virus. How long the virus can be detected on fomites depends on the type of surface and the environmental conditions. Under some conditions, the COVID-19 virus can be detected up to 72 hours after deposition on hard, shiny or plastic surfaces or up to 24 hours after deposition on more porous surfaces, but the risk posed by these day(s)-later detections is much lower than the initial risk because the amount of the detectable infectious virus decreases rapidly over time. Fomite transmission of a virus can be minimised through frequent cleaning and disinfection of commonly-touched objects, through use of automatic or touchless alternatives (e.g., automatic doors), and through frequent hand washing.*
>
> ***Long-range transmission*** *refers to transmission of virus in aerosols, which may be generated when an infectious person exhales, speaks, sneezes, or coughs and then travel out of the immediate 1.5 metre vicinity of the infectious person via airflow patterns. This airborne virus can remain aloft for more than an hour indoors to infect people who are not interacting closely with the infectious person. Long-range airborne transmission can be minimised by, among other things, increasing outdoor air*

ventilation to dilute the concentration of airborne virus or filtering air recirculating in a room or building.

Regardless of children's susceptibility to infection, symptom severity, and viral load, there are unique behavioural factors in this age group that can facilitate the spread of infectious disease, including the large number of contacts of school-aged children and the frequency with which children, particularly young children, put their hands or objects in their mouths. In the absence of further scientific knowledge about COVID-19 transmission among and by children, particularly in school settings, it is reasonable and prudent to assume that COVID-19 transmission may occur between children and from children to adults in reopened schools.

3.2 Statutory Compliance

From a statutory compliance perspective, the following extracts from the National Construction Code (NCC) and Australian Standard 1668.2 and 4 2012 define the minimum prescriptive requirements for natural ventilation applicable to classrooms.

3.2.1 NCC F4.6 – Natural Ventilation

The objective of Part F4.6 is to safeguard occupants from illness or loss of amenity due to lack of air freshness. The Deemed-to-Satisfy (DTS) Provisions of NCC Volume One Clause F4.6 require that natural ventilation must be provided to a habitable room and must consist of permanent openings, windows, doors or other devices which can be opened. The ventilating area must be not less than 5% of the floor area of the room required to be ventilated.

Classrooms, must be provided with either: natural ventilation complying with F4.6; or mechanical ventilation or an air-conditioning system that complies with both of the Standards referenced inF4.5(b).

If a room or building is served by a mechanical ventilation or air-conditioning system for heating or cooling purposes and the system does not provide ventilation in accordance with AS 1668.2, then the room or building must also be provided with natural ventilation complying with F4.6. Natural ventilation would therefore need to be provided to rooms served by a typical domestic type wall mounted air-conditioning split system. In addition, NCC does not preclude natural ventilation serving a room or building if it is also served by a mechanical ventilation or air-conditioning system compliant with AS 1668.2.

F4.6 Natural ventilation

(a) Natural ventilation provided in accordance with F4.5(a) must consist of openings, *windows*, doors or other devices which can be opened—
   (i) with a ventilating area not less than 5% of the *floor area* of the room *required* to be ventilated; and
   (ii) open to—
      (A) a suitably sized court, or space open to the sky; or
      (B) an open verandah, carport, or the like; or
      (C) an adjoining room in accordance with F4.7.

(b) The requirements of (a)(i) do not apply to a Class 8 *electricity network substation*.

Figure 1: Extract from NCC 2019

For the purpose of this guidance note, based on a typical classroom size of 65m² this equates to a minimum free openable area of **3.25m²** excluding obstructions such as flyscreens. Note the free area is not the frame size of the opening but the area available when the opening is fully open less any obstructions. This varies based on the type of opening as the image below illustrates.

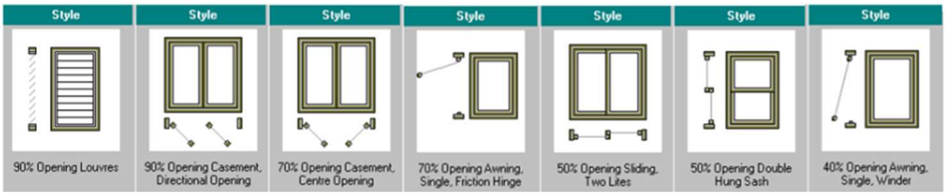


Figure 2: Examples of window types and likely free areas

3.2.2 Australian Standard 1668.4

Further to NCC, AS 1668.4 also requires that for classrooms with students under the age of 16 to have a larger opening size provided. This is calculated by multiplying the minimum requirement deemed by the NCC by a factor of 1.25 as highlighted in the figure below:

AS 1668.4—2012 14

TABLE 3.1

PERCENTAGE FLOOR AREA REQUIRED AS OPENINGS

Use of enclosure	Average adjusted metabolic rate watts/occupant	Net floor area per occupant, m² (use highest applicable value)			
		<2	2 to 5	Over 5 up to 15	>15
Low activity	Up to 160	7.5%	5%	5%	2.5%
Medium activity	161–200	7.5%	5%	5%	2.5%
High activity	201–340	10%	7.5%	5%	5%
Very high activity	Over 341	15%	10%	7.5%	5%
Class 1 Class 2 Class 4	Any	5%			
Classroom (students under 16 years old)	Any	Multiply the percentage floor area required by 1.25			

NOTES:

1 For information on metabolic rates/activity levels, see Table B1, Appendix B.

2 A description of building Class is given in the NCC.

Figure 3: Extract from AS 1668.4 - 2012

The minimum free area required is 5% x 1.25 which equals 6.25%. Based on a typical classroom size of 65m² this equates to a free openable area of **4.025m²** excluding obstructions such as flyscreen.

3.2.3 Free Area Adopted

For the purpose of the guidance note in assessing the effectiveness of natural ventilation we have taken a conservative approach and used 5% rather than 6.25% of floor area to calculate the opening free area which is considered the worst case.

3.3 SINSW DG 55 - Thermal Comfort and Indoor Air Quality Performance Brief

DG 55 is applicable to new school design and cannot be retrospectively applied to existing schools.

4.0 Indoor Air quality

4.1 Aim

To ensure that appropriate levels of indoor air quality (IAQ) are achieved in spaces under both natural ventilation mode and air conditioning mode.

4.2 Performance Criteria

The following is required to demonstrate compliance:

For natural ventilation provisions, these shall comply with the current NCC and relevant Australian standards. Ceiling fans shall be provided to further assist air movement.

For mechanical ventilation provision as part of the air conditioning systems:

1. Outdoor air ventilation rates are in accordance with the requirements of AS 1668.2. Classrooms serving persons up to 16 years of age 12 l/s per person.

   Classrooms serving persons over 16 years of age 10 l/s per person.

2. Mechanical ventilation systems shall be designed to provide adequate access for maintenance and cleaning.
3. Mechanical ventilation systems shall be linked to CO2 sensors to provide demand controlled ventilation if and when required by BCA.
4. Ventilation systems are designed to maintain an average daily CO_2 concentration as per the latest NCC code, and to ensure that maximum concentration does not exceed 1000 ppm for than 20 consecutive minutes in each day. A CO2 sensor and indicating light shall be provided.
5. The required outdoor air ventilation rates and CO_2 concentrations shall be maintained when windows and other ventilations opening are open.

6. Ventilation systems shall be designed to minimise the entry of outdoor pollutants through ensuring that the ventilation system design is in accordance with the relevant parts of AS 1668.2. and ASHRAE Standard 62.1.
7. Where local sources of pollutants are present e.g. photocopiers, minimum exhaust ventilation flow rates should be provided in accordance with AS1668.2: Table B1.

7.0 Natural Ventilation Design

7.1 Natural ventilation systems

The choice and configuration of windows and other opening types within a natural ventilation scheme can have a significant impact on building performance and occupant comfort. Collaboration between the client and design team will be necessary to ensure an appropriate design solution is developed in the relation to the natural ventilation design strategy.

Natural ventilation can be achieved through the use of one or a hybrid of the following solutions,

Opening windows or louvres (can be manual, automated, or a combination of both) opening dampers (can be manual, automated, or a combination of both)

Roof stacks (these can be manual or automated)

Manual control provides the opportunity for energy-efficiency education in the classroom, but automatic controls (such as interlocks) are likely to save energy.

7.2 Strategies for natural ventilation

Designers should refer to CIBSE AM10 for guidance on natural ventilation design.

Single-sided ventilation that relies solely on openings on one side of the room has a limiting depth for effective ventilation of typically 5.5m or 2 times the room height. Separating the openings sufficiently vertically can increase the effective depth to 2.5 times the room height.

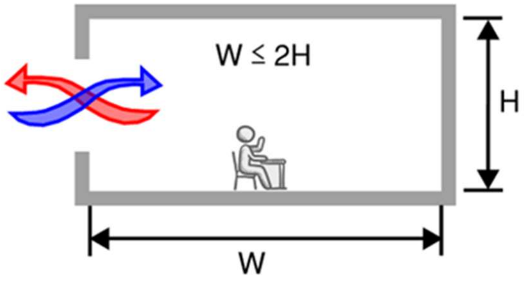


Figure 2 Single Sided Single Opening

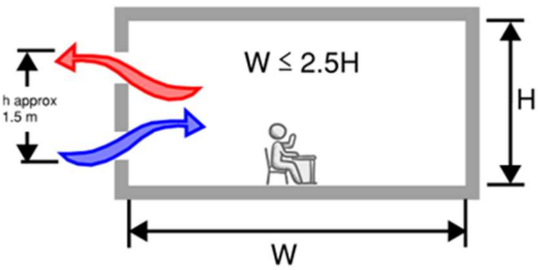
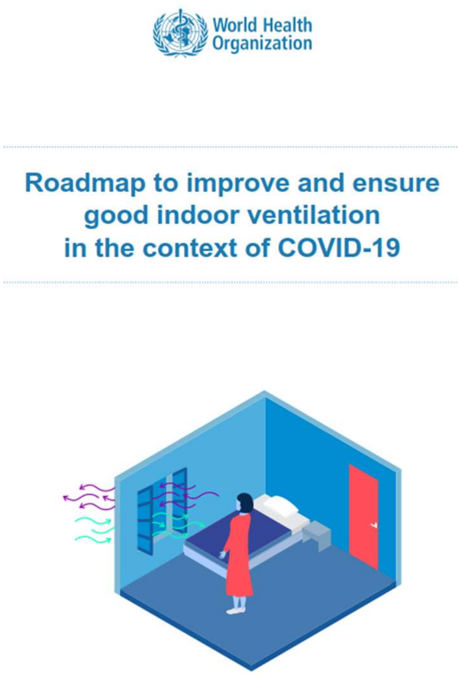


Figure 3 Single sided double opening

Cross-ventilation occurs when there are ventilation openings on both sides of a space. Across the space there is a reduction in air quality as the air picks up local pollutants and heat, limiting the effective depth for ventilation to typically 15m or 5 times the room height.

Figure 4: Extract from SINSW DG55 'Thermal Comfort and Indoor Air Quality Performance Brief'

3.4 World Health Organisation



The World Health Organisation (WHO) has published the ‘Roadmap to improve and ensure good indoor ventilation in the context of COVD-19” 2021 guideline. In the absence of specific Government advice for schools in NSW this reference has been used as the key reference document for recommendations made in this guidance note.

Extracts of the road map relevant for schools is captured in the following two tables below. One applicable for natural ventilation the other for mechanical ventilation.

> *For this document “non-residential setting” refers to public and private indoor spaces characterised by a heterogeneous occupancy rate with people not belonging to the same household, such as workplaces,* ***schools*** *and universities, accommodation sector buildings, and religious and commercial spaces. The load of air pollution or infectious aerosol potentially released in a building depends on the activities performed inside, the number of occupants and whether or not the occupants are wearing masks. National, regional or international requirements are available for each setting and several interim guidance documents have been developed. However, in order to strengthen proposed IPC measures, simplify the COVID-19 risk assessment and facilitate the implementation of corresponding countermeasures, a* ***minimum ventilation rate per person*** *is proposed. This figure, directly linked to space occupancy, will allow the assessment and improvement of ventilation and, if not possible, the adjustment of maximum building occupancy.*

Extract: WHO Roadmap

For the purpose of our advice we have used the WHO nominated ventilation rate of 10 l/s per person of outside air which is similar to Australian Standards.

The roadmap provides a hierarchy of strategies to be adopted under both **natural ventilation** and mechanical ventilation scenarios.

In summary as illustrated in the following figures the order of priority is to:

1. Achieve minimum ventilation rate;
    a. Open windows and doors.
    b. Enable cross ventilation through keeping opposing windows and doors open.
    c. Use pedestal type fans located adjacent to openings to mechanically assist and increase intake of fresh air.
    d. Install additional openings where practical to improve natural ventilation access.
    e. Consideration of standalone portable air purifiers / cleaners if no other strategy can be adopted. Note, air purifiers do not replace the need for fresh air. Where classrooms do not satisfy and comply with NCC and Australian Standards, then rectification measures need to be undertaken. This could be by either increasing openings to achieve NCC minimum area or the introduction of mechanical ventilation systems as a minimum.
2. Encourage uniform movement of air in the classroom via ceiling fans ONLY if the minimum ventilation rate of 10 l/s per person is achieved.
3. Open classroom natural openings (windows, louvres, doors, roof ventilators etc) before classes start to purge the classrooms and leave open after classes finish for cleaning / security staff, after class meetings and the like.
4. If naturally ventilated classrooms have non-ducted air conditioning systems that recirculate the air within the classroom such as wall split systems or ceiling cassette units then the units should be periodically cleaned and maintained. Where the device is equipped with filters investigate whether higher efficiency MERV 14 filters or highest compatible type can be installed to improve filtration effectiveness.

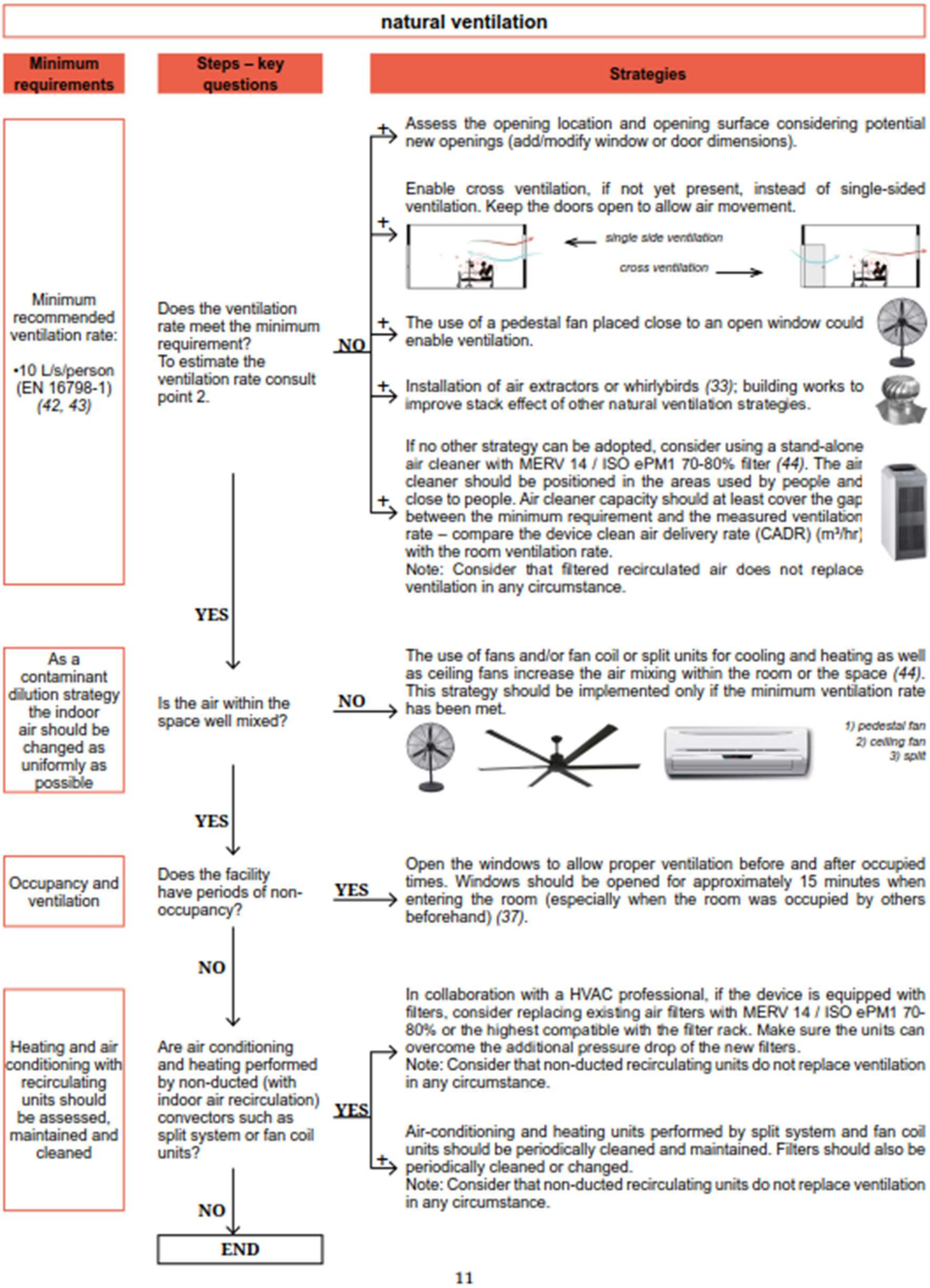


Figure 5: Extract from WHO – Roadmap to improve and ensure good indoor ventilation in the context of COVID-19

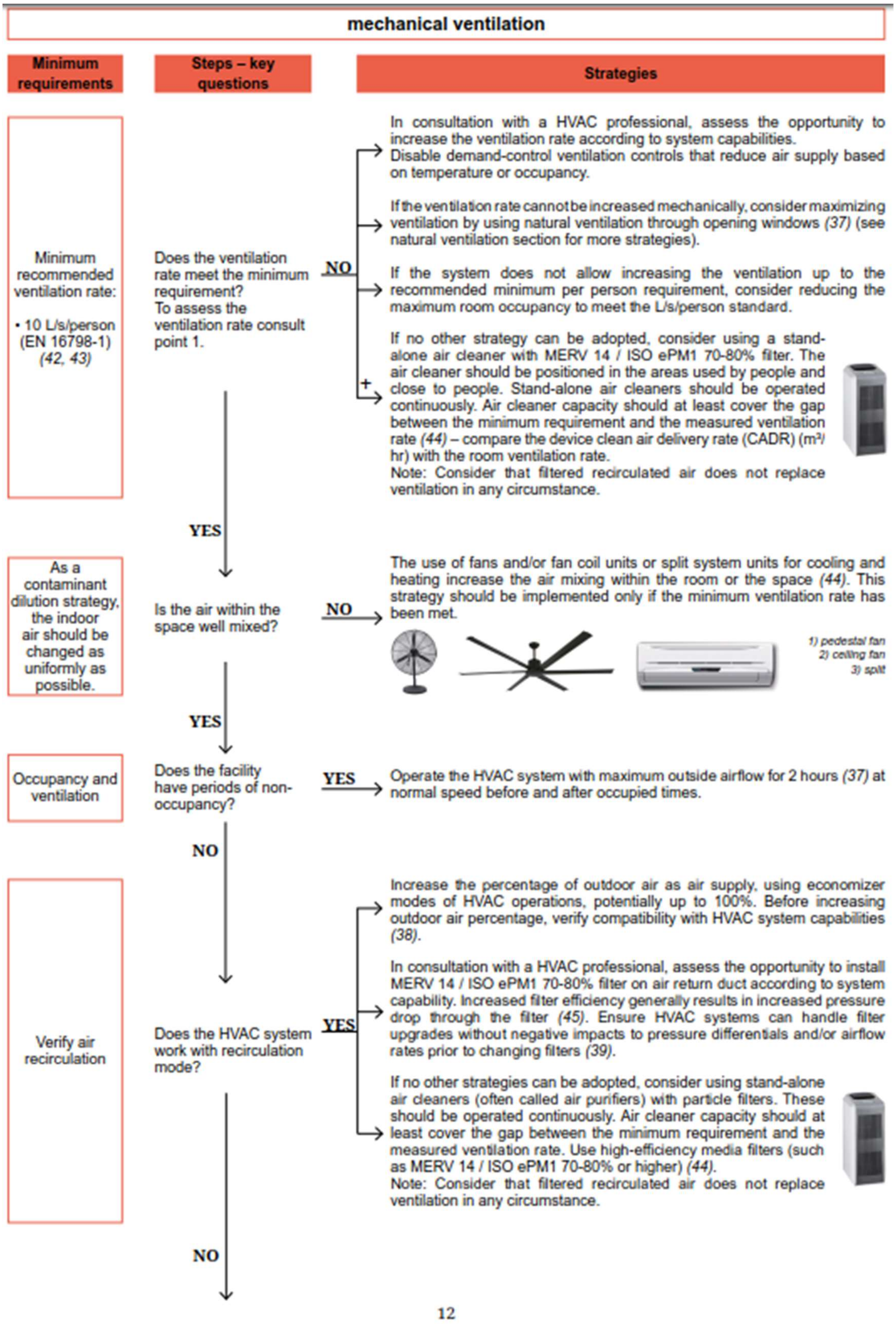


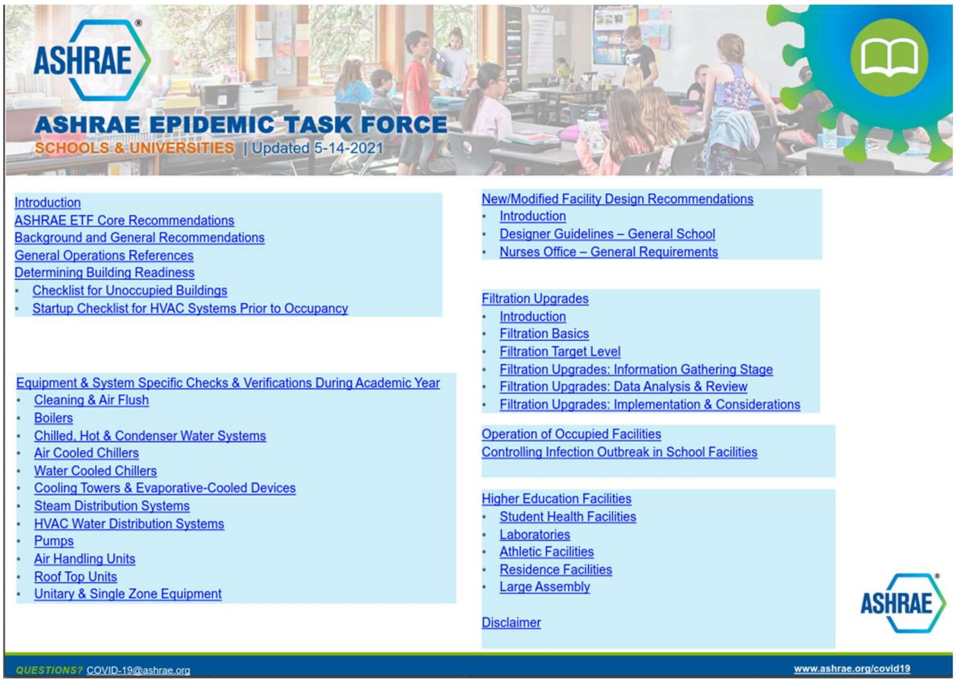
Figure 6: Extract from WHO – Roadmap to improve and ensure good indoor ventilation in the context of COVID-19

3.5 Reopening Schools and Universities C19 Guidance, ASHRAE

The following is a summary of key recommendations made in the “reopening of schools and universities guidance note (updated 14.05.2021)” published by The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

The guide is meant to provide practical information and checklists to school district and university campus environmental health managers, facility managers, administrators, technicians, and service providers to prepare educational buildings to resume occupancy. This information describes how the HVAC systems should be operating to help minimise the chance of spreading SARS-Cov-2 and how to practically check/verify that operation.

ASHRAE is more related to air conditioning and mechanical ventilation systems. If required further assessment of classrooms built recently with fan coil units, can be completed however the scope of this guidance note only relates to naturally ventilated classrooms.



Introduction
ASHRAE ETF Core Recommendations
Background and General Recommendations
General Operations References
Determining Building Readiness
- Checklist for Unoccupied Buildings
- Startup Checklist for HVAC Systems Prior to Occupancy

Equipment & System Specific Checks & Verifications During Academic Year
- Cleaning & Air Flush
- Boilers
- Chilled, Hot & Condenser Water Systems
- Air Cooled Chillers
- Water Cooled Chillers
- Cooling Towers & Evaporative-Cooled Devices
- Steam Distribution Systems
- HVAC Water Distribution Systems
- Pumps
- Air Handling Units
- Roof Top Units
- Unitary & Single Zone Equipment

New/Modified Facility Design Recommendations
- Introduction
- Designer Guidelines – General School
- Nurses Office – General Requirements

Filtration Upgrades
- Introduction
- Filtration Basics
- Filtration Target Level
- Filtration Upgrades: Information Gathering Stage
- Filtration Upgrades: Data Analysis & Review
- Filtration Upgrades: Implementation & Considerations

Operation of Occupied Facilities
Controlling Infection Outbreak in School Facilities

Higher Education Facilities
- Student Health Facilities
- Laboratories
- Athletic Facilities
- Residence Facilities
- Large Assembly

Disclaimer

Figure 7: Table of Contents for ASHRAE ‘Reopening Schools and Universities C19 Guidance’

1. *Public Health Guidance* - Follow all regulatory and statutory requirements and recommendations for social distancing, wearing of masks and other PPE, administrative measures, circulation of occupants, reduced occupancy, hygiene, and sanitation.

2. *Ventilation, Filtration, Air Cleaning*
   2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

3. *Air Distribution* - Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.

4. *HVAC System Operation*
   4.1 Maintain temperature and humidity design set points.
   4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources to acceptable levels.

5. *System Commissioning – Verify that HVAC systems are functioning as designed.*

Figure 8: Extract from ASHRAE 'Reopening Schools and Universities C19 Guidance'

ASHRAE's position is that Transmission of SARS-CoV-2 is significant and should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning (HVAC] systems, can reduce airborne exposures.

There is broad variation of complexity, flexibility, and age in HVAC equipment, systems, controls and Building Automation Systems (BAS) in educational facilities.

The guidance has been formulated to help schools retrofit and plan for the improvement of indoor air quality and to slow the transmission of viruses via the HVAC systems. The underlying effort should be to mitigate risk of airborne pathogen transmission through a combination of strategies, including increased ventilation, better filtration, improved air distribution, or use of other air cleaning or treatment technologies. Control options should be selected to provide desired exposure reduction while minimising associated energy penalties. Maintaining appropriate indoor comfort should also be considered.

ASHRAE notes, this guidance should be applied to each unique climate zone, unique school building and HVAC system. All retrofits and modifications must not contradict ASHRAE 62.1 guidelines and must continue to meet or exceed the standards and codes adopted by local jurisdictions.

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

4.0 Indoor Air Quality (IAQ)

4.1 Strategies

Healthy building strategies that improve air quality and clean surfaces should be incorporated as part of a layered defence against COVID-19 for NSW schools. For improving indoor air quality in the classroom, prioritised control strategies are recommended— ventilation, filtration, supplemental air cleaning — and targeting a combined 6 air changes per hour (ACH) for classrooms through any combination of these approaches.

Other spaces in schools such as gyms, labs, workshops, auditoriums, library, staff offices may require different targets for the combined clean air change rates. These spaces are outside the scope of this guidance note.

ACH can be calculated by adding the total amount of "clean" air entering the room and dividing it by the room volume. The "clean" air in a classroom can be calculated as the sum of the ACH from ventilation (e.g. outdoor air supplied by a mechanical system or open windows), from filtration of recirculated air by a mechanical heating, ventilation, and air conditioning (HVAC) system (accounting for the efficiency level of the filters in the system), and from air cleaning provided by a portable air cleaner with a HEPA filter.

For the purpose of this guidance note we have taken the advice provided by WHO which recommends a minimum ventilation rate of 10 l/s per person. For a typical classroom this equates to approximately 6 ACH of fresh air. This is explained further later in this section.

Classrooms should maximise fresh outdoor air to the extent possible. SARS-CoV-2 present in the coughs, sneezes, and exhaled breath of an infectious person can be transported in the air to disperse throughout a room and can remain aloft for hours. This long-range airborne virus can infect even people who haven't had close contact with the infectious person if they inhale a sufficient amount of virus. Bringing fresh outdoor air into a room can dilute and/or displace any present airborne virus, which thus reduces the probability that someone breathes enough infectious aerosol to become infected. As an ideal, holding class outdoors provides the freshest air and most effective dilution of any infectious airborne SARS-CoV-2.

4.2 Natural Ventilation

The guidance provided as requested in our brief from SINSW is primarily focused on air quality and natural ventilation for classrooms in preparation for the NSW governments planned opening of schools for the 25th October 2021. It is considered interim guidance as a first step to allow the safe re-opening of schools. As we are currently in Spring external temperatures are mild and favourable for natural ventilation. However as we approach summer and with rising ambient temperatures the reliance on natural ventilation will lead to thermal comfort issues in classrooms if windows are left fully open when outside temperatures are hot. This guidance note does not look to provide advice on thermal comfort other than to alert SINSW of the potential issue as we approach summer.

Classrooms that do not have air conditioning and/or mechanical ventilation systems will need to rely on natural ventilation. Natural ventilation is usually provided via open windows, doors, skylights and roof ventilators.

Opening windows and the like can help bring in outdoor air and dilute and exhaust contaminants in the indoor air. Natural ventilation through openings can be effective but is dependent on factors that drive pressure differentials between outdoors and indoors, like wind pressure and stack (or buoyancy) effects through temperature differences. Therefore, airflow into the classroom, even with open windows, will vary based on external and internal conditions, orientation, effective openable area, window type, obstructions such as flyscreens and size and location of openings.

As the quantity of air delivered via natural ventilation cannot be guaranteed particularly for classrooms with limited and/or broken windows, to help address this, classrooms can consider using window fans or movable pedestal fans positioned in or adjacent to openings to blow outdoor air into the classroom via one window and indoor air out of the classroom via another opening. Note that devices that simply recirculate the same indoor air without filtering it or replacing it with fresh air such as ceiling fans are not helpful in reducing any airborne virus present in the room (including most window air conditioning units, fans used in rooms with closed windows).

Where a room only has openable windows or vents only along one side, consideration should be given to areas within the room where air may become stagnant.

In deeper plan rooms, it is advisable to place a local recirculation unit or fan at the back of the room to enhance air disturbance, reducing the risk of stagnant air. This is particularly important when a small room has multiple or transient occupancy.

Greater air flow can be achieved when windows and vents can be opened on different facades to allow air flow through a room. This can also include layouts where cross ventilation occurs by air entering through the external façade, traveling across the floor plate to windows and/or doors on the opposite side.

Air pollutants are more concentrated on the leeward side of the room, where the air exhausts, compared to the windward side, where outside air enters the room. However, in the case of reducing the risk of COVID-19 transmission, this consideration cannot be relied on.

Cross ventilation will increase the outside airflow, and consequently increase the dilution and removal of any airborne pathogens. Cross ventilation pathways where air travels from one occupied room or zone into another should be avoided if possible by keeping internal partition doors closed, unless opening such partitions significantly increases the total volume flow rate of outside air.

WHO and other bodies such as ASHRAE and Harvard Public School of Health also recommend and encourage that windows are opened before and after school hours to allow the classrooms to purge.

Other factors may also impact the ability to increase outdoor air ventilation, particularly for naturally ventilated buildings, including but not limited to, security concerns, high outdoor air pollution or pollen levels, or high outdoor noise levels. The highest tolerable amount of outdoor air ventilation should still be used, even if students and teachers have to adjust their clothing to be comfortable. In cases where the outdoor air ventilation rate cannot be increased, the minimum ventilation rates specified by AS 1668 should be met while other strategies such as enhanced filtration and air purifying/cleaning are used to achieve 6 ACH from ventilation and filtration.

If it is windy, hot, cold or raining then it may not be practical to fully open the windows or vents; however they should be open as far as reasonably possible without causing intolerable discomfort.

There are security issues to consider with respect to leaving windows open, especially when the building is not occupied. A walk-round may be required to ensure that all windows that pose a security issue are closed before the building is vacated, and windows reopened as early as possible before reoccupation by the majority of the building users. Where leaving windows open does not cause a security issue or rain ingress issue it is recommended to do this overnight on warm or hot days to maximise purge of the room air. On cold days and nights this may cause overcooling and significant discomfort, so should be managed.

4.3 Mechanical Ventilation

As the next best solution, mechanical ventilation systems in schools can forcibly bring outdoor air inside and then distribute that air to different areas of the classroom/school. This would be the minimum intervention required for classrooms that are not able to provide the required ACH of outside air due to no or limited openable windows, external considerations such as noise and pollution and the like.

Where classrooms are air conditioned, some fraction of the indoor air is recirculated and mixed with the outdoor air coming in to save on cooling and heating energy costs.

However, during a pandemic, when long-range airborne viral transmission can occur, air recirculation can lead to a build-up of airborne viral particles indoors and also potentially spread the virus to other areas of the learning space / school. Therefore, schools with HVAC systems in place that mix the outdoor air with recirculated air should maximise fresh outdoor air to the extent possible during this period. This can be via fully opening outside dampers or disabling demand ventilation control systems that under normal circumstances modulate fresh air quantities based on student numbers in the classroom and are typically controlled via CO_2 sensors. This is the arrangement rolled out as part of the cooler schools program.

The World Health Organisation and Harvard School of Public Health recommends that air conditioning systems in schools should also have MERV 14 air filters or higher installed in their HVAC systems. Typically filters are only intended to trap airborne particulates not airborne viruses which MERV 14 filters and above are capable of.

For NSW schools this generally will not be practical as MERV 14 class filters are better suited for air handling units (AHU's) as they are larger and better suited at managing the higher pressure losses imposed by the filters. Typically classrooms in NSW where air conditioning has been provided range from wall mounted split systems, ceiling cassette units through to ducted fan coil units (FCU) which are incompatible to have MERV 14 type filters installed due to either their configuration and/or limited fan power and hence ability to overcome the higher pressure loss of the MERV 14 filters.

For such situations consideration of inclusion of portable air purifiers in classrooms should be considered where the minimum fresh air rate of 10 l/s per persons is not able to be maintained.

In addition, school buildings should not shut off or reduce their mechanical ventilation during before-school or after-school hours when there still may be people in the building, including students, staff during any before or after school student programs, cleaning times, teacher class preparation, sports (e.g., if students are returning to lockers), or other activities.

Finally, mechanically ventilated classrooms should evaluate any potential contaminant source near the outdoor air intake duct. For example, the outdoor air inlet should not be located too close to the exhaust air outlet, or places of dense occupancy or contaminated indoor air that is exhausted out of the building could re-enter.

4.4 Portable Air Purifiers

Where the practical measures for the deployment of good ventilation practices have been undertaken, and poor ventilation continues to exist in a particular room/area, air purifiers may be considered as an additional measure in conjunction with other methods of ventilation that are available.

As noted in the WHO Roadmap, if no other strategy can be adopted, consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter (44). The air cleaner should be positioned in the areas used by people and close to people. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate.

Mechanical Engineering
Lighting Design
Sustainable Design
Electrical Engineering

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

STEENSEN VARMING

Refer appendix A for further details.

Filter Efficiency Guide

European Standard (EN 1822) HEPA Filter Efficiency	American Standard (ASHRAE) Minimum Efficiency Reproting Values (MERV)	Efficiency
G1	MERV 1-4	Less than 20%
G2	MERV 1-4	Less than 20%
G3	MERV 5	Less than 20%
G4	MERV 6-8	20-40%
M5	MERV 8-10	50-60%
M6	MERV 9-13	60-80%
F7	MERV 13-14	80-90%
F8	MERV 14-15	90-95%
F9	MERV 16	95%
E10	MERV 16	95%
E11	MERV 16	95%
E12	MERV 16	95%
H13*	**MERV 17**	**99.95%**

Figure 9: Filter Efficiency Guide

4.5 Basis of Calculations

To determine compliance with the roadmap guidelines issued by WHO in relation to achieving a minimum 10 l/s per person of fresh air, a high level qualitative assessment has been undertaken.

This should be considered as 'Rule of Thumb' advice for a typical classroom as follows:

Floor area	65m^2
Number of students	25
Number of teachers	1
Floor to ceiling height	2.7m
Natural ventilation free area*	3.25m^2

Table 3

* Based on 5% of floor area as minimum free openable area required by NCC F4.6.

There are obviously numerous variables that would need to be considered when calculating and qualifying the effectiveness of natural ventilation for all the classrooms in the state. However, known industry tools have been used to estimate likely Air Changes per Hour (ACH) of natural ventilation together with conservative assumptions of some variables for a typical classroom.

The following variables have been used:

1. As a worst case we have assumed single sided ventilation
2. The classroom has openable windows with a minimum free area equal to 5% of the floor area (as per NCC). This is the worst case scenario as AS 1668.4 requires larger opening sizes, that is, 6.25%.
3. Average wind speed and temperature have been used for some selected locations in the state.
4. The School Day nominal "standard" operating hours for school 9.30am to 3.30pm for primary schools, break times include a midmorning break of 15 minutes and a midday lunch break of one hour where there is no occupancy.

The publication *AM10 - Natural ventilation in non-domestic buildings*, published by the Chartered Institute of Building Services Engineers (CIBSE) has been used to calculate the estimated number of air changes for the 'typical' classroom. The results presented in section 4.7 below have used the procedure outlined in CIBSE AM1o for case 1 and 2 as follows;

Case 1: Single-sided, two vents, buoyancy driven

This case represents single-sided ventilation through two identical vents driven by buoyancy alone, see Figure 4.9.

The area A of each opening required to give a ventilation rate q for a specified value of h is:

$$A = \frac{q}{C_d}\sqrt{\frac{(T_i + 273)}{\Delta T\, g\, h}} \qquad (4.12)$$

where A is the area of each opening (m²), q is the ventilation rate (m³·s⁻¹), C_d is the discharge coefficient, T_i is the internal temperature (°C), ΔT is the difference between the internal and external air temperatures (K), g is the gravitational force per unit mass (m·s⁻²) and h is the height between the openings (m).

A typical value for C_d is 0.6.

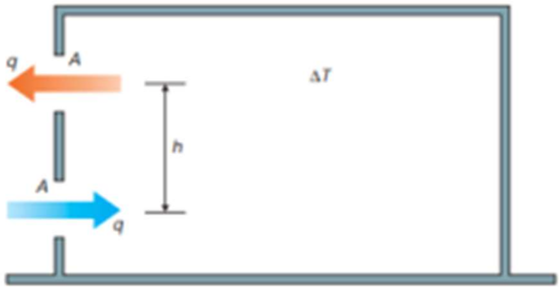


Figure 4.9 Case 1: single-sided ventilation, two identical openings, driven by buoyancy alone

Case 2: Single-sided, single vent, buoyancy driven

This case represents single-sided ventilation through an open window driven by buoyancy alone see Figure 4.10.

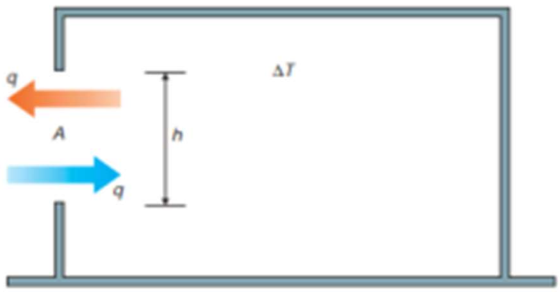


Figure 4.10 Case 2: single-sided ventilation, single opening, driven by buoyancy alone

The area required to give a ventilation rate through a single opening of area A is again given by equation 4.12 but in this case h is the height of the single opening rather than the distance between openings.

Case 2 is basically the same as case 1, but the value of C_d is typically 0.25. This is lower than the value in case 1 partly because only half the area A is available for air entry.

Figure 10: CIBSE AM10 Extract

Case 1 represents situations with high and low level openings distributed across the length of the classroom where fresh air enters at low level and warm air exits at high level. While case 2 represents situations where air enters and exits through the same opening such as a sliding window. Case 1 is generally more effective from a ventilation perspective and is capable of achieving a higher ACH than case 2 where free areas are similar.

4.6 Indoor Air Quality

The daily average CO_2 is taken to be during the period when the room is occupied, if the room is unoccupied, it is therefore excluded from the average.

The following calculations were carried out using a combination of the following tools;

- AM10 Design Tool for IAQ Analysis developed by CIBSE
- CO2 concentration build up calculator developed by Dr Owen Connick of Breathing Buildings
- Discharge coefficient calculator developed by Dr Benjamin Jones of Nottingham University
- Bureau of Meteorology

External CO2 concentration	410*	ppm
Fresh air rate	260	l/s
Occupancy (students and teachers)	26	
Infiltration rate	0.25	ACH
Room area	65	m2
Room height	2.7	m
Occupancy Age	11	years
Activity level	Seated	
Met level	1.2	
Co2 generation	0.0000061	kg/s/p

Typical Classroom		
Floor area	65	m²
Height	2.7	m
Volume	175.5	m³
Air change rate	6	ACH
Flow rate	292.5	l/s
Min BCA/NCA Natural ventilation opening 5% Floor area	3.25	m²

Table 4

* This varies based on geographic location and proximity to any external pollutant sources and will be different for each school and classroom locations.

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

	Occupancy	time	CO2 (ppm)	occupancy	average CO2 (ppm) during occ day
8:00:00	0	8:00:00	410	0	726
8:15:00	0	8:15:00	410	0	726
8:30:00	0	8:30:00	410	0	726
8:45:00	0	8:45:00	410	0	726
9:00:00	26	9:00:00	410	26	726
9:15:00	2	9:15:00	777	2	726
9:30:00	26	9:30:00	529	26	726
9:45:00	26	9:45:00	807	26	726
10:00:00	26	10:00:00	876	26	726
10:15:00	26	10:15:00	893	26	726
10:30:00	2	10:30:00	897	2	726
10:45:00	2	10:45:00	559	2	726
11:00:00	26	11:00:00	475	26	726
11:15:00	26	11:15:00	794	26	726
11:30:00	26	11:30:00	872	26	726
11:45:00	26	11:45:00	892	26	726
12:00:00	2	12:00:00	897	2	726
12:15:00	2	12:15:00	559	2	726
12:30:00	2	12:30:00	475	2	726
12:45:00	2	12:45:00	454	2	726
13:00:00	26	13:00:00	449	26	726
13:15:00	26	13:15:00	787	26	726
13:30:00	26	13:30:00	871	26	726
13:45:00	26	13:45:00	892	26	726
14:00:00	2	14:00:00	897	2	726
14:15:00	26	14:15:00	559	26	726
14:30:00	26	14:30:00	814	26	726
14:45:00	26	14:45:00	878	26	726
15:00:00	26	15:00:00	893	26	726
15:15:00	8	15:15:00	897	8	726
15:30:00	8	15:30:00	644	8	726
15:45:00	8	15:45:00	581	8	726
16:00:00	0	16:00:00	565	0	726
16:15:00	0	16:15:00	448	0	726
16:30:00	0	16:30:00	420	0	726
16:45:00	0	16:45:00	412	0	726
17:00:00	0	17:00:00	411	0	726
17:15:00	0	17:15:00	410	0	726
17:30:00	0	17:30:00	410	0	726
17:45:00	0	17:45:00	410	0	726
18:00:00	0	18:00:00	410	0	726
18:15:00	0	18:15:00	410	0	726
18:30:00	0	18:30:00	410	0	726
18:45:00	0	18:45:00	410	0	726
19:00:00	0	19:00:00	410	0	726
19:15:00	0	19:15:00	410	0	726
19:30:00	0	19:30:00	410	0	726
19:45:00	0	19:45:00	410	0	726
20:00:00	0	20:00:00	410	0	726
20:15:00	0	20:15:00	410	0	726
20:30:00	0	20:30:00	410	0	726
20:45:00	0	20:45:00	410	0	726
21:00:00	0	21:00:00	410	0	726

Table 5: Load profile and contaminant build up

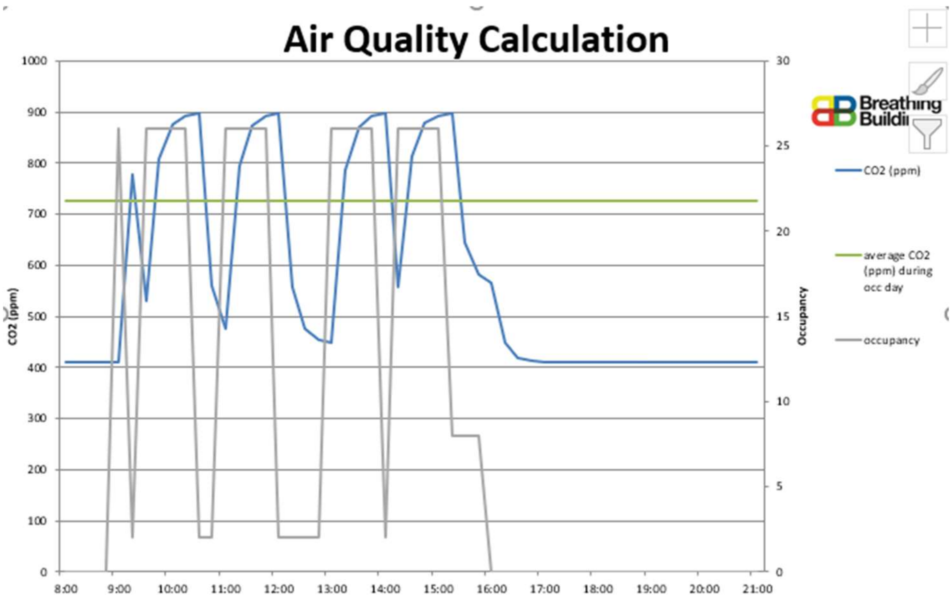


Figure 11: Average occupied classroom CO_2 concentration

The average CO_2 level during the occupied school day for the typical classroom is 726 ppm based on a supply flow rate of 260 l/s which is below the NCC maximum of 850 ppm as a weighted average. For a class size of 30 the ppm of CO_2 rises to 772.

Verification Methods

FV4.1 Verification of suitable indoor air quality

For a Class 2, 3, 5, 6, 9b or 9c building or Class 4 part of a building, compliance with FP4.3 and FP4.4(a) is verified when it is determined that the building under typical conditions in use is provided with sufficient ventilation with *outdoor air* such that contaminant levels do not exceed the limits specified in Table FV4.1.

Table FV4.1 Maximum contaminant limits for acceptable indoor air quality

Pollutant	Averaging time	Maximum air quality value
Carbon dioxide, CO_2	8 hours	850 ppm Note 1
Carbon monoxide, CO	15 minutes	90 ppm
Carbon monoxide, CO	30 minutes	50 ppm
Carbon monoxide, CO	1 hour	25 ppm
Carbon monoxide, CO	8 hours	10 ppm
Formaldehyde, CH_2O	30 minutes	0.1 mg/m^3
Nitrogen dioxide, NO_2	1 year	40 µg/m^3 (0.0197 ppm) Note 2
Nitrogen dioxide, NO_2	1 hour	200 µg/m^3 (0.0987 ppm)
Ozone, O_3	8 hour, daily maximum	100 µg/m^3(0.0473 ppm)
Particulate matter, $PM_{2.5}$	1 year	10 µg/m^3
Particulate matter, $PM_{2.5}$	24 hour (99th percentile)	25 µg/m^3

Figure 12: NCC verification method

4.7 Air Change Rate per Hour (ACH)

To calculate the estimated ACH of fresh air for a typical classroom we have used the CIBSE AM10 tool. For natural ventilation there are two variables that drive ventilation. One, temperature difference between inside and outside and secondly wind velocity.

For the purpose of the calculations we have sourced average temperatures and wind speeds for a number of locations in the state plus available ACT data for a cool temperate area and taken a representative figure. Obviously the results will vary based on the data used, however we believe for the purpose of this exercise to be representative of the locations selected.

Climate data:

The following climate zones have been referenced in the assessment to represent the majority of NSW climate conditions. The climate zones are based on the National construction code of Australia.

Data source: https://weatherspark.com/

January and December months have been excluded in the summary table below which aligns with the school calendar.

Climate zone	Description	Weather file	Average wind velocity m/s	Average low and high temperature range °C Feb-Nov
2	Warm humid summer, mild winter	AUS_NSW.Coffs.Harbour.947910_RMY	3.7-4.3	18-25
4	Hot dry summer, cool winter	AUS_NSW.Cobar.947110_RMY	3.7-4.8	4-32
5	Warm temperate	AUS_NSW.Sydney.947680_RMY	3.3-3.7	8-25
6	Mild temperate	AUS_NSW.Richmond.RAAF.957530_RMY	1.6-2	4-27
7	Cool temperate	AUS_ACT.Canberra.Airport.949260_RMY	2.4-3.1	1-25

Figure 13: Climate Zone Locations

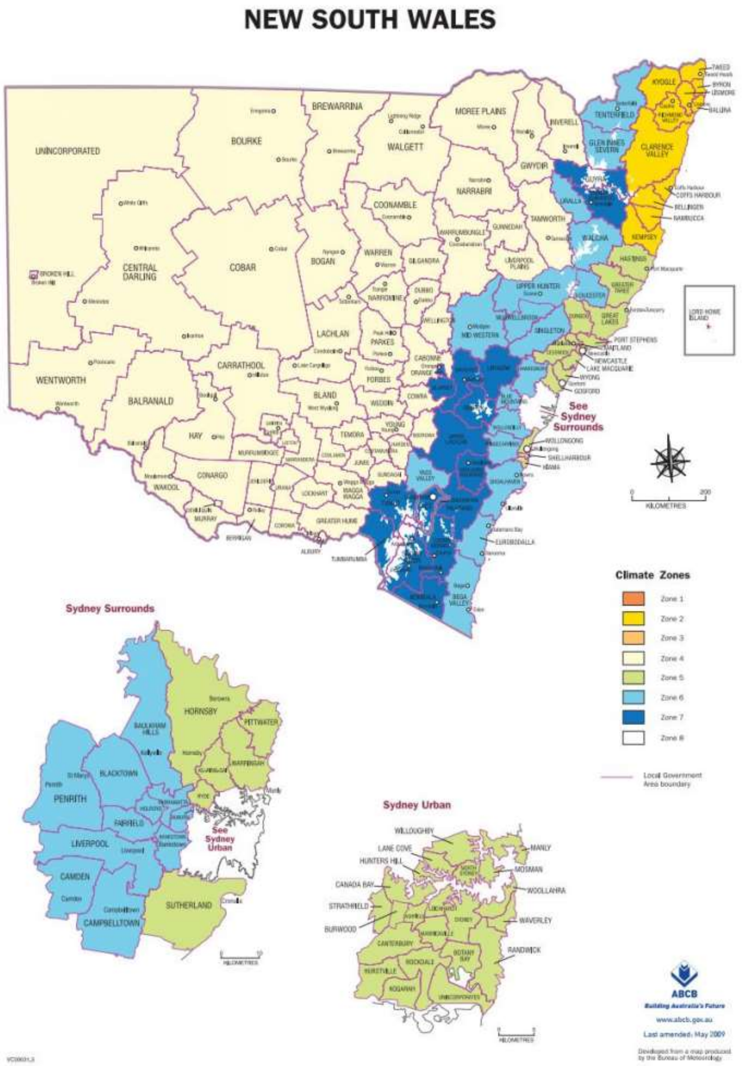
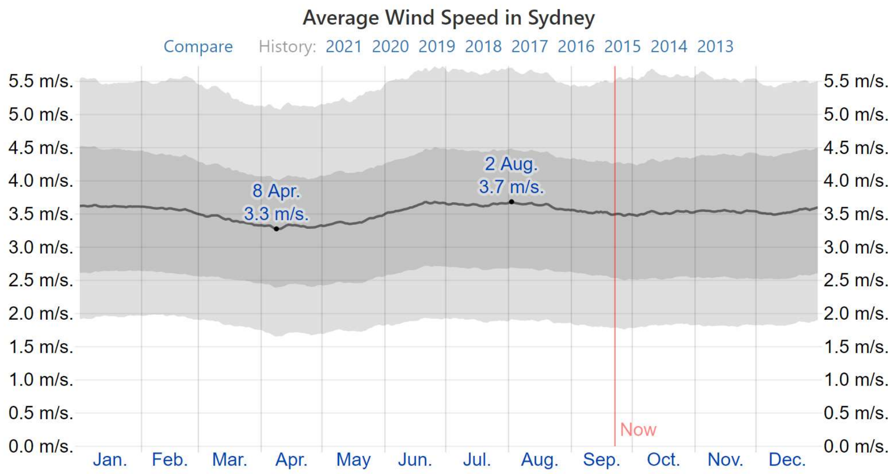
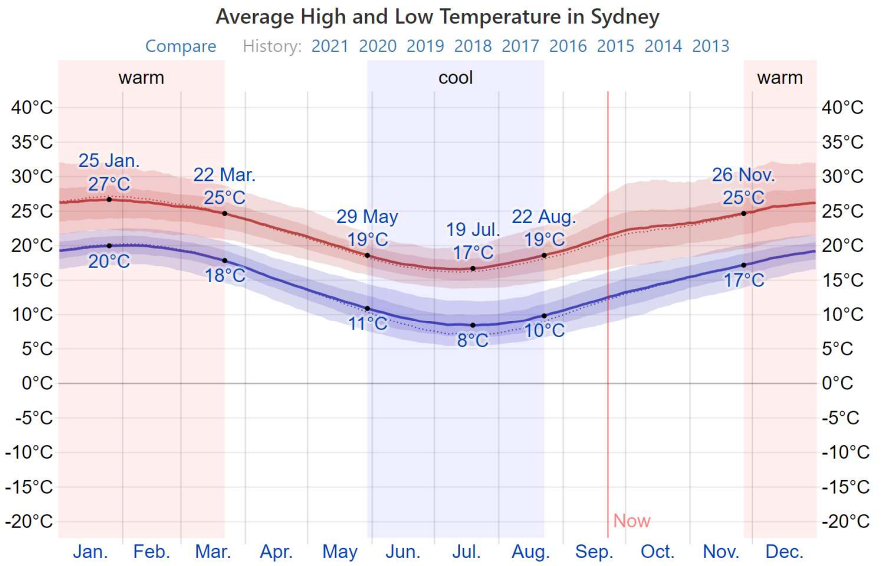


Figure 14: NSW Climate Zones



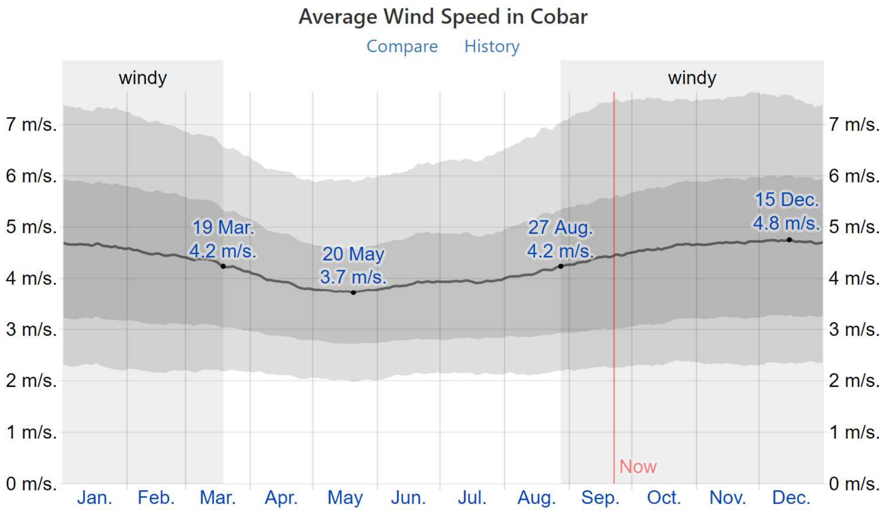
The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Graph 1: Average wind velocity in Sydney, NSW



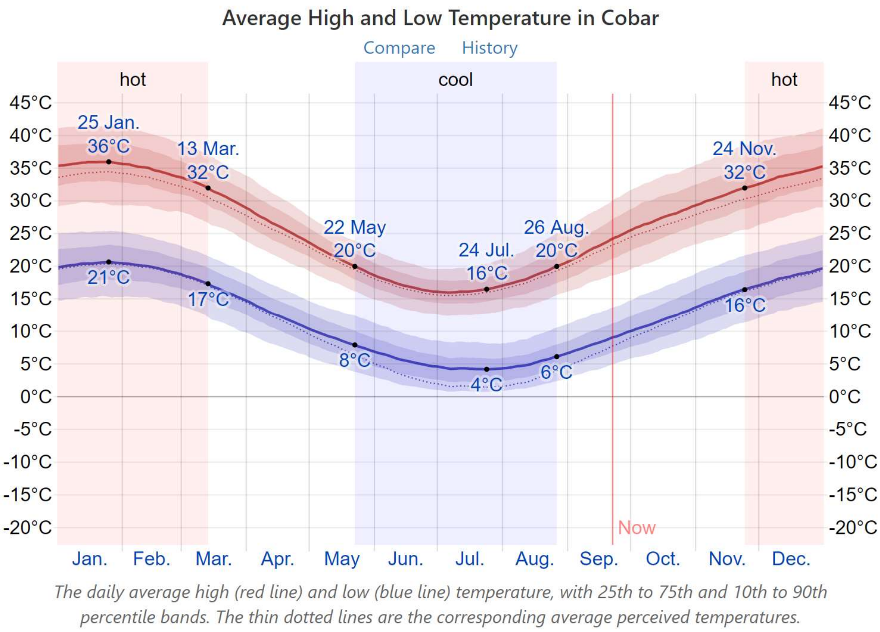
The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

Graph 2: Average high and low temperature in Sydney, NSW

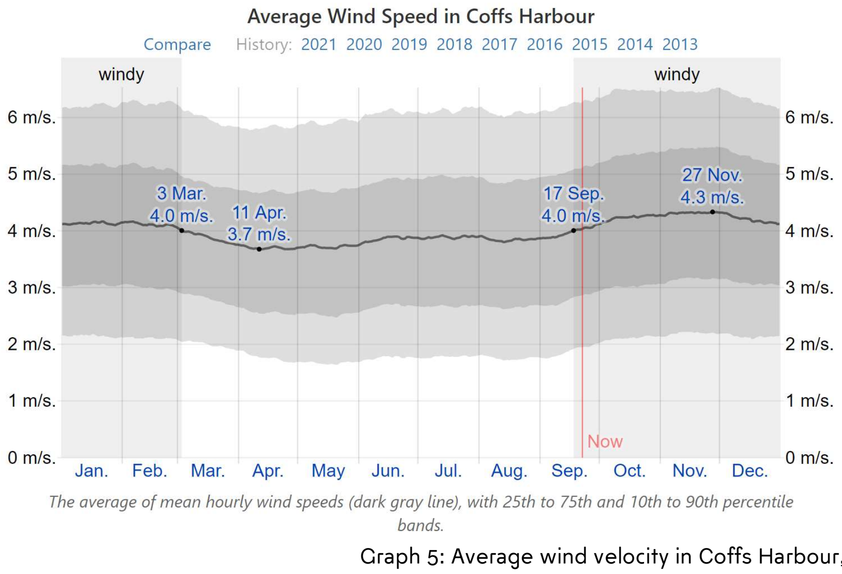


The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

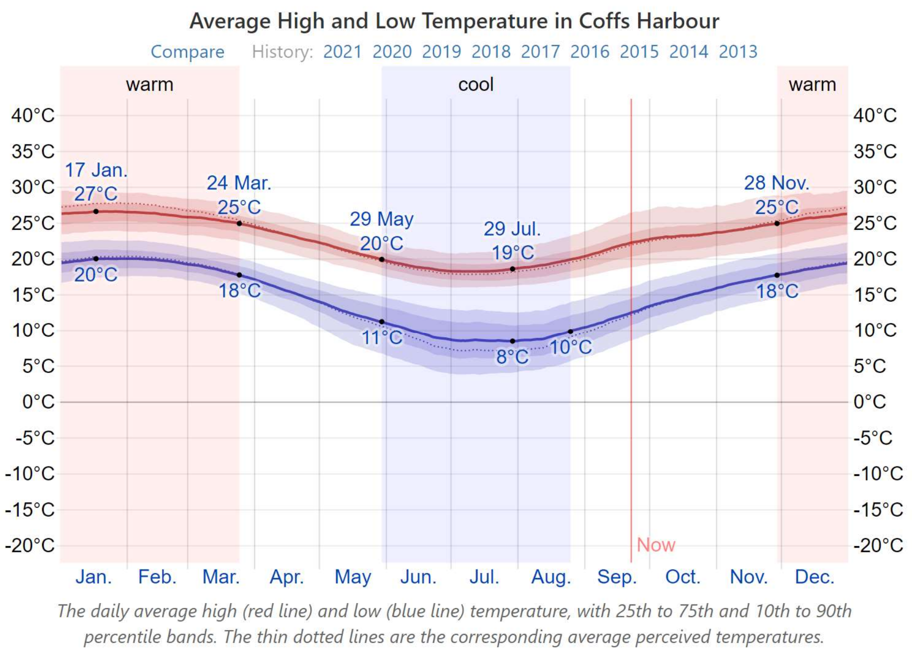
Graph 3: Average wind velocity in Cobar, NSW



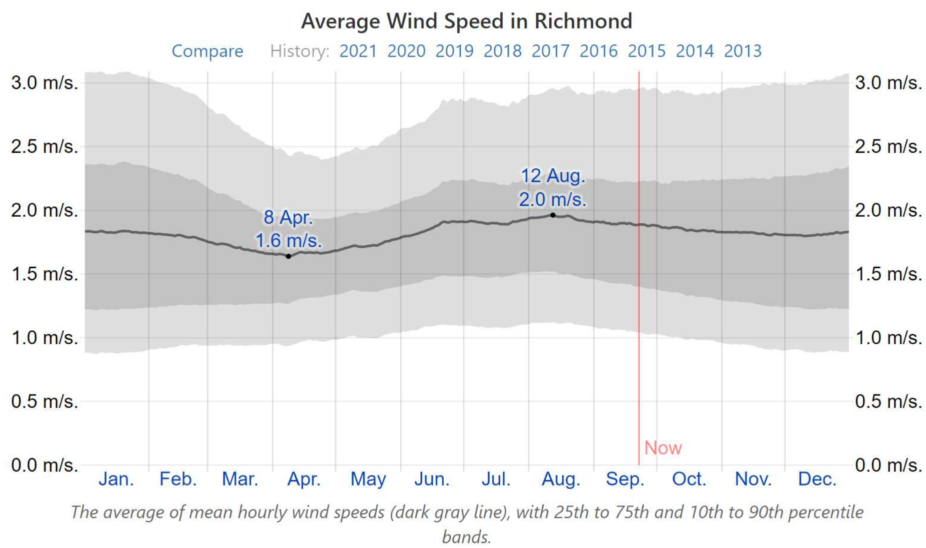
Graph 4: Average high and low temperature in Cobar, NSW



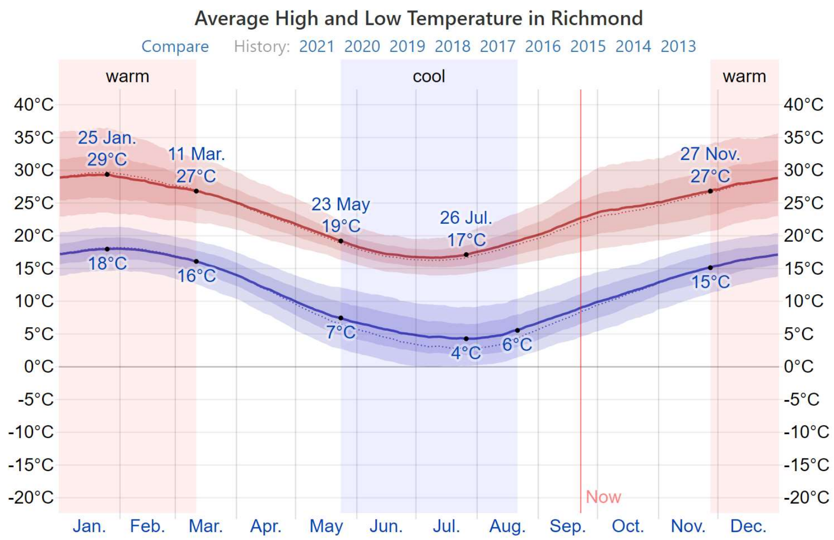
Graph 5: Average wind velocity in Coffs Harbour, NSW



Graph 6: Average high and low temperature in Coffs Harbour, NSW

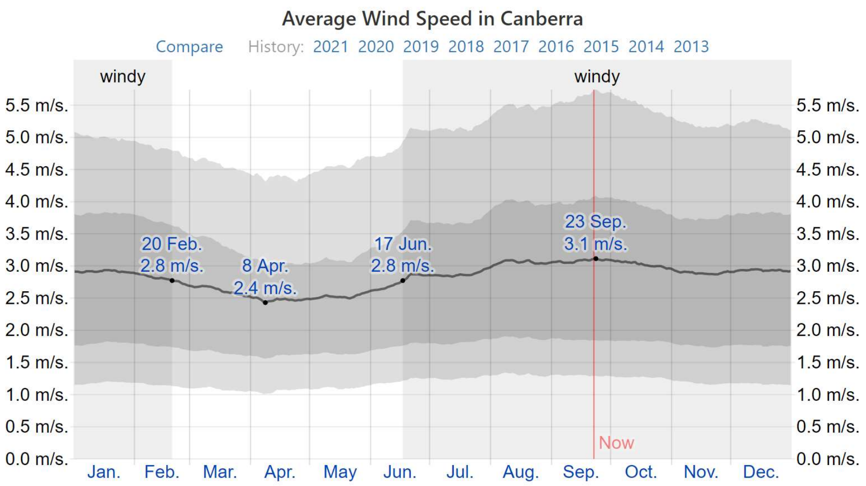


Graph 7: Average wind velocity in Richmond, NSW



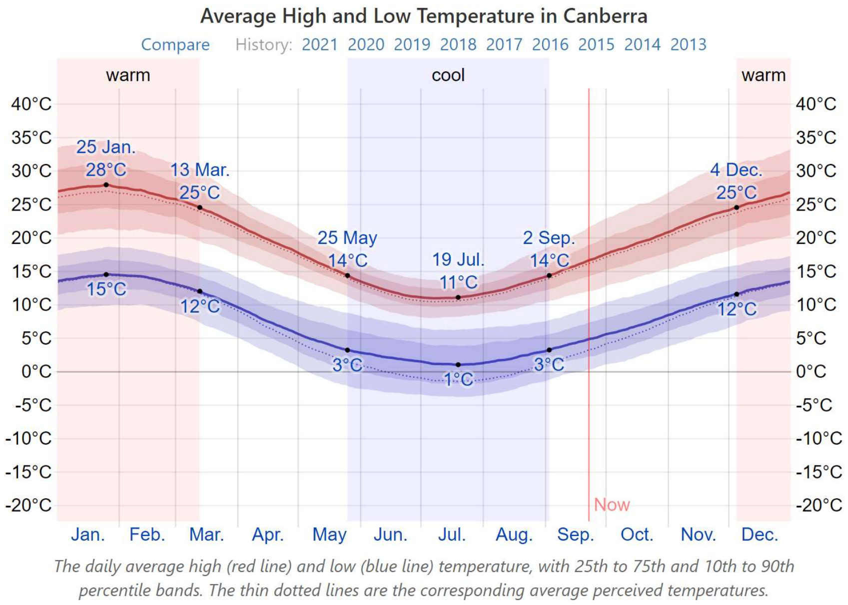
The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

Graph 8: Average high and low temperature in Richmond, NSW



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Graph 9: Average wind velocity in Canberra, ACT



Graph 10: Average high and low temperature in Canberra, ACT

The following tables show the results for two scenarios based on natural ventilation effect caused by temperature difference and secondly through the effects of external wind force.

The results of the high level assessment undertaken shows the typical classroom satisfies and exceeds the WHO roadmap first strategy approach of providing the nominated fresh air ventilation rate of 10 l/s per person. Additionally, the results also show satisfactory CO_2 levels in the typical classroom.

Case 1: Single sided ventilation by buoyancy forces alone i.e. no wind with high and low level openings.

Number of people present	26	
Required flowrate to achieve 10l/s/person	260	l/s
Discharge coefficient	0.61	
Outside temperature	22.5*	°C
Inside temperature	26.0	°C
Height between openings	1.2	m
Total opening free area required	2.296	m^2
Opening free area based on 5% of floor area	3.25	m^2

Table 6

*Estimated average temperature for selected locations.

Case 2: Single sided ventilation by buoyancy forces alone i.e. no wind with single opening

Number of people present	26	
Required flowrate to achieve 10l/s/person	260	l/s
Discharge coefficient	0.25	
Outside temperature	22.5*	°C
Inside temperature	26.0	°C
Height of opening	1.2	m
Opening free area required	2.802	m^2
Opening free area based on 5% of floor area	3.25	m^2

Table 7

*Estimated average temperature for selected locations.

Based on the assumptions made, the results presented in the tables above show that for a single sided natural ventilated 'typical' classroom, 2.296m² of free area of opening is required to provide 260 l/s of fresh air for single openings (case 1) and 2.802m² for high and low level openings (case 2), which is the minimum volume based WHO roadmap guideline. From a statutory compliance perspective the minimum free area required is 5% equating to 3.25m² which is greater than that calculated. Under this scenario, the 'typical' classroom is capable of providing a higher volume of fresh air to the classroom due to the greater free area of opening that should be available.

Reworking the calculations using an area of 5% free area or 3.25m², then for the conditions modelled the volume of fresh air increases to 300 l/s which would support a class size in theory of 30 people (29 students and 1 teacher).

Case 3: Single sided ventilation by wind forces alone

Required flowrate	260	l/s
Wind speed at building height	3	m/s
Flow coefficient	0.05	
Opening free area required	1.733	m^2
Opening free area based on 5% of floor area	3.25	m^2

Table 8

As expected with the presence of wind the ventilation rate is higher and the minimum ventilation rate of 260 l/s is easily achieved.

From an indoor air quality perspective, the average CO_2 level during the occupied school day for the typical classroom is 726 ppm based on a supply flow rate of 260 l/s which is below the NCC maximum of 850 ppm as a weighted average. Under the same conditions, for a class size of 30 the ppm of CO_2 rises to 772ppm.

When evaluating using the calculation method noted in the WHO guideline the minimum fresh air quantity is exceeded as shown in Figure 15.

7. Evaluating ventilation

Ventilation rate and airflow direction are key elements to be assessed and evaluated before undertaking any action on the ventilation system. This first evaluation will provide the baseline and allow the user to better understand the gap between the ventilation system functionality and the proposed requirements. A second evaluation should be carried out once improvement strategies have been implemented. Comparing the second evaluation with the initial baseline will provide an overview of the effectiveness of the implemented improvement strategies and a clear understanding of the new ventilation rate and flow.
Mechanical and natural ventilation systems require different methods to evaluate the ventilation airflow rate.

Point 1) Minimum ventilation rate – mechanical ventilation system. How to assess it?

Each mechanical ventilation system is designed for specific airflow rates. Consult the technical manual to verify the system capacity.

Point 2) Minimum ventilation rate – natural ventilation system. How to estimate it?

As a rule of thumb, wind-driven natural ventilation rate through a room can be calculated as follows *(20)*:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

k = 0.05 in the case of single-sided ventilation
k = 0.65 in the case of cross ventilation
in the case of mosquito net presence = ventilation rate x 0.5
wind speed: the wind speed refers to the value at the building height at a site sufficiently away from the building without any obstructions (e.g. at an airport) *(32)*

Figure 15: Extract from WHO, Roadmap to improve and ensure good indoor ventilation in the context of COVD-19

Number of students and staff	26	
L/s per person	10	
Minimum fresh air	260	l/s
Wind speed at building height	3*	m/s
Free area opening based on 5% of floor area	3.25	m^2

Table 9

*Estimated average velocity for selected locations.

Ventilation Rate (l/s) = 0.05 x 3 x 3.25 x 1000 = 487.5 l/s which is greater than the minimum quantity of 260 l/s recommended by the WHO guidelines.

Using Richmond wind data which has the lowest hourly mean average wind velocity of the indicative locations selected, the resulting ventilation rate is 260 l/s based on 1.6m/s

APPENDIX A

The following guidance note provides further details relevant to the selection and application of air cleaners in schools and has been included as reference for SINSW should air cleaners be procured.

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

An Roinn Oideachais
Department of Education

Room Air Cleaner Guidance for Schools.

May 2021

The implementation of the COVID-19 Response Plan is the means through which schools can best prevent the introduction and spread of COVID-19 and demonstrate that they are operating in accordance with the requirements of the Public Health advice from the Health Protection Surveillance Centre (HPSC) and the Return to Work Safely Protocol developed by the Health & Safety Authority. These documents are available at www.gov.ie/backtoschool. For information on ways to optimise ventilation, refer to the guidance provided in *Practical Steps for the Deployment of Good Ventilation Practices in Schools.*

Where the practical measures for the deployment of good ventilation practices have been undertaken, and poor ventilation continues to exist in a particular room/area, air cleaners may be considered as an additional measure in conjunction with other methods of ventilation that are available.

Room air cleaner selection is dependent on the particular setting and it is not possible to give a "one size fits all" solution, or a simple rule that everyone can follow.

The Air Infiltration and Ventilation Centre[1] notes that measures to reduce risk of exposure that causes COVID-19 from spreading indoors generally fall into three categories: source control, ventilation control and removal/ control.

Air cleaners can assist in removal control and provide an additional measure of precaution where poor ventilation exists. They should not be used to fully replace ventilation and should be used in conjunction with and to support other methods of ventilation that are available.

Some air cleaning units use ionising processes. Therefore care should be taken to avoid any devices that produce ozone or other chemicals as these may be a respiratory irritant.

Ultraviolet radiation (UVC) technology uses ultra violet lamps and has been typically utilised in areas such as healthcare settings to sterilise operating theatre type spaces. Ultra-violet lamps should not be used to disinfect hands or other areas of your skin and exposure of the eyes and bare skin to UVC radiation must be avoided.

Rooms cannot be occupied while direct UVC devices are activated and the lamps are emitting. Therefore use of direct UVC lamps is limited to sterilisation of spaces between uses and cannot assist with removal control during occupancy. UVC can feature in occupied spaces as an integrated part of an enclosed clean air unit. If considering direct UVC technology, professional advice should be sought from a Chartered Building Services Consulting Engineer.

You should consult with the air cleaner unit supplier to best match your requirements. This guidance document will help you understand the areas to consider during this consultation.

Air cleaner units can be purchased outright or rented from hygiene service suppliers and hire companies (these rental companies often maintain the units also).

If, following consultation with a supplier a school feels that their individual space may require specific technical specialist advice then the assistance of a Chartered Engineer or Registered Architect should be sought.

Room air cleaners are self-contained units that sit in the room they are to serve and must be plugged into an electrical power socket. They typically comprise a filter or multiple filters and a fan that sucks room air in over the filter system and discharges purified air back into the room. As air moves through the filter, pollutants and particles are captured.

When selecting an air cleaning unit the following should be considered and compared.

1. Matching the cleaning unit to the room in which it is to be located
2. The efficiency of the air cleaner
3. Filter types in the unit
4. Noise levels
5. Maintenance
6. Additional features

1.0 Matching the air cleaning unit to the needs of the room it is to be located in

It is important to select a unit that is capable of dealing with the needs of the space it is to serve. Small desktop devices aren't effective in large spaces, while larger air cleaners may be overkill in smaller rooms.

One metric included in air cleaning unit specifications is the unit's ability to deliver either air flow in m^3/hour or air change rate in air changes per hour (ACH). This metric is normally included in the air cleaning unit performance data sheets.

Additional reading and excel calculators are available online such as https://www.researchgate.net/publication/347575725_Guide_for_ventilation_towards_healthy_classrooms.

2.0 The efficiency of the air cleaning unit

Most air cleaners are labeled with a clean air delivery rate (CADR) number. The CADR defines an air cleaning unit's effectiveness in reducing particles and is typically expressed in m^3/hour. In general, the higher the number, the more particles the air cleaner can remove and the larger the room the device can reasonably be expected to clean.

To compare various units you can calculate the air change rate of cleaning equivalent to the air cleaner's CADR as:

$$\text{ACR(cleaning)} = \frac{\text{The CADR}}{\text{Volume of air in the room}}$$

Depending on the room volume and number of occupants you may need more than one unit. When calculating the room air volume be sure to exclude the volume taken up by built in furniture items.

Remember that you are using the air cleaner as a support to the natural ventilation and this should be taken into account when selecting your unit. It should be selected to bridge the ventilation gap in the short term until permanent ventilation solutions are put in place.

3.0 Filter types in the unit

Air cleaners typically use mechanical filtration, meaning that their filters physically trap the pollutants that pass through them. Air cleaners normally have at least two such filters: a pre-

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

filter, which catches large particles of dust, pollen, insects and animal hair, and the main filter, which nabs smaller pollutants. Typically, filters are made of paper, fibre (often fiberglass), or mesh, and require regular replacement to maintain efficiency.

The pre-filter is a filter that removes large unwanted contaminants from the air. They can be disposable or capable of being washed or vacuumed. The pre-filter also has a role in the extension of the life of the more sensitive filters that come after the pre-filter such as the HEPA filter. Air cleaners that are based on filtration with a HEPA filter are likely to be most effective.

HEPA stands for high-efficiency particulate air and it is an efficiency standard for air filters. HEPA filters trap 99.97% of particles that are 0.3 microns (millionths of a metre) or larger in size. To put that in perspective, the smallest objects that the average human eye can see are around 70 microns in size.

You may find devices that advertise "HEPA-type" filters but that aren't actually rated to meet a HEPA filtration level. Since individual HEPA filters aren't tested, it's hard to say that "HEPA-type" filters will always perform more poorly than actual HEPA filters. It is important that you <u>only</u> consider an air cleaning unit that says it uses HEPA filters or "True" HEPA filters, which amount to the same thing.

Some air cleaners have additional filters, such as activated carbon or charcoal, which trap gases, volatile organic compounds (VOCs) and odour compounds. These extra filters can be helpful in a smoky or pet environment but would be of limited value in a school setting.

4.0 Noise levels

As noted above most air cleaners have internal fans that pull air through a series of filters. Some of these fans are low noise emitting, especially on low settings, whereas others may be noisier as the speed is turned up.

It is important to choose a device that suits the required noise levels of the space the unit is serving. This can be assisted by selecting the unit that can deliver the required ACH and CADR at its mid/lower speed settings. For information on acoustic performance in various school spaces see https://www.education.ie/en/School-Design/Technical-Guidance-Documents/Archived-Technical-Guidance/TGD021-5-Acoustic-Performance-in-New-Primary-Post-Primary-School-Buildings.pdf.

5.0 Maintenance

Filters have to replaced periodically based on their usage. Therefore, it is necessary to keep a record of the unit's running hours and follow the manufacturer's recommendations on filter cleaning and replacement. It may be a good idea to have some spare filters in stock.

Filter-replacement costs vary from unit to unit. Some have very expensive filters that last for years, while others use cheap filters that have to be changed frequently. Some of the pre filters are washable. However, the HEPA filters themselves are disposable and must be entirely replaced. It is important to compare the replacement filter costs of the units you are considering.

6.0 Additional features

Some air cleaners have additional features, such as a filter-replacement indicator light, dimming and display shut-off options, programmable timer, remote control unit and smart functions (digital assistant and/or app integration). These extras may add a little bit of convenience which needs to be factored against the additional cost

Quick Summary Check List

There is no single air cleaner that's right for every situation. When you're buying or renting an air cleaner, consult with suppliers, determine the air volume of the space to be served, and ACR (cleaning) and have your suppliers give you the information on the CADR ratings and filter types and noise ratings and confirm to you how effective the air cleaning will be for your specific needs.

Comparison Table			
Items	**Model 1**	**Model 2**	**Model 3**
ACH			
CADR			
ACR(cleaning)			
Pre filter			
HEPA Filter			
Noise level			
Filter Replacement Interval			
Filter cost			

1. The Air Infiltration and Ventilation Centre (AIVC) is the International Energy Agency's information centre on energy efficient ventilation.

Copenhagen
London
Sydney
Canberra
Hong Kong
New York

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

APPENDIX B

Following is the Arup peer review report.

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

Memorandum

ARUP

To	SINSW	Date	2 October 2021
Copies	Barry Tam, Anthony Manning	Reference number	SINSW/Peer review
From	Julian Soper	File reference	
Subject	COVID Guidance for SINSW Classrooms Peer Review		

1 Introduction

This memorandum provides an independent peer review for SINSW of the following document:

- Consultant Advice Note COVID Guidance for SINSW Classrooms 30th September 2021 Revision 2- by Steensen Varming

The qualifications and author of this memorandum is:

Julian Soper

MIEAust CPEng

NPER 3611392

MCIBSE, CEng, MEng Engineering Science

2 Findings

Basis of design

The advice note correctly references and uses appropriate industry standard technical guidance including:

- WHO Roadmap to improve and ensure good indoor ventilation in the context of Covid 19 (2021)
- CIBSE AM10
- ASHRAE Guidance Notes
- NCC2019
- AS 1668

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

Memorandum

Limitations

The advice note correctly notes a number of limitations including:

- Ventilation and air quality are one of many layers needed to address Covid 19 transmission
- There is no zero risk scenario

Design Criteria

The advice note assumes:

- Classroom size and population is appropriate- 65m2 and 25 pupils plus one teacher
- Single sided natural ventilation is correctly noted as the worst case scenario for naturally ventilated classrooms
- For buoyancy driven flow calculations an internal classroom temperature of 26 deg C at an external temperature of 22.5 degC is appropriate.
- NCC compliant classrooms windows should have a free area of 5% of the floor area- this is appropriate.
- It appears that 1.5m window height is assumed, but this is not clear (see below)
- 4.3 correctly notes air purifiers should be considered for mechanically ventilated classrooms where a minimum of 10 l/s fresh air ventilation cannot be achieved- which is the same as the WHO guidance.

Calculation Methodology and Results

Section 4.6 of the advice note outlines the calculation methodology and results. The following comments apply to this section:

- **Case 1 buoyancy driven ventilation**. It is not explicitly stated which equations and calculation procedure have been used to generate the results. It is assumed it would be the procedure outlined in CIBSE AM10 for case 1 as follows:

Memorandum

Case 1: Single-sided, two vents, buoyancy driven

This case represents single-sided ventilation through two identical vents driven by buoyancy alone, see Figure 4.9.

The area A of each opening required to give a ventilation rate q for a specified value of h is:

$$A = \frac{q}{C_d} \sqrt{\frac{(T_i + 273)}{\Delta T\, g\, h}} \qquad (4.12)$$

where A is the area of each opening (m^2), q is the ventilation rate (m^3·s^{-1}), C_d is the discharge coefficient, T_i is the internal temperature (°C), ΔT is the difference between the internal and external air temperatures (K), g is the gravitational force per unit mass (m·s^{-2}) and h is the height between the openings (m).

A typical value for C_d is 0.6.

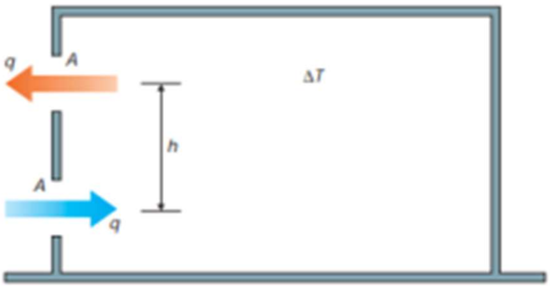


Figure 4.9 Case 1: single-sided ventilation, two identical openings, driven by buoyancy alone

Case 2: Single-sided, single vent, buoyancy driven

This case represents single-sided ventilation through an open window driven by buoyancy alone see Figure 4.10.

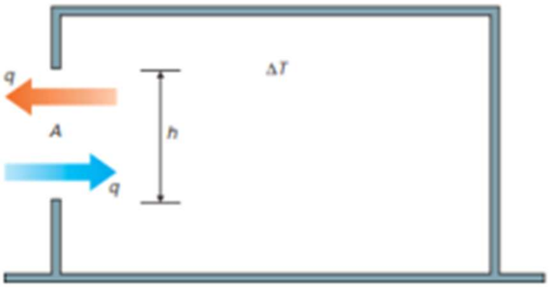


Figure 4.10 Case 2: single-sided ventilation, single opening, driven by buoyancy alone

Level 8, 9 Castlereagh Street
Sydney, NSW, 2000, Australia
ABN 50 001 189 037
t : +61 / 02 9967 2200
e : info@steensenvarming.com

Memorandum

> The area required to give a ventilation rate through a single opening of area A is again given by equation 4.12 but in this case h is the height of the single opening rather than the distance between openings.
>
> Case 2 is basically the same as case 1, but the value of C_d is typically 0.25. This is lower than the value in case 1 partly because only half the area A is available for air entry.

The author of this memorandum undertook his own calculation according to the case 1 methodology which resulted in a predicted total window free area of 2.06 m2 based on a vertical window height of 1.5m using the same temperature differentials. This is lower than the predicted window free area of 2.802m2 noted in table 6 as illustrated below:

Cases 1: Single sided ventilation by buoyancy forces alone i.e. no wind

Number of people present	26	
Required flowrate to achieve 10l/s/person	260	l/s
Discharge coefficient	0.61	
Outside temperature	22.5*	°C
Inside temperature	26.0	°C
Size of opening required	2.802	m^2
Size of window openings based on 5% FA	3.25	m^2

Table 6

This does not change the outcome of the recommendation (as the size of opening required is still smaller than the size of window opening based on NCC compliance/5% FA). It may be an assumption based on window height that is different and this is useful to know when assessing existing classrooms.

- **Case 2 Single sided ventilation by wind forces alone**

This calculation methodology uses the methodology outlined in the WHO Roadmap to improve and ensure good indoor ventilation in the context of Covid 19 (2021). The author checked this calculation and came up with the same results.

- **CO2 level calculation**

This calculation methodology is clearly stated and results appear to be appropriate and typical based on the ventilation rates used (the author did not check these in detail)

Memorandum

Other observations

- Both the WHO methodology and the Advice Note make note of flyscreens needing to be accounted for as they slightly reduce natural airflow. The calculation methodology and results in the Advice Note clearly state window free area, but when assessing actual window opening size, fly screens should be taken into account
- The Advice Note states it does not make an assessment of comfort criteria- specifically as this will be reduced during hot summer conditions when the effect of local air conditioning will be reduced with windows open to maintain high levels of airflow. Indeed, due to high internal/external temperature differentials during hot conditions, window openings are likely to be able to be reduced to maintain similar airflows. High external noise in some locations could also reduce internal comfort.
- The advice note mentions there will be operational challenges with ensuring windows are open prior and after lessons take place- security etc. This will require extra management.

3 Conclusion

- There are no obvious significant technical errors within the Consultant Advice Note
- Reference documents, assumptions and limitations appear to be appropriate
- Calculation methodology for 'Case 1 buoyancy driven ventilation' should be included in the Advice Note in the form of governing equations and assumptions for all parameters, so the results can be easily replicated.
- When assessing existing classrooms for compliance, fly screens should be accounted for (if present)
- Noting the limitations in the report for situations where fully open windows for maximum natural ventilation will introduce other issues such as:
  - Discomfort when outdoor ambient air temperatures are high
  - High external noise conditions leading to discomfort
  - Security issues opening and closing windows in the morning and night
- For the above it is assumed that SINSW will provide additional change management support to teachers and maintenance staff at schools during the transition period that schools are opening.