MINISTRY OF EDUCATION
TE TĀHUHU O TE MĀTAURANGA

Designing Schools in New Zealand (DSNZ)

Designing Quality Learning Spaces (DQLS)

Indoor Air Quality and Thermal Comfort

Version 2.0, February 2022

Document History

The table below is a record of the changes that have been made to this document.

Revision date	Version	Summary of changes
September 2017	1.0	First version for general release: • amalgamated two 2007 Designing Quality Learning Space guidance – Heating and Insulation, and Ventilation and Indoor Air Quality • substantial changes to content to reflect current teaching practise and flexible learning space design • document rewritten for a target audience of architects, designers and engineers involved in the design and specification of schools • Ministry requirements were marked as ‘mandatory’ or ‘recommendation’ to make them easy to find throughout the document
February 2022	2.0	Second version for general release: • document updated to align with the Ministry’s Te Rautaki Rawa Kura - School Property Strategy 2030 • document rewritten to separate the mandatory requirements from the design guide to enhance navigation and readability • improved mandatory performance requirements for air quality, thermal performance, overheating hours and fresh air openings or delivery • inclusion of climate-based heating, ventilation & cooling requirements & recommendations • inclusion of Life Cycle Cost Analysis (LCCA) calculator • improved insulation requirements • updated climate zone map • inclusion of design and built verification methodologies

Foreword

The Designing Quality Learning Spaces (DQLS) series of documents has been prepared by the Ministry of Education (the Ministry) and a panel of expert advisors. Compliance is mandatory for all projects starting the design phase after 1 July 2022.

This document was first released by the Ministry of Education in partnership with the Building Research Association of New Zealand (BRANZ) in 2007 as two separate guides: *Heating and Insulation*, and *Ventilation & Indoor Air Quality*. These were combined and updated in 2017 as *Indoor Air Quality and Thermal Comfort, Version 1.0*.

Changes have been made in this latest version to better align with industry best practice, the latest research, feedback received from the design review process, and responses to a wide range of technical queries.

The mandatory requirements have also been strengthened to support the Ministry's objectives in Te Rautaki Rawa Kura - School Property Strategy 2030, in particular the objective of providing quality learning environments to support teaching, learning, and the wellbeing of everyone on a school site.

Although the mandatory requirements have been developed as a result of best practice and specific Ministry requirements, it is not intended that this document addresses every conceivable scenario. Instead, it provides solutions where experience has indicated that problems commonly arise and has been structured for continual improvement to incorporate new research, technologies, developments, concepts, and feedback.

This document is freely available for download from the Ministry's Property pages.

Background

The Ministry owns one of the largest property portfolios in New Zealand, with more than 15,000 buildings and over 35,000 teaching spaces distributed across more than 2,100 schools. Learning space design and upgrades are commissioned through various mechanisms – nationally via Ministry-led programmes, regionally through the Ministry's Property Advisory divisions, and locally through schools' Boards of Trustees.

The objective of this indoor air quality and thermal comfort document is to ensure that the design and construction of school buildings provide quality physical environments that support effective teaching and learning. The requirements are not intended to be prescriptive to the degree of restricting thinking, but it is intended that the information provided will help facilitate school design that represents the best value for expenditure, while supporting a variety of teaching and learning styles.

Acknowledgements

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David Fullbrook *(eCubed Building Workshop)*	Renelle Gronert *(Senior Manager, School Design, Ministry of Education)*
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The Ministry would like to thank Design Review Panel (DRP) members and BRANZ for reviewing this document, and Prendos New Zealand Limited for preparing the illustrations.

Feedback, Review Date

Where architects, engineers, designers, building scientists or users have feedback, they are encouraged to contact the Ministry through the School.Design@education.govt.nz mailbox to facilitate continual improvement and usability of this document. Your feedback will be reviewed and, where suitable, incorporated into future amendments.

Scotty Evans

Head of TPHM-Te Puna Hanganga, Matihiko | Infrastructure & Digital

Contents

Colours and Hyperlinks in this document

Every underlined word is a hyperlink

It may be a defined term that takes you to the glossary, a reference or a link to a webpage that explains a concept in more detail or gives background information. Hovering your pointer over a hyperlink will give you information about that link and clicking it will take you there.

Using this document

In this document, the use of the word ***"must",*** **"required" and "requirement"** indicate that adherence is mandatory.

The use of the words ***"should"*** and ***"recommendation"*** mean that there may exist valid reasons or circumstances where a requirement cannot be met. In such cases the full implications must be understood and carefully weighed by designers before choosing an alternative approach.

New Projects: For new buildings, the Ministry's performance requirements must be met.

Existing Buildings: For major upgrades or redevelopments, the Ministry's performance requirements must be met where reasonably practicable. Project constraints that prevent requirements being met should be identified early by conducting a gap analysis to determine where DQLS requirements can be achieved and where they cannot. Design Teams are expected to present their findings during Master Planning or Preliminary Design to the Ministry for discussion, review and sign off.

Introduction

Purpose and Scope

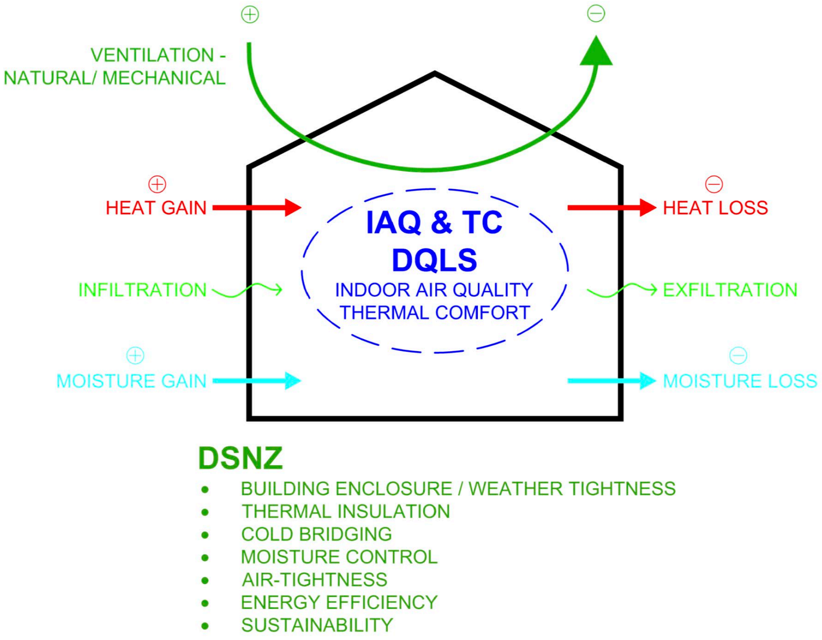
This document is part of the Ministry of Education's Designing Quality Learning Spaces (DQLS) suite of design requirements for building quality learning environments for schools. The DQLS series covers the four main internal environmental quality factors: indoor air quality and thermal comfort, lighting and visual comfort, and acoustics requirements. Together, these DQLS documents provide the Ministry's requirements for the internal environment within school buildings.

The closely related *Designing Schools in New Zealand - Requirements and Guidelines* (DSNZ), is the overarching guidance document for school design. The document provides the Ministry's requirements for planning and designing school buildings. The forthcoming revised DSNZ document will also include requirements on weathertightness, thermal insulation, bridging, moisture control, airtightness, energy efficiency, and sustainability.

The distinction between the DQLS & DSNZ documents relates to the different audiences, skills, and responsibilities associated with each document. The DQLS – Indoor Air Quality & Thermal Comfort (DQLS – IAQ&TC) is primarily aimed at Building Services Engineers, and the DSNZ is aimed at Architects and Building Enclosure Specialists.

Knowledge of all the DSNZ and DQLS documents is encouraged across all building disciplines, so that designers have a holistic understanding of school building design. Collaboration between disciplines within procured design teams is essential to achieving all the Ministry's requirements for school buildings.

This DQLS – IAQ&TC document has been developed to provide technical requirements to assist architects, designers and engineers in creating quality physical learning environments that are fit for purpose, and technical guidance for property managers undertaking school projects.



Relative scopes of the DSNZ & DQLS – IAQ & TC documents

The requirements set out in this document apply to all new buildings, including extensions, pre-fabricated, and any new contracts for modular buildings. The requirements also apply to refurbishments of existing school buildings, to significant alterations, and to temporary learning spaces that are used at a school for more than 28 days.

Overall purpose of the DQLS – IAQTC document
• To provide IAQTC performance standards that are appropriate to, and consistent across, school facilities
• Create spaces and environments that are comfortable and that support the educational delivery process across different teaching styles and practices
• Set mandatory minimum requirements that are part of achieving quality learning environments
• Set a basis for evaluating the IAQ & TC performance of project design submissions
• Set a basis for evaluating the IAQ & TC performance when undertaking Post Occupancy Evaluation (POEs)
• Facilitate school design that represents best value for expenditure while supporting educational outcomes

Compliance and Verification

In order to demonstrate compliance with the mandatory requirements, design teams must submit the completed Indoor Environmental Quality (IEQ) Design Report with their design. This will also be used as the basis for POE assessments. In some cases, a modelling report will be required to support the recommendations and system selections identified in the IEQ Design Report.

This document is divided into five sections:

- Section 1 specifies the **mandatory requirements** for indoor air quality & thermal comfort, which design teams must be able to demonstrate compliance
- Section 2 provides **a summary** of the Ministry's thermal and ventilation requirements and recommends a range of design solutions
- Section 3 specifies **requirements** and provides additional **guidance** for the upgrade of existing buildings
- Section 4 specifies **mandatory requirements** and provides **guidance** for specialist learning spaces and ancillary spaces
- Sections 5 provides **verification methods** to which design teams must adhere. This section sets out design compliance documentation required as part of the IEQ Design Report, as well as built verification requirements
- The Appendix provides the **rationale** behind the mandatory requirements contained in this document

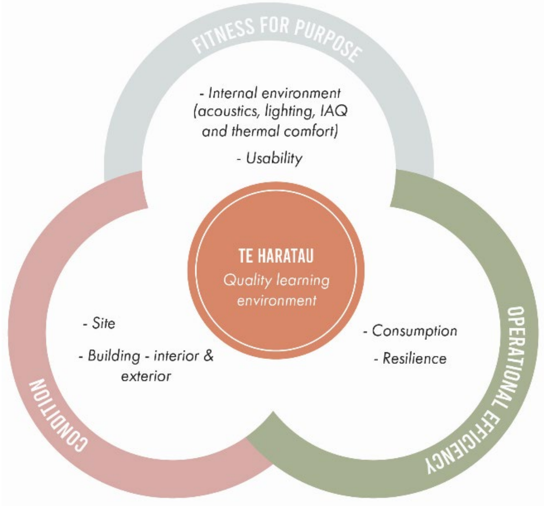
Lifting the Quality of New Zealand Learning Environments

Government has set a target of all schools providing quality learning environments by 2030 to enable students and teachers to thrive in environments that support their success. Te Rautaki Rawa Kura – the School Property Strategy 2030 has four objectives:

- **Quality Learning Environments** – school property meets agreed standards to support teachers to succeed
- **Sustainable Portfolio** – policies, planning and investment optimise long-term social, environmental and economic benefits
- **Well-managed Property** – everyone understands their role in managing school property and is supported to deliver
- **Equitable Outcomes** – diversity is recognised, and schools and students with the greatest needs are prioritised

These objectives for the quality of school property, have provided the Ministry the unique opportunity to develop a cohesive model for collecting and analysing performance data based on an assessment of Fitness for Purpose, Assest Condition Assessment and Operational Efficiency to determine the "quality" of school assets for property planning and making evidence-based decisions. The model consists of three interrelated objectives for the delivery of quality learning environments, as set out in **Table 1**.

Table 1: The three main interrelated aspects of the model

The Model		
1	Fitness for Purpose - Internal environment (lighting, acoustics, thermal comfort and air quality) and usability. Data sourced through internal environment monitoring and user feedback through the School Evaluation of the Physical Environment (SEPE) tool.	 *Te Haratau Model*
2	Asset condition assessment – data relating to condition grade and remaining useful life for building and site elements is sourced through detailed condition assessments.	
3	Operational Efficiency - Energy and water consumption, resilience, and maintenance costs. Data is sourced through a range of approaches.	

The model captures data across these key aspects to provide information about a school's buildings and site. The DQLS requirements provide the framework for assessing the 'fitness for purpose' internal environmental quality aspect. For example, when reviewing data about CO_2 levels and air temperature within a learning space, the acceptable ranges will be determined by reference to the DQLS requirements (refer to Sections 1.1.2 & 1.2).

Understanding Internal Environmental Quality

Internal environmental quality refers to the entire quality of a building's environment in relation to the health and wellbeing of the occupants within it. Internal environmental quality is determined by many factors such as:

Internal Environment Quality Factors	
1	**Lighting and Visual Comfort** – illuminance, luminance ratios, view, reflection, etc.
2	**Acoustic Quality** – noise from indoors, outdoors, vibrations, etc.
3	**Indoor Air Quality (IAQ)** – outdoor air supply, odour, indoor air pollution, etc.
4	**Thermal Comfort** – temperature, air velocity, relative humidity, moisture, etc.

There is strong evidence that good indoor air quality, temperature, humidity, acoustics, and lighting support educational outcomes (Barrett et al., 2015; Wall, 2016; Ackley et al., 2017; Ackley, 2021a). A United Kingdom study of 3766 students in 153 classrooms in 27 schools identified seven key design parameters that together explain 16% of the variation in students' academic progress. These design parameters were Light, Colour, Temperature, Air Quality, Ownership, Flexibility, and Complexity (Barrett et al., 2015).

Better internal environmental quality in learning spaces could support teachers/kaiako and learners/ākonga to succeed. Learning can be impeded if poorly ventilated rooms result in unwanted thermal effects (both through temperature and humidity) and lead to high levels of carbon dioxide, which could cause drowsiness (Ackley, 2021b). Indoor air pollutants can be odorous and could irritate the nose and eyes, causing itching and other negative reactions impeding learning.

With regard to sound, poor auditory conditions inside a room could make hearing difficult or undermine auditory privacy. Also, poor lighting conditions cause visual discomfort, which can lead to eyestrain and headaches and can disturb the circadian rhythm. Research on biological lighting demands has revealed that the dosing of daylight is important for health purposes. The amount of light that enters the eye affects our bio-rhythm: more light supresses melatonin production, thereby making us more awake and alert.

The Ministry is committed to providing better internal environmental quality in learning spaces to achieve the objectives of the Te Rautaki Rawa Kura – The School Property Strategy 2030. Setting standards for, monitoring, and evaluating internal environmental quality are extremely important across all stages of the building process: design, construction, commissioning, operation and renovation.

The built internal environment is considered a system with sub-systems that do matter, but the system will only function if all sub-systems (components) are optimised along with the total system, whether this is related to health, comfort or sustainability issues. Internal environmental quality factors are one of the key sub-systems that are interrelated in a building (**Figure 1**).

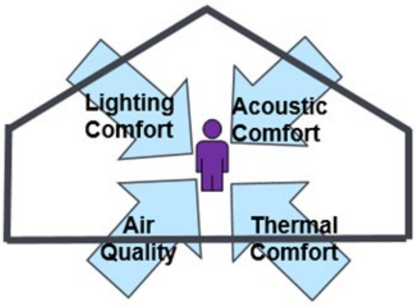


*Figure 1: What is internal environment quality? Source: **Bluyssen, (2009)***

These factors must be considered during the design phase so that comfort is achieved. A holistic approach is essential, and no single internal environmental quality factor should be altered without assessing its effect on all the others. This is because they interact with one another e.g., achieving good daylighting must be balanced against possible uncomfortable heat gain from the sun, and the need for ventilation can increase noise levels inside.

Given the complex nature of the internal environment, design teams must ensure that the indoor air quality and thermal comfort requirements set out in this document are applied together with the requirements set out in the other DQLS series of documents (acoustics, and lighting and visual comfort).

This document sets out requirements and guidance that will produce acceptable air quality and thermal conditions to the majority of occupants in a learning space.

To ensure that all new buildings and refurbishments provide comfortable environments, designers must consider the effective control strategies in **Table 2**.

*Table 2: Internal environment quality factors, parameters, and effective control strategies. Adapted from **Bluyssen, (2009)***

Description	Lighting Quality	Acoustic Quality	Air Quality	Thermal Quality
Parameters	• Illuminance and luminance • Reflectance(s) • Colour temperature and colour index • View and daylight	• Sound level (s) • Reverberation time • Frequency spectra • Speech intelligibility • Sound insulation	• Pollution sources • Carbon dioxide concentrations • Types of pollutants • Ventilation rate and efficiency	• Temperature (air and radiant) • Relative Humidity • Air velocity • Activity and clothing
Control	• Daylight harvesting • Luminance distribution • Electric lighting	• Acoustic design • Sound absorption • Sound insulation	• Source control • Operable windows • Ventilation systems • Maintenance • Air cleaning • Activity control	• Building design (e.g., insulation, façade, etc.) • Heating and cooling systems

Importance of Good Indoor Air Quality and Thermal Comfort

Good Indoor air quality and thermal comfort is very important to people's health and wellbeing and has a direct impact on the usability of a space and on learning outcomes.

Figure 2: The connection between physical health, mental wellbeing, & academic achievement (Source: derived from the Schools for Health Program, Harvard T.H. Chan School of Public Health).

There is clear evidence that school aged children have greater susceptibility to some environmental pollutants than adults because they breathe higher volumes of air relative to their body weight, and their body tissue and organs are actively growing. Children also spend more time in school than in any other environment except home. Indoor air quality is dependent on the concentrations of CO_2 and other respiration derived pollutants, volatile organic compounds (VOC), particulate matter and other pollutants such as formaldehyde.

The primary strategies for maintaining good indoor air quality are:

- providing suitable ventilation with clean fresh air
- selecting low VOC building materials
- maintaining a good cleaning programme
- using entry/exit mats to capture dust and dirt before they are brought into the building.

Children are also more sensitive to higher temperatures than adults, and they generally prefer conditions to be a few degrees cooler due to their higher metabolic rates and higher activity levels over the course of a school day.

In reality, what feels comfortable is not just related to air temperature, but also to relative humidity, surrounding radiant temperatures, air movement, occupant activity levels and clothing worn. ‘Comfort’ inside naturally ventilated buildings have been found to be related to the prevailing outdoor temperature, and in particular to the running average external temperature experienced in the preceding few days. Comfort expectations of staff and students will adapt accordingly to this experience of external temperature.

Figure 3: An example of a large open learning space. Multiple learning activities are taking place in different areas with varying occupant numbers throughout the space.

Ventilation and Covid-19

The provison of adequate ventilation has an important role to play in reducing the transmission of Covid-19. The updated design requirements and recommendations contained in this document will help to ensure that school buildings are healthy and comfortable. These include:

- improved performance requirements for fresh air openings or delivery
- climate-based heating, ventilation & cooling requirements & recommendations
- robust design verification procedures to ensure that designs are compliant, including modelling of larger buildings

- requirement for indoor environmental monitoring devices in all teaching spaces, which will inform ventilation system operation.

The Ministry will continue to review the latest public health research and will up-date its building design guidance as appropriate.

Good building design is only one part of providing healthy learning environments. Buildings must also be appropriately operated and maintained. This may mean opening and closing windows to achieve good internal conditions or adjusting mechanical ventilation settings and regularly cleaning air filters. Operational advice on how to ventilate learning spaces to minimize the transmission of COVID-19 can be found on the Ministry’s website through the link Ventilating Schools.

Building for Climate Change

In order to mitigate the effects of climate change, changes are being considered to building regulations. In addition to the DQLS suite of documents, designers should consult a range of other guidance documents to remain updated on prospective changes. These include:

- **Building for Climate Change Summary Report** (MBIE, 2021)
- **Weathertightness Design Standards for School Buildings** (MoE, 2023)

Section 1: Mandatory Requirements

This section quantifies the Ministry's mandatory performance requirements for indoor air quality and thermal comfort. These performance requirements have been set to enable the design and upgrade of schools in line with the Ministry's expectations about the way physical spaces will support a variety of teaching and learning approaches, while providing adequate levels of comfort, and ensuring an environment conducive to good health and wellbeing.

In addition to the requirements contained in this section, further requirements pertaining to the upgrade of existing buildings are contained in Section 3, and requirements pertaining to specialist and ancillary spaces are contained in Section 4.

Design teams must comply with the following:

- **Air Quality Requirements** – **Section 1.1**
- **Indoor Temperature Requirements** – **Section 1.2**
- **Thermal Performance Requirements** – **Section 1.3**
- **Systems & Specialist Components Requirements – Section 1.4**
- **Life Cycle Analysis Requirements – Section 1.5**
- **Monitoring & Control Requirements – Section 1.6**
- **Requirements & Recommendations for Existing Buildings – Section 3**
- **Workshop Technology Spaces – Section 4.5**
- **Science & Laboratory Spaces – Section 4.6**
- **Food Technology & Cafeteria Kitchen Spaces – Section 4.7**
- **Server Rooms & IT Equipment Cupboards – Section 4.8**
- **Toilets – Section 4.9**

The Ministry's requirements and recommendations given in this DQLS document are intended to apply to all school projects. The extent to which upgrades to existing buildings should meet these requirements and recommendations will depend on the nature and scale of the upgrade.

A major upgrade would be expected to meet all or most of the requirements and recommendations, whereas a minor upgrade should target specific requirements and recommendations where the works involved are practically capable of achieving them.

Project constraints that prevent requirements being met should be identified early, by conducting a gap analysis to determine which DQLS requirements can be achieved, and which cannot. Design teams are expected to present their findings during Master Planning/Preliminary Design to the Ministry for discussion, review and sign off.

The Ministry's mandatory minimum requirements are designed to go beyond the minimum standards required by the New Zealand Building Code (NZBC) to ensure that appropriate levels of comfort, ventilation and temperature control are provided to support good education outcomes in our learning spaces.

These requirements draw on a variety of relevant national and international best practice standards and guides. They have also been informed by thermal modelling of a typical school building. Refer to the Appendix for a discussion of the rationales behind the requirements and recommendations contained in this document.

Local environmental factors will also have significant implications for all aspects of the building design. Consideration of site-specific environmental factors is a key part of the design optimisation process, and a key part of these requirements.

Design teams should develop specific design solutions that ensure good and balanced performance outcomes across all parameters. The specific design solutions should consider and address the future impacts of climate change, including increased air temperatures, severe storms, and extended periods of drought.

1.1 Air Quality Requirements

Key Points

- The Ministry prefers natural, or mixed-mode ventilation, with full mechanical ventilation systems as a last resort only.
- Mixed mode ventilation should be provided in cold climate zones.
- Ventilation strategies must maintain CO_2 concentrations within stipulated limits; design compliance must be demonstrated either through a design statement or through modelling, depending on the building size and ventilation system type.
- Most carpets, paints and ceiling materials must be low-VOC and compliant with an approved certification scheme.
- Where systems containing refrigerants are specified, these must be designed to ensure that safety standards and refrigerant charge limits are adhered to.

1.1.1 Outdoor Air Supply

> “Kia tūpato koutou ki ō koutou whare he mea whakakikī puru kit e tangata, hore he putanga mō te hau haunga, hore he tomonga mō te hau ora e noho tawhio ana I waho o ō koutou whare”
>
> You should be careful with your buildings when they are crammed full of people and there is no outlet for the stale air, no inlet for fresh air which is located around the outside of your houses. Te Korimako
>
> (Māori-language newspaper) March 1888

To meet design requirements, there are a range of ventilation strategies from natural, mixed mode or full mechanical systems that can be explored.

Design teams are expected to determine the appropriate ventilation strategy, taking into consideration:

- climate zone
- the micro-climate
- building layout
- orientation
- glazing and solar gain
- external noise levels and transmission
- sources of pollution
- occupancy
- usage patterns
- energy use
- greenhouse gas emissions

The constraints of the project will determine which ventilation strategy is appropriate to be used. There is no ‘one size fits all’ ventilation strategy. The following requirements apply to ventilation design.

Mandatory Requirements

- Natural ventilation can be achieved by any one of the following:

  - Single-sided ventilation, when:
    - the depth of the space is to be no more than twice the floor to ceiling height at its lowest point (CIBSE: AM10, 2005), and
    - total opening area is more than 10% of the floor area, and
  - Cross-ventilation when:
    - all parts of the enclosure are within 7 m of an openable window, and
    - in compliance with AS1668.4:2012 Section 3.5; or a total opening area ≥ 5% of the floor area, distributed across at least two sides, whichever is the greater, and
    - openings are distributed approximately proportionately on each outside wall

- A fully modelled design verification analysis of natural ventilation performance, in accordance with Section 5, is required for all naturally ventilated spaces in buildings ≥600m^2 GFA. This should demonstrate that the maximum CO_2 levels given in **Table 3** are achievable.

- Ventilation modelling is not required for small (<600 m^2 GFA) buildings. A design statement should instead be provided for naturally ventilated spaces in small buildings. Refer to Section 5 for Design Verification requirements.

- Where natural ventilation (with supplementary mechanical ventilation) is precluded for valid reasons, a filtered mechanical outdoor air supply ventilation system must provide a minimum flow rate of 10 l/s per person, and with filtration to grade G4 or higher (refer to NZS4303: Ventilation for acceptable indoor air quality, or AS1668.2: Mechanical Ventilation in Buildings).

- Mechanical ventilation systems >500 litres per second must automatically modulate air flow rates in response to internal CO_2 concentrations, as measured by the CO_2 monitors within the spaces served, in order to maintain the concentration limits, set out in Section 1.1.2, below.

- Mechanical ventilation systems of >500 litres per second must include:
  - heat recovery by a counter-flow heat exchanger or run-around coil in Climate Zones 4, 5, & 6 (refer to **Figure 6**). Heat recovery systems may also be used in other zones, as appropriate to local conditions
  - heat recovery systems must include a summer bypass mode (for night purging)
  - where heat recovery systems are provided, building infiltration must be ≤ 3 ACH at 50 Pa. Buildings must be subject to an airtightness test.

- All opening windows must have restrictors, except those at high level (height FFL to bottom of sash > 1.5 m generally, or > 2.0 m where adjacent to pedestrian walkway), or where operated by either electric motors or window winders. Refer to **Figure 4**, below. Ensure compliance with requirements for restrictors in NZBC Clauses F4 and D1.

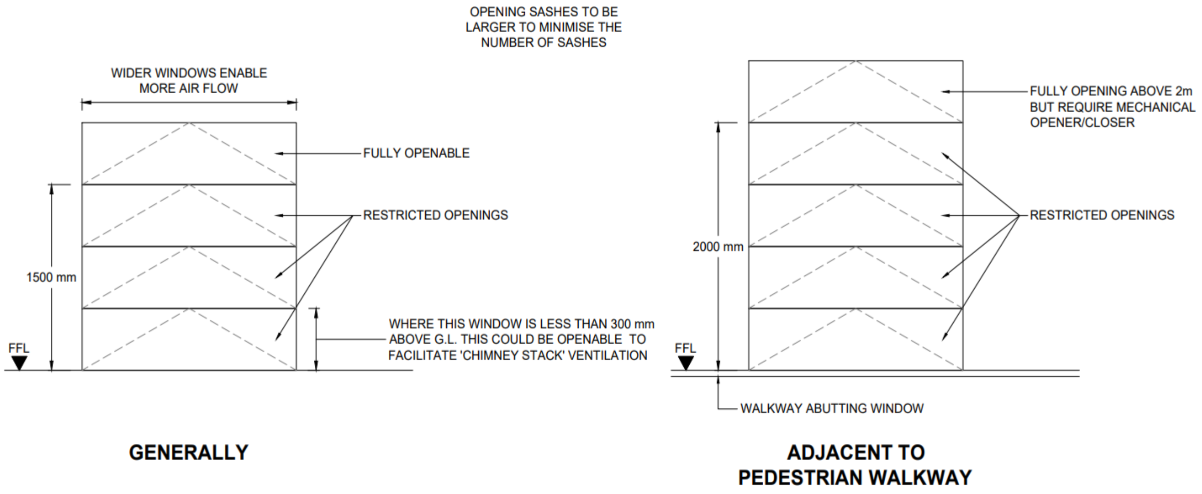


Figure 4: Requirements for window restrictors on school buildings

Refer to the Ministry’s Toilet & Changing Space Design for Schools document for more information on ventilation requirements for bathrooms and toilets.

Refer to Section 5 for outdoor air supply verification requirements.

1.1.2 CO_2 Concentration

The Ministry wants to ensure adequate outdoor air is provided to each learning space to ensure students and teachers can learn and work comfortably in the space. The concentration of carbon dioxide (CO_2) in the air is a good indicator of general indoor air quality (Chatzidiakou, 2014; Chatzidiakou et al., 2015), and is typically used as a proxy for ventilation effectiveness (Ackley, 2021a). However, low CO_2 levels don't necessily equate to low levels of pollutants, particularly where there are strong local sources of the pollutant, or where the pollutant is generated outdoors (such as traffic emmissions).

The concentration of CO_2 in outside air depends largely on the geographic location, air movement (wind), and proximity to air pollutant sources (such as roads, heavy industry, or geothermal areas). CO_2 concentration is typically measured in parts per million (ppm). The current (2021) atmospheric concentration measured by NIWA is ~410 ppm.

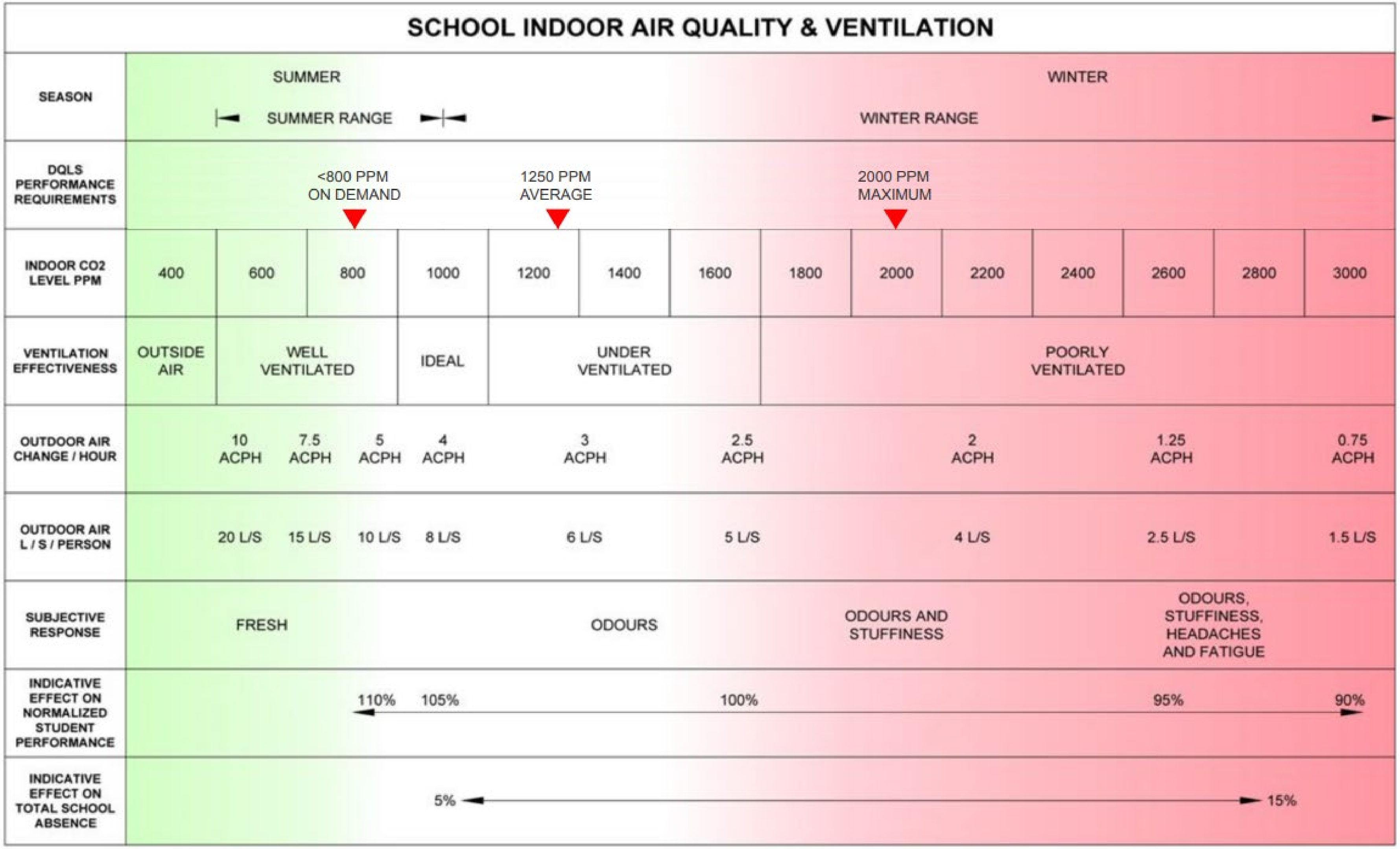
In enclosed spaces, normal respiration rates of occupants will naturally increase CO_2 levels above atmospheric levels. **Figure 5** illustrates the relationship between indoor CO_2 concentrations, ventilation rates expressed both as air changes per hour (ACPH) and as litres per second per person (l/s/p), and subjective occupant response.

Mandatory Performance Requirements:

- The average concentration of CO_2 should not exceed the 'Design Goal' in **Table 3,** for each space type during continuous periods of occupation during the day, when measured at a height of 1,500 mm above the ground. For most teaching spaces, this will be between 9:00 am and 3:00 pm. However, for spaces with highly intermittent occupancy, such as halls, periods of occupancy may be limited to a few hours per day.
- For design modelling purposes, the default occupied design period is between the 1st of February to the 20th of December, 9:00 am to 3:30 pm, Monday to Friday. For design verification purposes, CO_2 concentrations should be assessed only over occupied hours.
- Maximum peak concentration of CO_2 must not exceed 2,000 ppm during the teaching day.
- At any occupied time, the occupants should be able to purge air to lower the concentration of CO_2 below 800 ppm within 10 minutes, either by opening windows or by increasing mechanical ventilation rates.
- Internal environmental monitor must be provided in a central location within each teaching space, with instant visible feedback to local users, and the ability to store and download accumulated data (Refer to Section 1.6). This is to assist the teaching staff and students in managing CO_2 levels by opening windows, and to support built verification and Post Occupancy Evaluations (POEs).

Table 3: Indoor CO_2 concentration design criteria

Space	Recommended daily average during occupied periods (ppm)	Mandatory requirement max daily average during occupied periods (ppm)	Maximum permissible peak CO_2 concentration (ppm)
Learning Spaces	800	1,250	2,000
Food Technology	800	1,250	2,000
Science Laboratories	800	1,250	2,000
Staff & Administration	800	1,250	2,000
Auditoriums, Halls, Music Spaces	800	1,250	2,000
Gymnasiums	800	1,500	2,000



SCHOOL INDOOR AIR QUALITY & VENTILATION

SEASON	SUMMER SUMMER RANGE WINTER WINTER RANGE
DQLS PERFORMANCE REQUIREMENTS	<800 PPM ON DEMAND 1250 PPM AVERAGE 2000 PPM MAXIMUM
INDOOR CO2 LEVEL PPM	400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
VENTILATION EFFECTIVENESS	OUTSIDE AIR WELL VENTILATED IDEAL UNDER VENTILATED POORLY VENTILATED
OUTDOOR AIR CHANGE / HOUR	10 ACPH 7.5 ACPH 5 ACPH 4 ACPH 3 ACPH 2.5 ACPH 2 ACPH 1.25 ACPH 0.75 ACPH
OUTDOOR AIR L / S / PERSON	20 L/S 15 L/S 10 L/S 8 L/S 6 L/S 5 L/S 4 L/S 2.5 L/S 1.5 L/S
SUBJECTIVE RESPONSE	FRESH ODOURS ODOURS AND STUFFINESS ODOURS, STUFFINESS, HEADACHES AND FATIGUE
INDICATIVE EFFECT ON NORMALIZED STUDENT PERFORMANCE	110% 105% 100% 95% 90%
INDICATIVE EFFECT ON TOTAL SCHOOL ABSENCE	5% 15%

Figure 5: School indoor air quality, ventilation parameters, and performance outcomes

Section 5 for CO_2 concentration verification requirements.

1.1.3 Pollutants

Mandatory Requirements:

VOCs and Formaldehyde

- For all new or up-graded learning spaces, 90% of carpets, ceiling materials, and paints installed within the building envelope must be specified to comply with the maximum allowable Volatile Organic Compound (VOC) content, or the maximum allowable VOC-emission rates, according to one of the standards or certification schemes identified in the New Zealand Green Building Council (NZGBC) or Green Building Council of Australia (GBCA) Recognised Eco-Labels list. A comprehensive list can be found at: https://www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=3719.
- New and up-graded buildings must be unoccupied for a minimum of one week 'bake off' period after completion of the interior linings, carpet/vinyl and interior painting, to allow for the dissipation of VOCs. During the first 8 weeks of occupancy, buildings should be regularly purged (windows and doors opened fully, maximum mechanical ventilation) outside of occupied hours.

Refrigerants

- All HVAC installations containing refrigerants must comply with relevant refrigerant safety standards, particularly AS/NZS 5149.1.
- Wherever practicable, refrigerant charges should be limited such that leak detection systems are not required. This is due to the capital cost and on-going maintenance and calibration obligations associated with refrigerant leak detection systems. Where leak detection systems are specified, justification must be provided as part of the design verification submission.

  Verification requirements can be found in Section 5.

1.1.4 Particulate matter - guidance

Particulate matter (PM) is an air-suspended mixture of solid and liquid particles from both human and natural sources. PM is normally classified by size (PM10 includes particles of <10 μm diameter, and PM2.5 <2.5 μm). PM10 particles are coarser. Due to their size, they can be intercepted and filtered by the nose and throat.

Finer PM2.5 particles may pose a greater risk than PM10 particles as they can penetrate the deepest parts of the lung. Generation and re-suspension of these particles is a function of indoor/outdoor movement and activity levels in the learning space. Indoor levels can be two to five times higher than outside, and sometimes significantly higher.

Strategies that reduce PM levels, including good ventilation, using well-maintained HEPA vacuum cleaners, and the use of entry/exit door mats to mitigate dirt tracking inside, must be considered.

Ventilation openings (windows, air supply intakes) must be orientated to avoid sources of particulate matter, such as busy roads. Where windows face onto roads or other sources of particulate matter, they should not be relied upon for ventilation.

1.2 Indoor Temperature Requirements

Key Points

- Buildings must be designed such that temperature can be maintained during occupied hours.
- Overheating has become more of a concern than under-heating, due to high levels of insulation & glazing, particularly in passively ventilated spaces.
- The design team must demonstrate that the design will comply with criteria to limit overheating, either through calculations or via modelling, depending on the size & complexity of the building.
- Orientation, form and shading are critical parameters that must be included in design verification. Shading, such as verandahs, should be provided where possible to control solar heat gain, and to allow windows to be opened in rainy weather.

Minimum temperature – mandatory requirements:

- All learning spaces (except gymnasiums and multipurpose halls) must be provided with a heating system sized to efficiently and effectively maintain an air temperature of 19˚C (+/-1°C) during occupied hours, measured at a height of 1.5m AFFL.
- Administration, resource work and meeting spaces, and staffrooms, are to be provided with a heating system sufficient to maintain an air temperature of 21°C (+/-1°C) during normal periods of occupation, measured at 1.5m AFFL.
- Spaces such as corridors, multipurpose halls and gymnasiums are to be provided with a heating system sufficient to maintain an air temperature of 17°C (+/-1°C) during normal periods of occupation, measured at a height 1.5m AFFL.
- Where radiant heating systems are provided, operative temperature may be used instead of air temperature for sizing and compliance purposes. Designers should take care to ensure that total irradiance at floor level is reasonably uniform.
- Provision for heating Universal School Bathrooms to 23°C (+/-1°C) is required.
- Toilets and changing rooms:
  - When located within the building envelope and accessible only from inside the building envelope, dedicated heating is not required
  - In Climate Zones 4, 5, & 6 (Figure 6), heating to 17°C (+/-1°C) is required in toilet common areas that are accessible from outside the building envelope. Heating should be considered in other locations, depending on local climate.
  - Where heating is provided to toilet common areas, energy saving measures (such as time clock control, occupancy sensors, heat recovery ventilation, and vestibules) must be considered.

Maximum temperature – mandatory requirements:

- Learning spaces, libraries, administrative offices, staffrooms, and multipurpose spaces must be designed to avoid significant overheating.
- Overheating hours are to be assessed during warmer periods between the dates 10th October to 20th December, and 1st February to 15th April (school terms 4 and 1 respectively).
- To show that the proposed school building will not suffer from overheating, learning spaces, libraries, administrative offices, staffrooms, and multipurpose spaces are to be designed such that there should be no more than 80 occupied hours when the air temperature in the space rises above 25°C, and no more than 40 occupied hours when the space air temperature rises above 28°C.
- The design team is to demonstrate within a project's Developed and Detailed Design reports that the maximum summertime temperature requirements described above will be achieved with the proposed ventilation strategy:
    - For small building forms (<600 m² GFA) provision of a design statement and supporting calculations will be sufficient
    - For larger building forms (≥600 m² GFA), the design statement is to be supported by a thermal modelling report.
- Occupant numbers and school hours need to be confirmed and agreed with the school principal and Ministry Delivery Manager before modelling is undertaken.

Verification requirements can be found in Section 5

1.3 Thermal Performance Requirements

Key Points

- The Ministry's required minimum R-values (thermal resistance) for different components of the building are stipulated in **Table 4**, below. These minimum levels of insulation seek to maintain a balance between winter heat retention, and summer heat release and exclusion. The requirements vary by climate zone - refer to **Figure 6**, below.
- Effective thermal insulation requires good thermal design, adequate materials (as expressed by the material's R-value) and high-quality installation.
- For each learning space, window area should be between 25% to 35% of the total external wall area. This is to minimise overheating, while achieving adequate daylight levels.
- If the design proposes a window to wall ratio (WWR) of more than 35% for a space, modelling must be carried out to demonstrate over-heating compliance.
- The WWR of a building may strongly influence the thermal comfort of occupants and affect both the heating and cooling loads of the indoor environment, and thus energy use over the building's lifetime.

1.3.1 Thermal Insulation

The Ministry's required minimum R-values (thermal resistance) for different components of the building are stipulated in **Table 4**, below. These minimum levels of insulation seek to maintain a balance between winter heat retention, and summer heat release and exclusion. The requirements vary by climate zone - refer to **Figure 6**, below.

These minimum required R-values are based on the New Zealand Building Code Clause H1, Acceptable Solution H1/AS2 (1st Edition, 2021) – Energy Efficiency for Buildings Greater than 300 m^2. Where buildings have an occupied floor area less than 300 m^2, or otherwise fall within the scope of H1/AS1, then the higher values prescribed in H1/AS1 shall prevail.

Refer to H1/AS2, Table 2.1.2.2A, for minimum required R-values for building elements with embedded heating systems.

It is possible that, as a result of the on-going Building For Climate Change (BFCC) consultations, whole-of-building thermal modelling will become more commonplace. Both heating and cooling load limits may be introduced, and subsequently reduced over time. Achieving these limits may necessitate higher levels of airtightness and increased control over ventilation rates, as well as higher levels of thermal insulation. These anticipated regulatory changes will make it even more important that designs include adequate provisions to control internal and interstitial moisture. Specialist advice should be sought where necessary.

Mandatory Requirements:

- Minimum requirements for thermal insulation are outlined in **Table 4** below; where justified by thermal and energy use (heating and cooling) analysis, higher levels of thermal insulation may be used, as appropriate.
- Where multiple layers of insulation are used to achieve the required construction R-values, care must be taken not to create an interstitial condensation plane. If there is no track record or history

of use for the proposed insulation systems, the design must be subject to a hygrothermal peer review.

- Warm roof construction is required in Climate Zones 3, 4, 5 & 6 (**Figure 6**).
- Thermal insulation must be provided to concrete slab floor edges, perimeters, or in full, as required to meet the requirements set out in **Table 4**, below.
- The project Architect or façade/enclosure consultant must provide a design statement setting out the R-values of each building element. The design statement must include an interstitial moisture risk assessement covering each building element (or type thereof). The risk analysis must describe in each case how mositure risks have been controlled. Where the proposed insulation systems have not been established by prior use to be low risk, the design statement must include a supporting hygrothermal report.
- Refer to the Ministry's Weathertightness and forthcoming updated DSNZ documents for general façade/enclosure design guidance.

Table 4: Requirements for thermal resistance of building components for new buildings

Climate Zone	Districts	Towns/Cities	Building Component	Minimum R-Value
1	Far North, Whangārei, Kaipara, Auckland, Thames-Coromandel, Western BoP, Tauranga, Whakatāne, Kawerau, Ōpotiki	Kaitāia, Whangārei, Auckland, Thames, Whakatāne	Roof	R 3.5
			Wall	R 2.2
			Floor	R 2.2
			Windows	R 0.33
			Skylights	R 0.42
2	Hauraki, Waikato, Matamata-Piako, Hamilton, Waipa, Otorohanga, South Waikato, Waitomo, Gisborne, Wairoa, Hastings, Napier, Central Hawke's Bay, New Plymouth, Stratford, South Taranaki, Whanganui	Hamilton, New Plymouth, Wanganui, Gisborne, Napier	Roof	R 4.0
			Wall	R 2.4
			Floor	R 2.2
			Windows	R 0.33
			Skylights	R 0.42
3	Manuwatū, Palmerston North, Horowhenua, Rangitīkei South, Kāpiti Coast, Porirua, Lower Hutt, Wellington, Tasman, Nelson, Marlborough, Kaikōura, Chatham Islands	Palmerston North, Wellington, Blenheim, Nelson, Kaikōura	Roof	R 5.0
			Wall	R 2.7
			Floor	R 2.2
			Windows	R 0.37
			Skylights	R 0.46
4	Taupō, Rotorua, Ruapehu, Rangitīkei North, Tararua, Upper Hutt, Masterton, Carterton, South Wairarapa, Buller, Grey, Westland	Taupō, Rotorua, Upper Hutt, Masterton, Westport, Hokitika	Roof	R 5.4
			Wall	R 3.0
			Floor	R 2.4
			Windows	R 0.37
			Skylights	R 0.46
5	Hurunui, Waimakariri, Christchurch, Selwyn, Ashburton, Timarau, Waitaki East, Waimate, Dunedin, Clutha	Christchurch, Timarau, Dunedin	Roof	R 6.0
			Wall	R 3.0
			Floor	R 2.5
			Windows	R 0.40
			Skylights	R 0.49
6	Mackenzie, Waitaki West, Central Otago, Queenstown Lakes, Southland, Gore, Invercargill	Twizel, Alexandra, Queenstown, Gore, Oamaru, Invercargill	Roof	R 7.0
			Wall	R 3.2
			Floor	R 2.6
			Windows	R 0.42
			Skylights	R 0.51

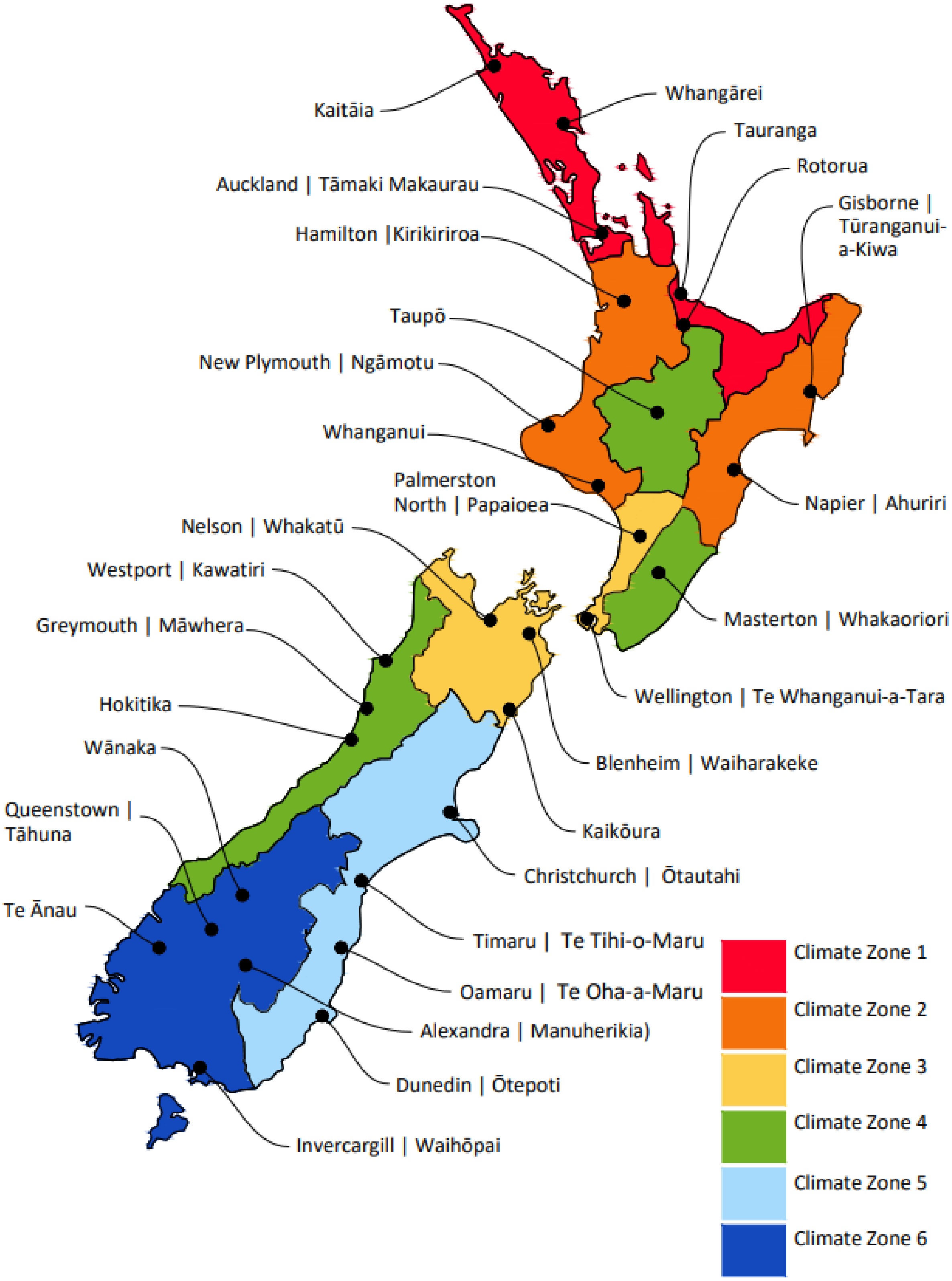


Figure 6: New Zealand climate zones

1.3.2 Window to Wall Ratio

Mandatory Requirements:

- For each learning space, aggregate window area should be between 25% to 35% of the total external wall area. Window areas should be concentrated across the northern, eastern (subject to appropriate shading), and southern elevations.

  Should the project team propose a WWR >35%, then modelling analysis is required in order to demonstrate that the design will comply with over-heating criteria in Section 1.2, without the need for mechanical cooling.

- The tendency to selectively increase the WWR of breakout spaces must be avoided so that these spaces are not prone to over-heating.

1.4 Systems & Specialist Components Requirements

Key Points

- The Ministry prefers naturally ventilated buildings. However, where the maximum temperature criteria (Section 1.2) cannot be reasonably achieved by natural ventilation, then mechanical or mixed-mode ventilation (with cooling, where appropriate) may be considered for summertime temperature control.

- The selection of heating, cooling and ventilation systems must be in accordance with a lifecycle analysis, as prescribed in Section 1.5, below.

- The installation of new gas, diesel, oil or coal boilers is prohibited, as part of the Ministry's commitment to carbon abatement.

Mandatory Requirements:

- The Ministry prefers naturally ventilated buildings. However, where it can be demonstrated that, following optimisation by thermal modelling, the maximum temperature criteria (Section 1.2) cannot be reasonably achieved by natural ventilation, then mechanical or mixed-mode ventilation (with cooling, where appropriate) may be considered for summertime temperature control.
- Heating systems must be appropriate to the project climate zone, and the long-term availability of fuel/energy sources must be considered.
- A lifecycle costing/options report is required as described in Section 1.5: Life Cycle Analysis.
- The installation of new gas, diesel, oil or coal boilers is prohibited, as part of the Ministry's commitment to carbon reduction.
- Plant equipment is to be located with due care, with appropriate safe access, and with provision for servicing and on-going maintenance. Design teams must justify the positioning of equipment, and design documents must detail maintenance access requirements and provisions. Avoid placing plant on roofs, particularly equipment requiring maintenance.
- Plant and equipment should be inaccessible to students; where appropriate, provide tamper-proof enclosures.
- Electrical installations must comply with *AS/NZS 3000:2018.*
- Electrical installations must comply with the Ministry's *Electrical Installations: Standards for Schools.*
- Heating, ventilation, and air conditioning systems must be properly tested and commissioned to either CIBSE or ASHRAE standards, to demonstrate compliance with the New Zealand Building Code, any relevant standards, and with the requirements of this DQLS guideline. ASHRAE standards require involvement of an independent commissioning agent, which may be more appropriate on larger, more complex projects.
- Compliance schedules must be provided for specified systems as part of the building consent application, identifying continued maintenance, testing, and warrant of fitness requirements.
- Heating and cooling systems must be sized to ensure compliance with Section 1.2, at ventilation loads which ensure compliance with Section 1.1.2.

1.5 Life Cycle Cost Analysis Requirements

Key Points

- Life cycle cost analysis (LCCA) is required to support the selection of heating ventilation and cooling systems for all new buildings and for major up-grades.
- The analysis must take into consideration initial economic costs, as well as all likely subsequent costs.
- An Options Report detailing the analysis methods, assumptions, and results is to be provided by the design team at the project's Preliminary Design stage and updated throughout the project development.
- The design team must use the Ministry's Life Cycle Cost Analysis Calculator Tool in the preparation of the Options Report.

Mandatory Requirements:

An **Options Report** is to be provided by the design team at the project's Preliminary Design and updated throughout the project development. The options report is required for all new build projects, and for all major upgrade projects >$3M or >600m² GFA.

An online LCCA Calculator is provided by the Ministry for use in the preparation of the Options Report. It may be accessed from here: LCCA Calculator.

The Options Report must consider:

- A range of ventilation, heating, and cooling systems (as required) appropriate to the climate zone, site microclimate, building envelope performance, and expected occupancy.
- Net Present Value (NPV) analysis that considers capital, energy, maintenance, and replacement costs, over a 20-year period. The discount rate is to be that published by the New Zealand Treasury for infrastructure and special purpose buildings – as of April 2021, it is 5%.
- Capital costs for different building services options must be jointly agreed on by the project team, and specifically by the Building Services Engineer and the Quantity Surveyor. Where the project team agree that capital costs differ from the defaults provided in the LCCA Calculator, these are to be updated under 'Specific Capital Costs' in the LCCA Calculator 'Inputs' sheet.
- All associated costs (e.g., associated infrastructure costs such as electrical transformer up-grades, and any associated builder's work) are to be included under 'Specific Infrastructure Costs' in the LCCA Calculator 'Inputs' sheet.
- Annual energy demand associated with different building services systems should be approximated using energy modelling, or by other estimation methods. Where energy demand is expected to differ from the regional defaults provided in the LCCA Calculator, these are to be updated under 'Specific Energy Demand' in the 'Inputs' sheet.
- System energy conversion efficiencies (e.g., COP) should be assessed under design conditions for both heating, and where applicable, cooling. Where efficiencies differ from the defaults provided in the LCCA Calculator, these are to be updated under 'Specific Energy Conversion Efficiency' in the 'Inputs' sheet.

- Fuel/energy prices are to be assessed using existing school electricity bills, if available. Where local energy pricing is not available to designers, the default pricing in the LCCA Calculator should be used.
- Where wood boilers are considered, security of fuel supply and fuel price stability must be assessed and justified in the Options Report. Wood fuel costs should be derived from existing school supply contracts, where available. Alternatively, quotes should be sought from local wood fuel suppliers, and the costs used in the LCCA analysis should be justified in the Options Report. Default wood fuel costs should only be used for preliminary design purposes and must be updated at Developed design with pricing from local suppliers.
- LCCA only accounts for economic costs. Competing options may involve attributes that cannot be readily reduced to economic values. Such attributes may include health/comfort, environmental impact (e.g., from greenhouse gas emissions) and ease-of-use considerations, including school disruption. These non-economic considerations must form part of the overall decision making, along with the LCCA. The options report must justify system selection recommendations with reference to these non-economic considerations.
- The options and costs presented are to be free of any perceived bias towards a particular/preferred design solution. Based on this report and on costings, the Ministry, in conjunction with the Project Team, will determine which system(s) are the most appropriate for the school project, so that capital and operating budgets can be forecast.

1.6 Internal Environmental Monitoring (IEM) Requirements

Key Points

- All new and major upgrades of teaching spaces must be provided with internal environmental monitors that measure CO_2, temperature, lighting, sound levels and relative humidity, which must have the ability to store data and be remotely accessible by the Ministry.
- The Ministry conducts Internal Environment Monitoring (IEM) and will use the environmental data from the electronic monitors to assess building performance and for Post Occupancy Evaluations (POEs).
- This monitoring forms part of the Ministry's quality learning environment model, which involves collecting and analysing performance data to monitor school achievement of the Ministry's building quality standards for property planning purposes. The DQLS requirements provide the framework for assessing the internal environmental quality aspects of the model.

Mandatory Requirements:

- All new teaching spaces (including major upgrades projects >$3M or >600m² GFA) must be provided with wall mounted internal environmental monitors (with digital display) in a central location. These electronic monitors should have a multi-element capability to monitor CO_2, temperature, lighting, sound levels and relative humidity.
- Where appropriate, monitors should be linked to mechanical ventilation systems to modulate system performance in order to maintain the concentration limits set out in Section 1.1.2, above.
- Project Teams must source all internal environmental monitoring devices from the Ministry (contact your Ministry Delivery Manager for the ordering process).
- Internal environmental quality data from each teaching space will be recorded and made accessible to the Ministry. The data will be used as part of the Post Occupancy Evaluation (POE) tool and ongoing improvement of comfort in learning spaces.
- As part of internal environmental monitoring, the Ministry will investigate teaching spaces where temperature exceed the 18 °C to 25 °C threshold, relative humidity exceeds 35% to 70% threshold and CO_2 levels exceed 1250 ppm.
- Monitors must clearly indicate on an LCD display whether conditions are within the allowable parameters - for example, a green/orange/red 'traffic light' or 'emoji'. It is not sufficient that the IEM devices merely show numeric values for temperature and CO_2 levels.
- Monitors must have the ability to store data and be remotely accessible by the Ministry.
- The project team must provide building user manuals and building occupant training at project handover, including information regarding monitor locations, integration with HVAC systems where applicable, and acceptable internal environmental quality levels.

  Verification requirements can be found in Section 5.

Internal Environment Monitoring Device Deployment Requirements:

The Ministry uses Internal Environment Monitoring (IEM) devices, also called dataloggers, to monitor the internal environment of teaching spaces by measuring lighting levels, sound levels, temperature, humidity and CO_2 levels. These are small electronic devices which are installed into learning spaces and collect data over a span of time.

The data from IEM devices will be analysed to understand the building performance of the space. In any monitoring program, the location of the device is often one of the most important things to consider, to ensure that the data collected is reliable. When deploying IEM devices, the deployment requirements set out below must be followed.

These requirements are based on findings from Ackley (2021a), and aim to ensure that the data collected is reliable and indicative of the environmental conditions of the most frequently occupied parts of a space.

Summary of Deployment Requirements

- All IEM devices must be located centrally on an unglazed wall around a 1.5 m height above the floor level and at least 1 m away from occupants.
- IEM devices must strategically be located away from:
    - Direct sunlight
    - The sound field of the teacher
    - The breathing zone of occupants
    - TV and computer screens
    - Heating and cooling systems
    - Drafts from windows and doors
- If permanently installed, the device must be hardwired.
- If temporary installed, and powered by electricity, the device must be placed relatively close to source of power and positioned to avoid tampering.
- IEM devices that use Wi-Fi connection must be connected to a segmented Wi-Fi network.
- The manufacturer’s/supplier’s installation manual must be followed when configuring the device.

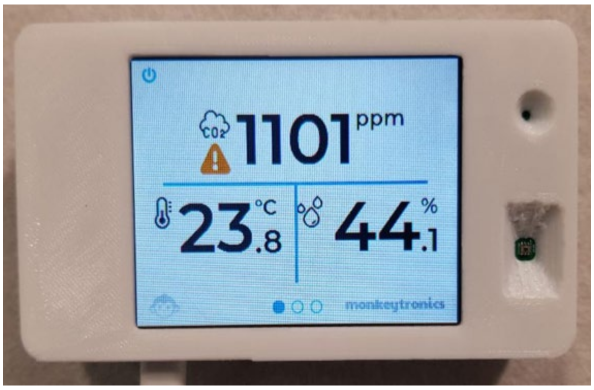


Figure 7: Example multi-element internal environmental monitoring device (data logger)

Mandatory Requirements for Specialist & Ancillary Spaces

For mandatory requirements pertaining to specialist and ancillary spaces, please refer to the following sections:

- **Workshop Technology Spaces – Section 4.5**
- **Science & Laboratory Spaces – Section 4.6**
- **Food Technology & Cafeteria Kitchen Spaces – Section 4.7**
- **Server Rooms & IT Equipment Cupboards – Section 4.8**
- **Toilets – Section 4.9**

Section 2: Summary of Thermal & Ventilation Requirements & Recommendations

This section provides a summary of some of the Ministry's thermal and ventilation requirements and recommends a range of design solutions.

Tables 5 & 6 provide a summary of the Ministry's thermal requirements and climate-based heating, ventilation, and cooling requirements.

Figures 8, 9 & 10 provide a visual summary of required and recommended design features, applied to a typical school building section.

Note that the general recommendations given in **Tables 5 & 6** and **Figures 8, 9 & 10** should be justified by project-specific thermal, energy and daylight modelling for each school building project, and should be subject to a life cycle cost analysis. Modelling and cost analysis forms important part of the Ministry's validation process for larger and more complex school buildings and should inform design decisions and system selections.

Table 5: Summary of Ministry thermal requirements & climate based heating & ventilation recommendations

Summary of Ministry thermal requirements and climate based heating and ventilation recommendations																
				Building Envelope Requirements***					Heating Options Recommendations **				Ventilation Recommendations		
									Small Projects#		Large Projects#				
Climate Zone		Districts	% School Population (2020 data)	R-Value Roof	R-Value Walls	R-Value Floor	R-Value Glazing (Except Skylights)	WWR Range *	Electric Radiant Heating ****	Split or Multi-Split Heat Pumps ****	Air to Water Heat Pumps & Fan Coils ****	Wood Chip/Pellet Boiler	Natural Ventilation Only	Mixed Mode (Natural/ Mechanical Heat Recovery)	Airtight Construction ***
1	↑ Warmest	Far North, Whangārei, Kaipara, Auckland, Thames-Coromandel, Western BoP, Tauranga, Whakatāne, Kawerau, Ōpotiki	44%	3.5	2.2	2.2	0.33	25-35%	✓	✓	✓		✓		
2		Hauraki, Waikato, Hamilton, Waitomo, Gisborne, Hastings, Napier, Central Hawke's Bay, New Plymouth, Stratford, South Taranaki, Whanganui	15%	4.0	2.4	2.2	0.33	25-35%	✓	✓	✓		✓		
3		Manawatū, Palmerston North, Kāpiti, Horowhenua, Rangitīkei South, Porirua, Lower Hutt, Wellington, Tasman, Nelson, Marlborough, Kaikōura, Chatham Islands	15%	5.0	2.7	2.2	0.37	25-35%			✓	✓	✓		
Total			74%												
4	Coldest ↓	Taupō, Rotorua, Ruapehu, Rangitīkei North, Tararua, Upper Hutt, Masterton, Carterton, South Wairarapa, Buller, Grey, Westland	6%	5.4	3.0	2.4	0.37	25-35%			✓	✓		✓	✓
5		Hurunui, Waimakariri, Christchurch, Selwyn, Ashburton, Timarau, Waimate, Dunedin, Clutha, Waitaki East	14%	6.0	3.0	2.5	0.40	25-35%			✓	✓		✓	✓
6		Mackenzie, Central Otago, Queenstown Lakes, Southland, Gore, Invercargill, Waitaki West	4%	7.0	3.2	2.6	0.42	25-35%			✓	✓		✓	✓
Total			26%												

* Optimise by a combination of thermal and climate-based daylight modelling

** Use life cycle cost analysis tool to present options for Ministry approval as part of the design review process

*** Based on NZBC Clause H1/AS2; where occupied floor area ≤300 m^2, requirements of Clause H1/AS1 apply. Refer also to the Ministry's Weathertightness guidance documents for details of thermal bridging, vapour retarding layers, and airtightness

**** Refer to hot climate cooling recommendations (Table 6, below) which take precedence in choice of heating systems

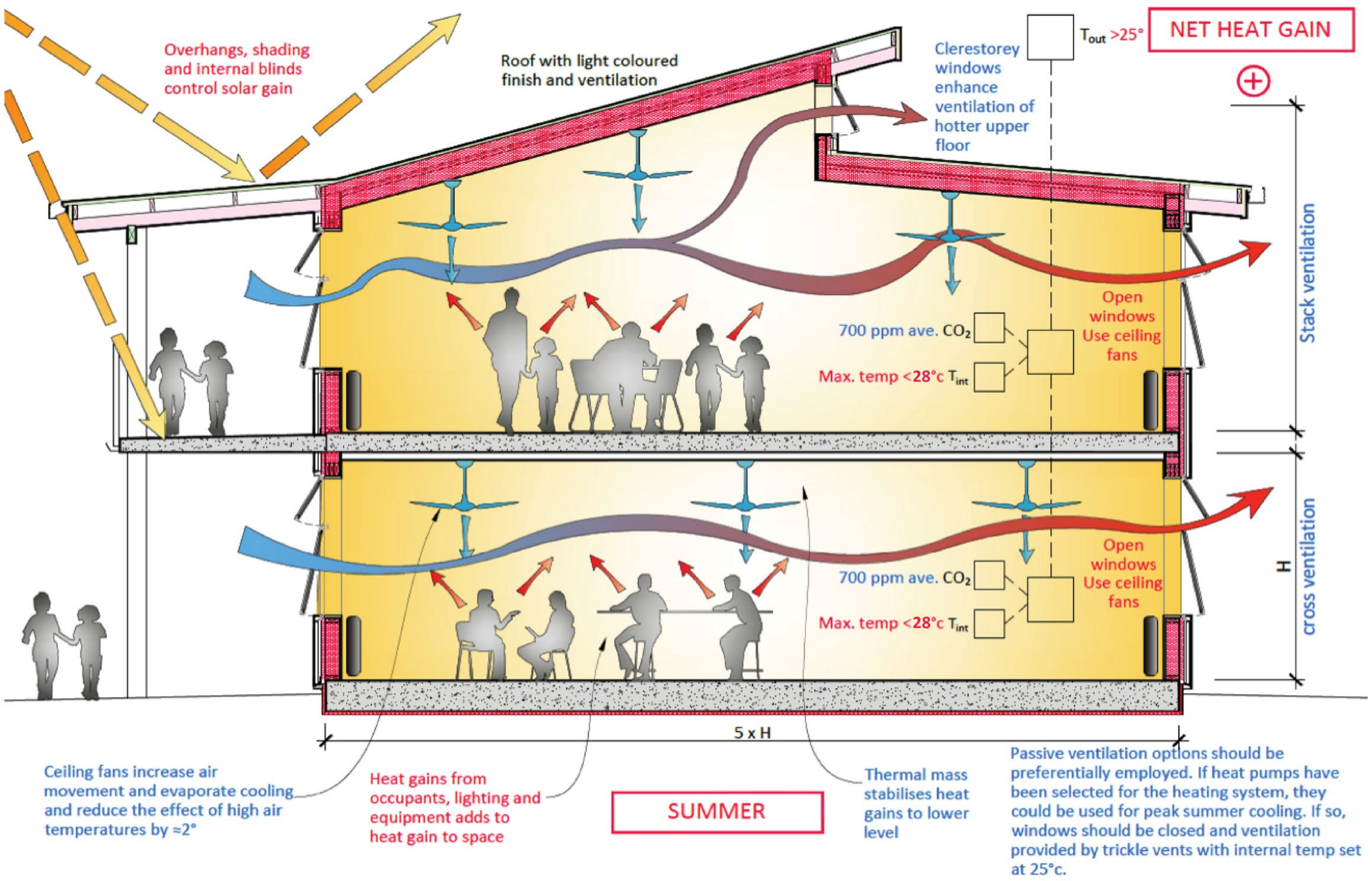
\# With respect to the heating recommendations, small projects < 1,200 m^2 GFA; large projects > 1,200 m^2 GFA

Table 6: Summary of Ministry climate based cooling recommendations

Summary of Ministry climate based cooling recommendations										
Summer Climate Type	Mean Daily Max' Air Temp' - February & December	Towns & Cities*	Open Plan Learning Spaces Cooling Recommendations**				Enclosed Breakout Spaces Cooling Recommendations**			
			Passive Cooling by Natural Ventilation	Ceiling Fans	Night Purge	Passive Cooling by Natural Ventilation & Heat Pump Cooling	Passive Cooling by Natural Ventilation	Ceiling Fans	Night Purge	Passive Cooling by Natural Ventilation & Heat Pump Cooling
Hot	>23°C	Alexdandra, Cromwell, Kaitāia, Whangārei, Hamilton, Gisborne, Whakatane, Napier, Tauranga, Masterton, Blenheim		✓	✓	✓				✓
Warm	20-23°C	Auckland, Palmerston North, Rotorua, New Plymouth, Wanganui, Taupo, Nelson, Fairlie, Christchurch, Queenstown, Lake Tekapo, Twizel, Timaru, Oamaru, Wanaka	✓	✓	✓					✓
Mild	<20°C	Wellington, Westport, Kaikoura, Hokitika, Dunedin, Gore, Invercargill	✓	✓	✓					✓

* Refer to NIWA climate data for other locations

** Use life cycle cost analysis tool to present options for Ministry approval as part of the design review process



Overhangs, shading and internal blinds control solar gain

Ceiling fans increase air movement and evaporate cooling and reduce the effect of high air temperatures by ≈2°

Heat gains from occupants, lighting and equipment adds to heat gain to space

Thermal mass stabilises heat gains to lower level

Passive ventilation options should be preferentially employed. If heat pumps have been selected for the heating system, they could be used for peak summer cooling. If so, windows should be closed and ventilation provided by trickle vents with internal temp set at 25°c.

Figure 8: Summer ventilation modes for typical flexible learning spaces

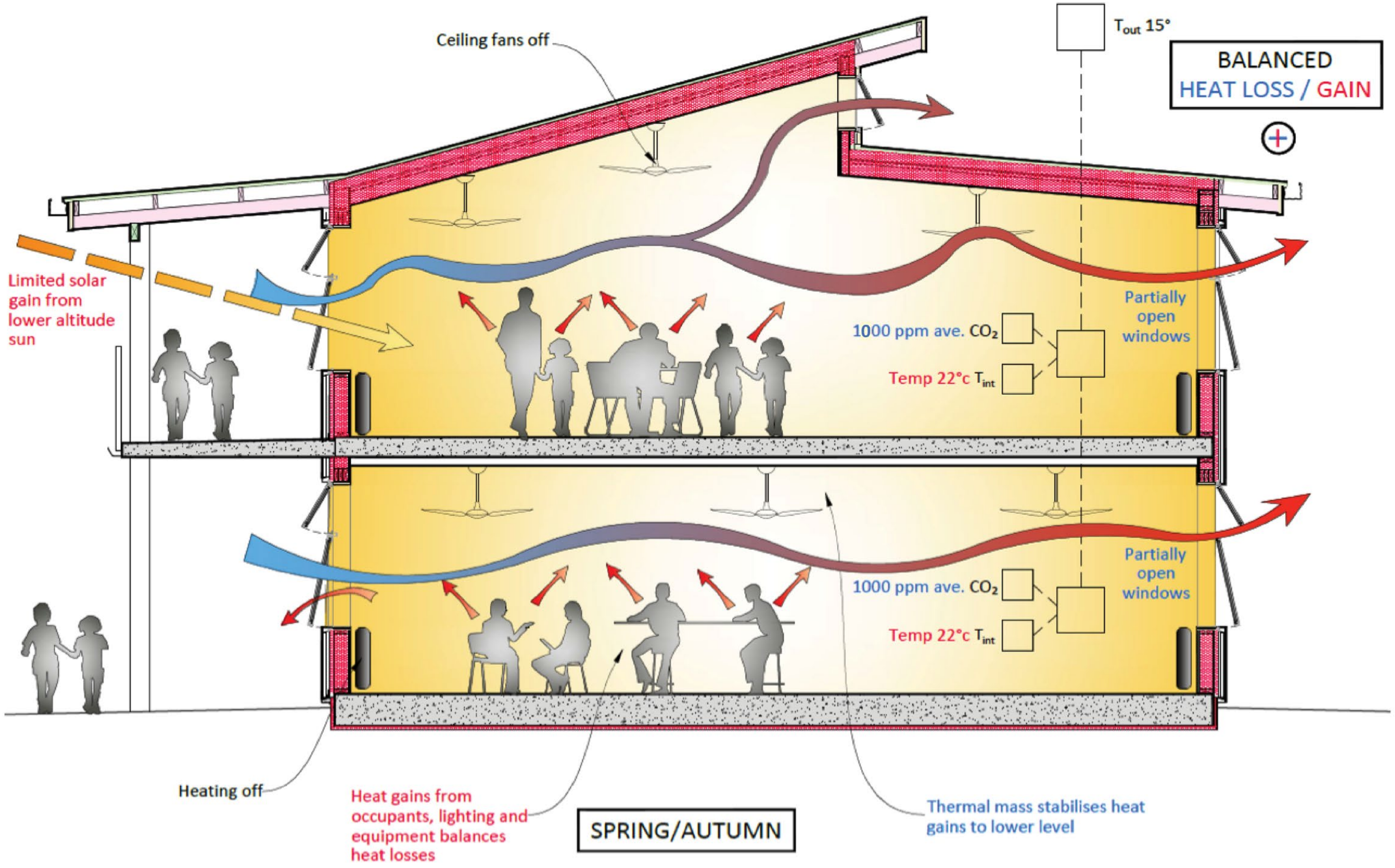


Figure 9: Spring/autumn ventilation modes for typical flexible learning spaces

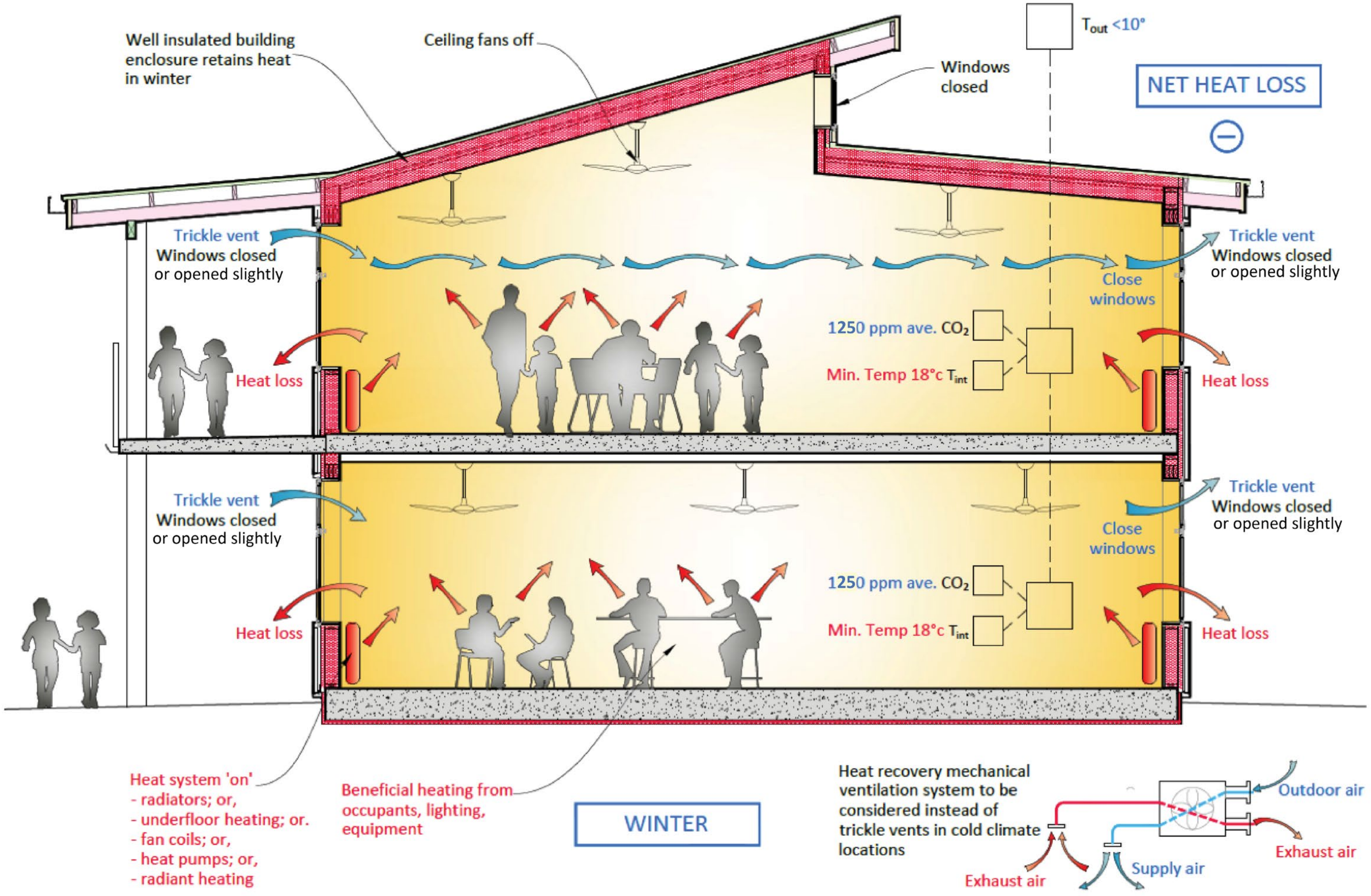


Figure 10: Winter ventilation modes for typical flexible learning spaces

Section 3: Requirements & Recommendations for Existing Buildings

Key Points

- Modification of older buildings may disturb hazardous material that had been sealed within the structure. Any existing mechanical ventilation systems be isolated from any potentially hazardous materials.
- When considering the implications of an upgrade project, three questions should be investigated:

  1) Will expected use (occupancy levels, activity types) of the space change?
  2) Will the upgrade involve modification of the building envelope?
  3) Does the existing space fail to meet the Ministry's indoor air quality & thermal comfort requirements?

  If the answer to any of these is 'yes', then it may be necessary to upgrade some or all of the heating, ventilation and cooling systems.
- Before carrying out any major upgrade, project teams must consider data sourced through internal environment monitoring devices (if available) and user feedback through the School Evaluation of the Physical Environment (SEPE) tool to inform whether there are aspects of building performance that needs improving.
- Wherever upgrade projects present an opportunity to improve the indoor air quality & thermal comfort within learning spaces, the requirements contained in Section 1 should be met (particularly when significant works to walls, floors, glazing, and roofs are undertaken).

The following section quantifies the Ministry's minimum performance requirements and recommendations for existing buildings. It outlines the performance requirements which have been set to enable the upgrade of schools to be in line with The Ministry's expectations for learning environments.

School Evaluation of Physical Environment (SEPE)

School principals are asked to complete a questionnaire which evaluates the **usability** of their space, as part of the property planning process. Their answers to SEPE translate into a score for usability. Some questions will also provide the user's perspective on **acoustics, lighting, thermal comfort**, and **indoor air quality** for each block.

In addition to Internal Environment Monitoring (IEM) data (Section 1.6), SEPE responses also provide valuable insights into how school staff, teachers, and students interact with their physical environment. By reviewing the school's ratings and comments, Project Teams gain a better understanding of what is working well at a school and where there is room for improvement. In some cases, the school might have a clear view on how to improve an issue, and in others they may not have fully identified the cause of the problem.

Before carrying out any major upgrade, project teams must consider data sourced through internal environment monitoring devices (if available) and user feedback through the School Evaluation of the Physical Environment (SEPE) tool.

Design teams will need to consider the following design requirements, recommendations, performance guidance, and associated control measures:

- **Historical Material Pollutants – Section 3.1**
- **Ventilation – Section 3.2**
- **Indoor Temperature - Section 3.3**
- **Existing Building WWR – Section 3.4**

3.1 Historical Material Pollutants

Modification of older buildings may disturb hazardous material that had been sealed within the structure. Older buildings frequently contain materials that are now deemed unsafe, such as asbestos, PCBs or lead paint. Building contractors should be aware of the hazards posed by such materials, ensuring that any such materials are contained when discovered, removed, and disposed of appropriately. These hazards should not be overlooked even during the course of minor upgrades or routine remedial work.

Building and project managers should ensure that they are kept informed of any potentially hazardous materials that are discovered, as appropriate management may affect the scope and scheduling of the project. A hazardous materials survey of the building is recommended prior to any construction works commencing. Some substances such as asbestos, lead particulates, and mercury are highly toxic. Friable asbestos materials may release dangerous fibres into the air supply if disturbed.

It is imperative that any existing mechanical ventilation systems be isolated from any potentially hazardous materials. Attention should be paid to ducts and building cavities through which ventilation air will circulate. Management of asbestos is regulated by the **Health and Safety at Work (Asbestos) Regulations (2016)**. Further guidance is provided by the supporting technical bulletin **Management and Removal of Asbestos (2016)** published by WorkSafe NZ. If high risk materials are found on site, subsequent air quality monitoring will be required by the Ministry (and possibly WorkSafe NZ) before the space can be considered safe for re-occupation.

3.2 Ventilation

General

Issues and strategies for indoor air quality are similar for upgrade projects as for new buildings. It may not be immediately apparent whether an upgrade project will require modification of the existing ventilation arrangements. The recommendations below offer guidance on determining whether indoor air quality considerations should fall within an upgrade project brief. When upgrading existing buildings, the key parameters are occupancy level, activity type and how changes to the building envelope may affect the existing heating and ventilation arrangements.

Older buildings are particularly likely to be highly permeable, effectively allowing a constant exchange of outdoor air through gaps in the building envelope. Changes to the building envelope may affect thermal resistance and air permeability – increasing the airtightness of the building will improve thermal performance, but will also reduce this exchange of outdoor air (refer to Build 152 – Ventilation Options for further information). An increase in the airtightness (reduced permeability) of the envelope will exacerbate poor ventilation provisions in older buildings. It is important that changes in infiltration rates resulting from up-grades to the building envelope be taken into consideration, and that ventilation provisions are assessed to ensure compliance with Ministry requirements.

When considering the ventilation implications of an upgrade project, three questions should be investigated:

(1) Will expected use (occupancy levels, activity types) of the space change?

(2) Will the upgrade involve modification of the building envelope?

(3) Does the existing space fail to meet the Ministry's indoor air quality requirements?

If the answer to any of these questions is yes, then further exploration of the ventilation implications of the upgrade is warranted.

Requirements:

- Heating, ventilation and cooling design must endeavour to meet the Ministry's minimum requirements as specified in Section 1, as near as is reasonably practicable.
- Existing mechanical ventilation systems must be isolated from any potentially hazardous materials on site. Attention should be paid to ducts and building cavities through which ventilation air will circulate. Toxic substances such as asbestos, lead particulates, and mercury may be uncovered during up-grade projects.

Recommendations:

- If either the occupancy levels or the activity types are expected to change, then re-assess whether minimum ventilation requirements set out in Section 1 can be met with existing ventilation systems. These ventilation rates should be sufficient to maintain CO_2 and other contaminant concentrations within Ministry limits.
- When assessing ventilation rates for a component space within a larger complex space (e.g., a breakout space), consider the broader ventilation context. Local modifications to the space's ventilation arrangements should support the overall ventilation strategy for the complex space.

  Verification requirements can be found in Section 5

Figure 11: An open plan learning space in an upgraded building

3.3 Indoor Temperature

General

Building upgrade projects present an opportunity to improve the thermal performance of older buildings. As with new building projects, significant upgrades require integrated consideration of several aspects of building design and performance. This is particularly so when the upgraded spaces will be subject to different occupancy and activity patterns post completion.

When considering the thermal comfort implications of an upgrade project, the following questions should be considered:

(1) Will expected use (occupancy levels, activity types) of the space change?
(2) Will the upgrade involve modification of the building envelope?
(3) Will the upgrade involve a change in ventilation strategy?
(4) Does the existing space fail to meet the Ministry's thermal comfort requirements?

If the answer to any of these questions is yes, then further exploration of the thermal comfort implications of the upgrade should be considered.

Recommendations:

- Wherever upgrade projects present an opportunity to improve indoor temperatures within learning spaces, the temperature requirements contained in Section 1 should be met (particularly when significant works to walls, floors, glazing, and roofs are undertaken).

- Wherever upgrade projects present an opportunity to improve the thermal performance of a building, the thermal insulation requirements contained in **Table 4** should be met.
- Selection of heating cooling systems should be subject to a life cycle analysis, as set out in Section 1.5.

  Verification requirements can be found in Section 5.

3.4 Existing Buildings WWR

Recommendations:

- Where practicable, the WWR requirements and recommendations in Section 1.3.1 should be targeted. The project team should evaluate the existing thermal and lighting performance of the space, with particular reference to over-heating, daylighting, and glare. Changes in use, occupancy, and surroundings (shading, surface reflectance, etc.) should be taken into consideration when revising the design and layout of windows in existing spaces.
- Historical school building reference designs may have WWRs that depart significantly from current guidance. These reference designs include, but not limited to the following:
    - Nelson Blocks (1 & 2 Storey)
    - Canterbury & Canterbury Intermediate Blocks
    - Dominion Blocks
    - 1950's Blocks (1 & 2 Storey)
    - Aranui Blocks

Many of these existing building designs have large areas of single pane glazing with minimal shading (see **Figure 12**). Design Teams should consider reducing the glazing area of these buildings in line with DQLS requirements and recommendations. Where appropriate to their climate zone, glazing should be replaced with IGUs.

Verification requirements can be found in Section 5.

Figure 12: Canterbury Block reference design
- an example of existing infrastructure with a high WWR

Section 4: Guidance for Specialist & Ancillary Spaces

Design Teams may need to consider the following Specialist & Ancillary Spaces when designing for Indoor Air Quality & Thermal Comfort:

- **Halls and Multipurpose Spaces –** **Section 4.1**
- **Gymnasiums –** **Section 4.2**
- **Libraries –** **Section 4.3**
- **Music Facilities –** **Section 4.4**
- **Workshop Technology Spaces –** **Section 4.5**
- **Science & Laboratory Spaces –** **Section 4.6**
- **Food Technology & Cafeteria Kitchen Spaces –** **Section 4.7**
- **Server Rooms & IT Equipment Cupboards –** **Section 4.8**
- **Toilets –** **Section 4.9**

These sections include specific building and system design requirements and recommendations that directly impact indoor air quality, thermal comfort, and safety. Additionally, these sections provide guidance to enable Design Teams to develop specific design solutions that ensure good and balanced performance outcomes across all parameters.

4.1 Halls and Multipurpose Spaces

Key Points

- Multipurpose halls may have highly variable ventilation and heating/cooling requirements, depending on the range of occupancy and activity types.
- Coordination is required between the school and the design team to ensure that the full range of intended uses is encompassed in the design.
- Special care should be taken to select HVAC strategies that are both effective and efficient over the full range of expected usage patterns.
- Passive design opportunities should be exploited wherever cost effective and should form part of the strategic design decision making.
- In colder locations where mechanical heating may be required, a combined heating and ventilation system may be preferable for heat recovery reasons.
- Many halls have high internal spaces which promote thermal air stratification. This can lead to warm air becoming trapped high in the building envelope, while cold air surrounds the occupants below. Any convective heating proposed for high internal spaces should be accompanied by a suitable destratification strategy.
- When intended for occasional use only, simple heating systems such as electric radiant panels may be appropriate.

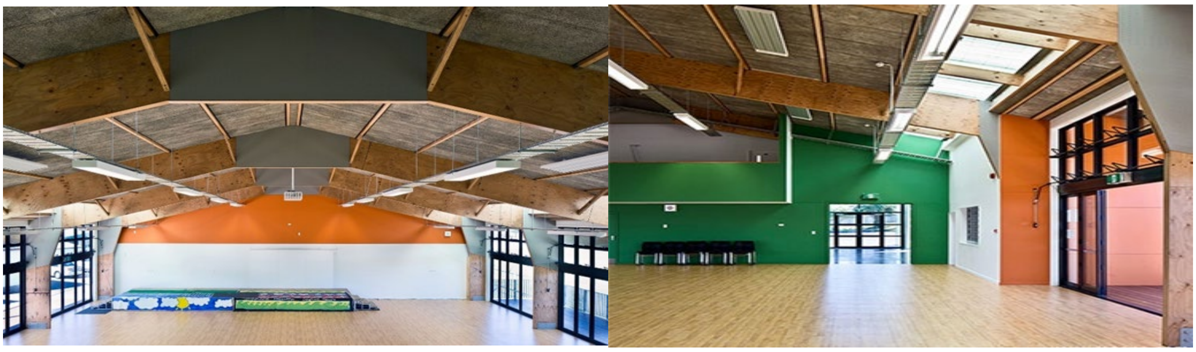


Figure 13: Primary school hall
with a simple intuitive design incorporating good cross ventilation through a combination of open doors for warm weather and openable high-level windows for less clement weather. Low-cost electric radiant heating provides quick warming of the space, suited for intermittent use and warm climates.

Figure 14: Secondary school hall
with mechanical ventilation to mitigate outside traffic noise and providing the ability to mix air sources to minimise stratification effects in the high spaces.

4.2 Gymnasiums

Key Points

- Gymnasiums are subject to some of the same HVAC considerations as multipurpose halls (refer above), but are characterised by physically strenuous activities and by variable occupancies (from a few players during lunch break, to competitive team sports with capacity spectator crowds).
- Ventilation and cooling are critical in these spaces, with heating usually being of less importance.
- In most parts of New Zealand, reliance on natural ventilation should be possible for gymnasiums. In colder locations where mechanical heating may be required, a combined heating and ventilation system may be preferable for heat recovery reasons.
- Poorly heated, poorly insulated, and under-ventilated gymnasiums will be particularly prone to condensation issues due to the high respiration rates associated with strenuous activities.
- Heating and ventilation system components exposed within the gymnasium space must be of robust design. They should avoid trapping objects like balls and shuttlecocks, be impact-resistant and/or protected from impact using cages, and be suitably secured to the structure.

Figure 15: School gymnasium with openable windows for natural ventilation

4.3 Libraries

Key Points

- Libraries may be highly variable in their size and usage patterns. They may be fully occupied as a recreational space during a break on a rainy day, or be sparsely occupied on a cold winter morning.
- Special care should be taken to specify air quality and temperature control strategies that are both effective and efficient over the full range of expected usage patterns.
- The temperature requirements detailed in Section 1.2 apply.
- Where libraries are intended as quiet study spaces, and external noise sources are an issue, mechanical ventilation and air conditioning may be required. The DQLS – Acoustics guideline should be consulted for guidance regarding libraries, in addition to receiving specific design advice from an acoustic consultant.
- Where libraries will have high IT equipment loads, this should be identified early in the design, and HVAC strategies selected accordingly.
- Computer laboratories and IT hubs associated with libraries, or distributed within learning spaces, have high IT equipment loads in addition to the normal learning space occupancy, lighting, and fabric loads. Computer labs may therefore need to be cooled/air conditioned with a set point of 25°C. Glazing should be limited in these areas in order to reduce glare and additional heat gain due to solar gains. If cooling/air conditioning is provided an associated mechanical ventilation system is to be provided.

Figure 16: Use of an external sunshade to manage library heat gain

4.4 Music Facilities

Key Points

- Music facilities may have variable ventilation and heating/cooling requirements, depending on their size, occupancy, and use. Facilities may range from small solo practice rooms to large performance spaces.
- The principal factor constraining the design of music facilities is the need for good acoustic performance. This requirement may limit reliance on natural ventilation and may have implications for the thermal performance of the space. HVAC systems must be selected to meet acoustic performance criteria. The DQLS – Acoustics guideline should be consulted for guidance regarding the acoustic requirements of music facilities.
- The HVAC strategy for a music facility should be tailored to deliver the ventilation, heating/cooling requirements based on its particular uses, including consideration for acoustic requirements. The selected approach should be both cost effective and energy efficient throughout its operational range, and lifespan. Strategies may include more than one system, operating in combination or independently.
- Where solo practice rooms are provided with mechanical systems, local controls should also be provided to allow for individual preferences.
- Where high value or temperature-sensitive musical instruments are stored, air conditioning by means of a local split system, similar to a server room, should be considered.
- Electronic music and recording spaces may have high equipment heat loads and may require active cooling.

Figure 17: A large music rehearsal space

4.5 Workshop Technology Spaces

Key Points

- Particular requirements and recommendations apply where dust extract systems, and mechanically vented welding, painting or gluing booths are provided.
- Where mechanical ventilation is provided for these facilities, large flow rates may be required; care should be taken to provide adequate make up air, tempered where local climatic conditions require.
- Where a dust extract system is required, the room layout and workshop equipment schedule should be agreed with the school as the basis for the system design.
- There are particular fire and explosion risks associated with dust extract systems. The design, supply and installation of dust extract systems must be by specialists in these systems.
- Where 3D printers are used, consideration must be given to the provision of of vented cabinets in accordance with manufacturers and industry recommendations.
- Electrical and ICT cabinets must not be located in workshop spaces, where dust ingress may interefere with active equipment.
- Fan noise from dust extract systems may be significant and may require acoustic treatment; advice should be sought from the fan supplier and/or from an acoustic engineer.
- Centralised dust extraction units should be externally located.

The general requirements and recommendations of Sections 1 & 2 apply to workshop and hard technology spaces. Additional requirements and recommendations apply where dust extract systems, and mechanically vented welding, painting or gluing booths are provided. Where specific mechanical ventilation is provided for these facilities, care should be taken to provide adequate make up air, tempered where local climatic conditions require.

Refer to specific requirements and recommendations, below. For guidance on fume cupboards, refer to Section 4.6, Science & Laboratory Spaces, below.

Refer to Section 5 for design verification requirements.

4.5.1 Dust extraction systems

Mandatory Requirements:

- A dust extraction system must be provided to all items of machinery which produce dust; systems may be integral, local, or centralised.
- Coordination is required with technology teaching staff regarding room layout and equipment requiring dust extraction. A schedule of equipment, and the technology space layout, should be agreed with the school as the basis for the design. Equipment diversity factors should include consideration of after-hours use by outside groups (adult education classes, etc.) where applicable.
- The design of centralised dust extract systems must be based on the advice of a dust extraction systems specialist, and in accordance with appropriate local and international standards as listed below.

- A specialist supplier/installer must be used for any centralised space dust extraction system.
- Local and centralised dust capture devices must include a sight level so that maintenance personnel can easily identify when they need to be emptied.
- All dust extraction systems must be provided with local On/Off switching from within the technology space, by means of a master isolating switch (normally key operated to prevent tampering). The switch should also control the power to all the machines and outlet sockets in the individual technology spaces.
- Emergency shut off buttons that isolate both the machinery and the associated extraction system must be provided in the immediate vicinity of the equipment.
- A suitable means of interlocked make up air must be provided (either via natural ventilation in warm climate zones, or via tempered mechanical ventilation in cold climate zones).
- Electrical and ICT cabinets must not be located in workshop spaces, where dust ingress may interefere with active equipment.

Recommendations:

- Centralised dust extraction units should be externally located, away from air intakes, outdoor circulation routes, and occupied spaces.
- Centralised dust collectors should be sized according to the types and diversity factors of the connected machinery. A larger unit with a larger filter area (the number and diameter of filter socks) will generally give better performance over time than a smaller dust collector. “Total Filter Area” should be taken into consideration.
- Fan noise from dust extract systems may require acoustic treatment; advice should be sought from the fan supplier and/or from an acoustic engineer.
- Ductwork is expected to comply with *HVAC Specification DW144*, and with any appropriate industrial standards for high velocity sheet metal ductwork.
- The extract duct layout should be at high level, to suit the equipment layout.
- Duct connections to individual items of equipment should be wire-reinforced, transparent, flexible plastic. They should be provided with spade dampers at 1.5m above floor level, orientated to avoid causing a hazard.
- Flexible ducting should be no more than 0.5 m in length, except where necessary to accommodate machine movement. Flexible ducting significantly reduces the extract flow rate of the branch and reduces overall system efficiency.
- Duct sizing should maintain the minimum recommended carrier velocity of 18 to 20 m/s.
- **Table 7** provides indicative extract duct diameters suitable for flow rates at 20 m/s; this should be used as a general guide only – seek specialist advice on ductwork design and refer to machinery manufacturer’s instructions.
- Generally, machinery should be provided by the supplier with existing dust extract points. Connections to the dust extract system should be provided according to the manufacturer’s instructions.

- Where sanders are provided with integral dust capture devices, these should not be connected to a centralised dust extract system.
- Where fixed sweep-up points are provided and connected to the central dust extract system, the sweep up points should be fitted with a grille to prevent objects entering the duct system. **Table 8** provides indicative extract rates for typical school machinery; this should be used as a general guide only – refer to manufacturer's instructions and seek specialist advice.
- Where band saws are supplied without integral dust capture outlets, provide an extraction duct close to the saw. Confirm whether an outlet is provided at the rear of the collection chamber.
- All tees and bends are to be designed to minimise friction losses and avoid blockages (90 degree 'Tees" should be avoided, branch joint angle should be 30 degrees).

Table 7: Indicative dust extract duct sizing & airflow velocity

Diameter of Extraction Point (mm)	Airflow (m^3/hr at 20 m/s velocity)
40 mm	90 m^3 per hour
50 mm	140 m^3 per hour
63 mm	220 m^3 per hour
80 mm	360 m^3 per hour
100 mm	560 m^3 per hour
125 mm	900 m^3 per hour
150 mm	1250 m^3 per hour
180 mm	1800 m^3 per hour
200 mm	2200 m^3 per hour

Table 8: Indicative dust extract requirements

Machine	Diameter of Extraction Point (mm)	Extraction Volume Required (m^3/hour)
Scroll Saw	40 - 80	90 - 360
Drop Saw	60 - 100	200 - 600
Band Saw	100 - 150	500 - 1250
Table/Circular Saw	100 - 150	680 - 1450
Radial/Mitre Saw	100 - 125	680 - 1000
Panel Saw	125 + 80	1280
Belt Sander (150 mm)	100	560
Belt Sander (enclosed, 200 mm)	125	1000
Belt Sander (enclosed, 350 mm)	150	1000
Disc Sander	50 - 125	140 - 1000
Drum Sander	125	1000
Spindle Moulder	100 - 150	560 - 1200
Thicknesser	100 - 180	560 - 1800
Lathe	100 - 150	560 - 1250
Downdraft Table	200	2200
Router Table	125	850
Sweep Up	100	560

Relevant Standards:

Relevant standards for combustible dust regulations are listed below:

  - ATEX Equipment Directive 2014/34/EU
  - ATEX Workplace Directive 99/92/EC
  - NFPA 664
  - AS/NZS-60079 Explosive Atmospheres series.

Some of the ATEX standards are directly adopted in Australia and New Zealand through inclusion under the AS/NZS 60079 Explosive Atmospheres series.

Relevant standards and guidelines for woodworking published in the UK, Ireland and the US are listed below:

  - BS EN 12779:2015 Safety of woodworking machines. Chip and dust extraction system with fixed installation. Safety requirements
  - Health and Safety Executive UK publication 'Wood dust: controlling the risk'
  - Health and Safety Executive UK publication 'Safe collection of wood waste: Prevention of fire and explosion'
  - Department of Education and Skills, technical guidance document TGD-032 'Guidelines for the Design & Installation of Woodwork Dust Extraction Systems in Post Primary Schools'
  - American Conference of Governmental Industrial Hygienists 'Industrial Ventilation – A Manual of Recommended Practice' 23rd Edition, 1998.

4.5.2 Welding, small scale painting booths and gluing tables

Mandatory Requirements:

- Welding, spray-painting booths, and gluing tables in technology spaces must be provided with local non-recirculating extraction hoods to capture fumes effectively and exhaust them externally in a safe manner.
- A suitable means of interlocked make up air must be provided. This may be via passive vents in warm climate zones, or via tempered mechanical supply ventilation in cold climate zones.

Recommendations:

- Design Teams should refer to the *American Conference of Governmental Industrial Hygienists – Industrial Ventilation: Manual of Recommended Practice* for practical advice on the design of general and local extract ventilation systems.

Workplace Exposure Standards

- Exposure to contaminants in New Zealand workplaces is regulated by the *Workplace Exposure Standards and Biological Exposure Indices for New Zealand (2013)*. Workplace exposure standards detail the airborne concentration of substances at which it is believed that nearly all workers can be repeatedly exposed, day after day, without coming to harm. The values are normally calculated on work schedules of five shifts of eight hours duration over a 40-hour work week. Children are particularly vulnerable to all types of pollutants because of their high respiration and metabolic rates.

- The *Workplace Exposure Standards* provide two exposure measures: a long-term time weighted average (WES-TWA) standard and a short-term exposure limit (WES-STEL). The WES-STEL is not an alternative to the WES-TWA; both the short term and time weighted average exposures apply.

Figure 18: A secondary school workshop space

4.6 Science & Laboratory Spaces

Key Points

- Particular requirements and recommendations apply to gas reticulation installations, fume cupboards and chemical storage cabinets, as detailed below.
- A suitable means of interlocked make up air must be provided for vented fume cupboards. This may be via vents or via tempered mechanical supply ventilation.
- Draughts from windows and ventilation outlets in the vicinity of fume cupboards must be controlled to ensure that they do not disrupt fume containment.

The general requirements of Sections 1 & 2 apply to science and laboratory spaces. Additional requirements and recommendations apply where fume cupboards, chemical storage cabinets, or gas reticulation is provided.

In addition to the requirements and recommendations listed below, reference should be made to all applicable regulatory standards. **AS/NZS 2982:2010 Laboratory design and construction** specifies requirements for the design and construction of laboratories; Section 10 of this standard pertains specifically to secondary school science laboratories. Additional design guidance may be found in the ASSIST Guidelines for the Design and Planning of Secondary School Science Facilities in Australian Schools.

Refer to Section 5 for design verification requirements.

Requirements:

- Local emergency gas shut-off must be provided wherever a reticulated gas supply is installed.
- An automatic gas detection system and shut off system must be provided.
- Gas installations must comply with AS/NZS 5261 and/or AS/NZS 5601.1:2013 and must include a manual shut off valve, and an automatic gas shut off valve linked to the fire alarm system.

4.6.1 Fume cupboards

Mandatory Requirements

- Fume cupboards must comply with the following standards:
    - AS/NZS 1668.1:2015 The Use of Ventilation and Air Conditioning in buildings
    - AS/NZS 4303:1990 Ventilation for Acceptable Indoor Air Quality
    - AS/NZS 2243.8:2014 Safety in Laboratories – Fume Cupboards.
- Recirculating fume cupboards must not be installed in school science laboratories.
- A suitable means of interlocked make up air must be provided for vented fume cupboards. This may be via vents in warm climate zones, or via tempered mechanical supply ventilation in cold climate zones.

- Ceiling air diffusers or grilles located within 3 m of the fume cupboard must not discharge directly towards the fume cupboard.
- Openings that are subject to unpredictable turbulent draughts which could overwhelm fume cupboard containment must not be used to supply make-up air.
- Exhaust fans and all runs of positively pressurised ducting must be located external to the building.

Recommendations

- A 'bypass' design should be used to ensure constant air change regardless of the cupboard's sash opening size.
- Fume cupboards should continue to operate after the hazardous substances have been removed from the cupboard, so that hazardous substances are flushed from the exhaust ducting.
- Fume cupboards should have a means to indicate they are operating (such as a 'tell-tale').
- Consider double-sided fume cupboards, which allow the cupboard to be shared between the laboratory space and technician room.
- Consider whether any other extraction will be required (i.e, for heat or dust).
- Laboratories should be provided with the ability to be rapidly flush with fresh air.

4.6.2 Chemical storage

Mandatory Requirements

- Chemical storage cabinets must comply with AS/NZS 2243.10:2004 Safety in Laboratories – Storage of Chemicals and must be provided with mechanical ventilation as and where required by this standard.
- Mechanical ventilation must be provided to storage cabinets where required to maintain vapour concentrations below the limits set out in the *Workplace Exposure Standards and Biological Exposure Indices (2018).*
- Where segregated chemical storage cupboards are provided, these must be vented through independent extract systems.
- Chemical storage must comply with the *Hazardous Substances and New Organisms Act 1996 (HSNO)* and *Health and Safety at Work (Hazardous Substances) Regulations 2016.*

Refer to the following documents for further guidance:

- Guidance to the Code of Practice for School Exempt Laboratories Overlaid with Information About Duties Under the Health and Safety at Work Act 2015 (MoE, 2016)
- Code of Practice for School Exempt Laboratories (ERMA, 2007).

Workplace Exposure Standards

- Exposure to contaminants in New Zealand workplaces is regulated by the *Workplace Exposure Standards and Biological Exposure Indices (2018).*

- Workplace exposure standards detail the airborne concentration of substances at which it is believed that nearly all workers can be repeatedly exposed, day after day, without coming to harm. The values are normally calculated on work schedules of five shifts of eight hours duration over a 40-hour work week. These levels are assessed for individual compounds, not for a combination of compounds. Where there are two or more compounds present, a cautionary approach is required to the exposure limits.
- The *Workplace Exposure Standards* provide two exposure measures: a long-term time weighted average (WES-TWA) standard and a short-term exposure limit (WES-STEL). The WES-STEL is not an alternative to the WES-TWA; both the short term and time weighted average exposures apply.
- Children are particularly vulnerable to all types of pollutants because of their high respiration and metabolic rates. Exposure limits are set for healthy adults and are not availble for children. For obvious ethical reasons, exposure testing is not possible on children. Significantly lower, cautionary, exposure levels should be used for children.

Figure 19: A secondary school science laboratory with fume cupboard and extraction duct

4.7 Food Technology & Cafeteria Kitchen Spaces

Key Points

- Particular requirements apply to gas reticulation installations and kitchen extract systems, as detailed below
- Kitchen extract systems may involve high air flow rates; a suitable means “make up” air must be provided, either naturally in warm climate zones & where appropriate to smaller spaces, or mechanically and tempered in cold climate zones and larger, more intensively used spaces
- Commercial kitchen equipment (>8kW), including dishwashers, must be provided with commercial kitchen extract hoods designed in accordance with *AS 1668: Part 2-2012*

Depending on the scale and size of the food technology space and its location/climate zone, kitchen spaces should be provided with either a natural or mechanical general ventilation system, as well as local kitchen extract ventilation systems.

The temperature requirements and recommendations detailed in Sections 1 & 2 generally apply to technology spaces. Consideration should be given to the heat output of the equipment contained in the space, and to the range of ventilation rates.

High occupancy and warm weather conditions may necessitate cooling of the space. Selection of systems with both heating/cooling modes should be considered for spaces in warmer climate zones where both natural and mechanical ventilation may be ineffective for temperature control purposes. Note that food technology spaces may also be used for theory classes, when kitchen extract ventilation will not be operating – comfortable conditions should be provided.

Where residential hobs/ovens (<8kW) are provided for teaching purposes, each unit is to be provided with a residential stainless-steel kitchen hood sized to match the hob. Alternatively, a commercial-grade hood could be provided to serve a group or line of residential hobs/ovens. In the latter case, the hood is to be designed and sized in accordance with AS 1668: Part 2-2012.

Commercial kitchen equipment (>8kW), including dishwashers, are to be provided with commercial kitchen extract hoods designed in accordance with AS 1668: Part 2-2012. There is a preference for modern hoods with integral make-up air and capture jet designs. UV filtered hoods are to be avoided for capital and operating cost reasons.

Refer to Section 5 for design verification requirements.

Mandatory Requirements:

- Food technology spaces must be provided with both a general ventilation system (natural or mechanical) as well as with local kitchen extract ventilation systems.
- A suitable means of make-up air must be provided, either:
  - naturally, in warm climate zones, or where appropriate for smaller extract systems
  - mechanically and tempered in cold climate zones, and for larger extract systems
- Where residential hobs/ovens (<8kW) are provided for teaching purposes, each unit must be provided with a residential stainless-steel kitchen hood sized to match the hob (or with a commercial hood where this serves multiple items of equipment).

- Commercial kitchen equipment (>8kW), including dishwashers, must be provided with commercial kitchen extract hoods designed in accordance with *AS 1668: Part 2-2012*.
- Venting of commercial exhaust systems above the roof must comply with *AS 1668: Part 2-2012.* Venting of domestic hoods should avoid nuisance from cooking odours.
- Venting of extraction points above the roof must be provided with upstands and back-flashing in accordance with the Ministry's weathertightness guidance; this will require careful detailing and review.
- Operation of any gas supply in conjunction with commercial kitchen equipment and associated hood must be interlocked such that the gas supply is only available when the hood and any associated makeup air system is operational.
- An automatic gas detection system and shut off system must be provided to any gas installations.
- Gas installations must comply with AS/NZS 5261 and/or AS/NZS 5601.1:2013. Gas installations must include a manual shut off valve, and an automatic gas shut off valve linked to the fire alarm system. Local shut off facilities must be provided in kitchens.

Figure 20: A secondary school food technology space with residential grade cookers and residential extraction

4.8 Server Rooms & IT Equipment Cupboards

Key Points

- Server rooms should be designed to ensure equipment is kept within optimal operating temperatures. The Ministry's preference is for cooling via passive or mechanical ventilation, where adequate.
- Where mechanical ventilation is not adequate to maintain optimal operating temperatures, mechanical cooling (single split heat pumps) must be provided.
- For larger and more intensive school server rooms, duplicate split systems should be considered.
- The set point of the air conditioning unit should be set to comply with the server equipment manufacturer's recommendations. If no temperature is specified, then 25°C is recommended to minimize energy use.
- If a Building Management System (BMS) is provided, server room over-heating must be monitored by an independent temperature-monitoring function of the BMS. If there is no BMS, a high-limit direct acting thermostat set at 30°C is recommended. This should operate an audible alarm immediately outside the server room.
- It is recommended that server rooms be positively pressurized, with a filtered air supply sized to provide 50 l/s of supply air. A suitable door grille or under-cut should be provided for relief air.
- IT equipment cupboards (without servers) should also be provided with a filtered air supply sized to provide 50 l/s of supply air. A suitable door grille or under-cut should be provided for relief air.
- Refer to Section 7 & Appendix F of the Ministry's Information & Communications Technology (ICT) Cabling Infrastructure: Policy & Standards for Schools (MoE, 2024).

4.9 Toilets

Key Points

- Refer to the Ministry's *Toilet & Changing Space Design for Schools*, which contains specific design requirements for toilets and accessible bathrooms.

Ventilation provisions are required to meet the performance requirements of the New Zealand Building Code. Refer also to the Ministry's Toilet & Changing Space Design for Schools which contains specific requirements for toilets.

Refer to Section 5 for design verification requirements.

Section 5: Design & Built Verification Methods

General

This section outlines the specific verification documentation required from each project with regards to occupant comfort described in Section 1 Comfort Requirements.

5.1 Mandatory Design Verification Requirements

Due to the interrelated nature of comfort requirements, the Ministry requires an IEQ Design Report at Preliminary Design, and updates to this report at each design stage as the project develops. The report must include, but should not be limited to, the items described below. A Sample IEQ Design Report is available to guide designers.

5.1.1 Outdoor Air Supply & CO_2 Concentration

- A **design statement**, supported by documentation, is required to demonstrate that the design is compliant with the requirements set out in Section 1.1.1. Where spaces are not naturally ventilated, justification must be provided for the use of mechanical ventilation.

5.1.2 CO_2 Concentration

- For buildings <600m^2 GFA, a **design statement**, supported by documentation, is required to demonstrate that the design is compliant with the requirements set out in Section 1.1.2.
- For buildings ≥600m^2 GFA, for all naturally ventilated spaces a **climate-based modelling report** must be provided to demonstrate compliance with the CO_2 concentration limits stipulated in Section 1.1.2. The analysis may either:
    1. directly demonstrate that maximum CO_2 levels will not be exceeded, or
    2. demonstrate that for each naturally ventilated space, sufficient air changes per hour (ACPH) as determined by **Figure 5** (Section 1.1.2) will be achieved under local climatic conditions to ensure compliance.
- For each space modelled, the following model parameter values must be stated and justified within the report:
    1. Ambient atmospheric CO_2 concentration
    2. Location, type, & authority of weather files
    3. CO_2 generation rate per occupant
    4. Occupancy schedule
    5. Occupancy density
    6. Window/vent opening schedule
    7. Openable window areas (apertures, elevations, orientations)

The effect of window restrictors, as required in Section 1.1 above, must be realistically accounted for in the modelling of window apertures.

Default occupant densities in general learning spaces should be about 2 m^2 per student (for specialist learning spaces refer to AS 1668.2:2012, Table A1) unless otherwise agreed with the Architect and Client.

The climate-based modelling report should be updated at Detailed Design, and parameter values should be carried through into construction to ensure built compliance.

- For all buildings ≥600m^2, for any mechanically ventilated spaces a **design statement** must be provided, supported by documentation, to demonstrate that the design is compliant with the requirements set out in Section 1.1.1. Justification must be provided for the use of mechanical ventilation. It must be demonstrated that outdoor air supply rates are able to achieve sufficient air changes per hour (ACPH) as determined by **Figure 5** to maintain the maximum CO_2 concentrations stipulated in **Table 3.**
- For all new buildings or refurbished spaces, a **design statement** must be provided, with supporting documentation, demonstrating compliance with Ministry of Education monitoring systems for CO_2 (Sections 1.1.2 & 1.6).

5.1.3 Pollutants

- A **design statement** must be provided, confirming compliance with the VOC limits stipulated in Section 1.1.3. A schedule of installed carpet, ceiling materials and paints must be provided, detailing VOC content and/or emission rates.
- A **design statement** and supporting calculations must be provided, demonstrating compliance with the current edition of AS NZS 5149.1.
- Where refrigerant leak detection systems are specified, justification must be provided, explaining why refrigerant charges could not be reduced within permitted limits.

5.1.4 Thermal Comfort

- For small building forms (<600 m^2 GFA), a **design statement** must be provided by the Mechanical Engineer, together with supporting calculations, confirming that minimum and maximum indoor air temperature levels can be maintained for the prescribed times during the school year, as per the detailed requirements given in Section 1.2.
- For larger building forms (≥600 m^2), a **thermal modelling report** must be provided by the Mechanical Engineer, confirming that minimum and maximum indoor air temperature levels can be maintained for the prescribed times during the school year, as per the detailed requirements given in Section 1.2.

  For each space modelled, the following model parameter values must be stated and justified within the report:

  - Location, type, & authority of weather files
  - Building element R-values
  - Glazing characteristics (U-value$_{COG}$, SHGC$_{COG}$, VLT, SC, R-value$_{Window}$)
  - Occupancy & activity schedules

    - Occupancy density
    - Internal heat loads (equipment, lighting, etc.)
    - Window/vent opening schedules
    - Openable window areas (apertures, elevations, orientations)
    - Mechanical ventilation rates
    - Ventilation schedules
    - Shading details (neighbouring buildings & vegetation, verandahs & overhangs, etc.)

  Ventilation parameters must be sufficient to ensure compliance with Section 5.1.2 - CO_2 Concentration.

  Default occupant densities in learning spaces should be about 2m^2 per student, for learning spaces (AS 1668.2) unless otherwise agreed with the Architect and Client.

  The thermal modelling report should be updated at Detailed Design, and parameter values should be carried through into construction to ensure built compliance.

- A **design statement** must be provided, together with supporting calculations, confirming that HVAC systems have been selected in accordance with the requirements of Section 1.4, and particularly with respect to system sizing and setpoints.

5.1.5 Thermal Performance

- A **design statement** must be provided, together with supporting calculations, confirming that building element R-values meet the requirements set out in **Table 4.**
- A **design statement** must be provided, together with supporting calculations, confirming that the WWR ratio of each space is within the stipulated range. Where a WWR >35% is proposed, a **thermal modelling report** is required to confirm that the temperature requirements in Section 1.2 have been met without the need for additional mechanical cooling.
- Where a **thermal modelling report** is required, model parameter values must be stated and justified within the report, as set out under 'Thermal Comfort', immediately above.
- The thermal modelling report should be updated at Detailed Design, and parameter values should be carried through into construction.
- The project Architect or façade/enclosure consultant must provide a **design statement** setting out the R-values of each building element. The design statement must include an interstitial moisture risk assessement covering each building element (or type thereof), and must describe in each case how moisture risks have been controlled. Where the proposed insulation systems have not been established by prior use to be low risk, the design statement must include a supporting hygrothermal report.

5.1.6 Other

- A **life cycle analysis options report** must be provided at Preliminary Design, and updated at each design stage, demonstrating that heating and cooling systems have been selected in accordance with the requirements of Section 1.5.

- A **design statement** must be provided, together with supporting documentation, demonstrating compliance with Ministry of Education Internal Environment monitoring system requirements in Sections 1.2 & 1.6
- A **design statement** must be provided for specialist learning spaces and ancillary spaces covered by the requirements of the following sections:
    - Workshop Technology Spaces – Section 4.5
    - Science & Laboratory Spaces – Section 4.6
    - Food Technology & Cafeteria Kitchen Spaces – Section 4.7
    - Server Rooms & IT Equipment Cupboards – Section 4.8
    - Toilets – Section 4.9

5.2 Mandatory Built Verification Requirements

During the construction and operation of the building, Design Teams are expected to provide the following verification documentation:

- Evidence of Internal Environment Monitoring (IEM) devices in all learning spaces in compliance with Section 1.6, with LCD display, data storage and remote access capability.
- As-built drawings and schedules recording any changes. This should be provided in a format that allows for future updates as/when changes are made.
- Commissioning documentation indicating compliance with Internal Environment Monitoring (IEM) systems.
- Commissioning report and documentation demonstrating compliance with CIBSE codes (Code: A, B, C, L, M, R, W) or ASHRAE standards for buildings with HVAC systems. The report must include commissioning dates, records of all functional testing, any future seasonal testing, outstanding issues, and include outcomes and changes made to the building as a result of the commissioning process.
- Producer statements and electrical certificates of compliance, as appropriate.
- Undertake insulation installation inspections during construction to confirm the insulation has been installed as shown in detail.
- Schedule of as-built ceiling materials, carpets, and paints with record of VOC content.
- The school and the Ministry are to be provided with suitable operating and maintenance manuals, a detailed functional description, and accurate construction record drawings. The functional description should detail the operation and control routines of each piece of HVAC equipment under all operating conditions (e.g., calls for cooling/heating, calls for increased ventilation due to high CO_2, occupied operation, after-hours operation, morning pre-occuopancy operation, fault alarms, etc.).
- School management and caretaking staff are to be provided with a user guide and adequate training to enable the heating, ventilation and air conditioning systems, plant, and equipment, to be safely operated and maintained. Where a space is naturally ventilated, it is an expected outcome that teachers will manage this process and understand the reasons for it. The traditional practice of appointing a class window monitor from among the learners is suggested.

- Compliance schedules are to be provided for specified systems as part of the building consent to identify continued maintenance, testing and warrant of fitness requirements.

Appendix: Applying the Ministry's Requirements to New School Buildings

Scope

This section provides the rationale behind some of the requirements contained in Section 1. Summary tables of some of the Ministry's requirements are also provided in this section.

Wintertime Heating

In the Building Code Clause H1 Update 2021, MBIE propose new climate zones which appear to be based on heating requirements only, as set out in **Table 9**, below. Generally, the Ministry has adopted the NZBC Clause H1/AS2 requirements. Where the H1/AS1 criteria for smaller buildings (occupied floor area ≤ 300 m^2) apply, then the higher values prescribed in H1/AS1 shall prevail.

Table 9: Winter heating climate zones

Climate Zone	Districts	Towns/Cities
1	Far North, Whangārei, Kaipara, Auckland, Thames-Coromandel, Western BoP, Tauranga, Whakatāne, Kawerau, Ōpotiki	Kaitāia, Whangārei, Auckland, Thames, Whakatāne
2	Hauraki, Waikato, Matamata-Piako, Hamilton, Waipa, Otorohanga, South Waikato, Waitomo, Gisborne, Wairoa, Hastings, Napier, Central Hawke's Bay, New Plymouth, Stratford, South Taranaki, Whanganui	Hamilton, New Plymouth, Wanganui, Gisborne, Napier
3	Manuwatū, Palmerston North, Horowhenua, Rangitīkei South, Kāpiti Coast, Porirua, Lower Hutt, Wellington, Tasman, Nelson, Marlborough, Kaikōura, Chatham Islands	Palmerston North, Wellington, Blenheim, Nelson, Kaikōura
4	Taupō, Rotorua, Ruapehu, Rangitīkei North, Tararua, Upper Hutt, Masterton, Carterton, South Wairarapa, Buller, Grey, Westland	Taupō, Rotorua, Upper Hutt, Masterton, Westport, Hokitika
5	Hurunui, Waimakariri, Christchurch, Selwyn, Ashburton, Timarau, Waitaki East, Waimate, Dunedin, Clutha	Christchurch, Timarau, Dunedin
6	Mackenzie, Waitaki West, Central Otago, Queenstown Lakes, Southland, Gore, Invercargill	Twizel, Alexandra, Queenstown, Gore, Oamaru, Invercargill

Summertime Overheating

Modelling has shown that for well insulated school buildings with high internal gains, overheating rather than underheating tends to be the more important aspect for thermal control. Summer temperatures do not correlate well with the climate zones in the Building Code Clause H1 Update 2021. An additional set of climate categories, based on overheating, has therefore been developed, as shown in **Table 10**, below.

Table 10: Summer overheating categories

Summer Temperature Category	Mean Daily Max' Air Temp' - February & December	Towns/Cities
Hot	>23°C	Alexdandra, Cromwell, Kaitāia, Whangārei, Hamilton, Gisborne, Whakatane, Napier, Tauranga, Masterton, Blenheim
Warm	20 - 23°C	Auckland, Palmerston North, Rotorua, New Plymouth, Wanganui, Taupo, Nelson, Fairlie, Christchurch, Queenstown, Lake Tekapo, Twizel, Timaru, Oamaru, Wanaka
Mild	<20°C	Wellington, Westport, Kaikoura, Hokitika, Dunedin, Gore, Invercargill

Modelling has demonstrated that detailed consideration and additional care needs to be given to the design of school buildings in locations with high summer temperatures, including more effective passive environmental control and/or the selection of cooling systems.

Analysis of the modelling overheating results shows that the extent of overheating is dependant on the size and location of the space or zone. Larger, open plan spaces with cross ventilation are less prone to overheating. Smaller, more enclosed breakout spaces are more prone to overheating. These spaces are generally located at the perimeter of the building, have single sided ventilation, and often have high window to wall ratios for architectural effect. High WWR must be avoided in breakout spaces, so that these spaces are not as prone to over-heating.

Passive ventilation and cooling will be more successful for larger spaces than for smaller breakout spaces. Supplementary ventilation or limited mechanical cooling by heat pumps may be an appropriate approach for breakout spaces in hot and warm zones.

Modelling has also shown that the use of a secure supplementary ventilation system for night purge offers only a slight reduction in overheating. This benefit is most pronounced in locations with a higher diurnal temperature range - generally these locations are in the 'hot' climate category as identified in **Table 10**, above. The effect of night purge ventilation could be increased by including a 'boost' mode with higher ventilation rates. Indoor and outdoor temperature sensors would further increase the effectiveness of night purge ventilation by allowing it to operate in the shoulder seasons, as opposed to a fixed summer time schedule only.

Whilst ceiling fans do not actually make learning spaces physically cooler, they do cool the occupants within them. Properly sized and placed ceiling fans disrupt the stagnant layer of air that surrounds the body. Air movement over the skin removes heat via convection and increases the rate of evaporation from the skin. Ceiling fans can be particularly helpful in warm locations, which also tend to have higher humidities. The use of ceiling fans reduces reliance on mechanical cooling, and they are recommended in learning spaces where heat pumps are not provided.

The effects of climate change

Buildings have traditionally been modelled using 10 years of historical hourly weather data. As the effects of climate change become increasingly apparent, historical weather data will be an unreliable basis for modelling analysis.

Modelling of a typical school building has been carried out using draft NIWA 2030 and 2080 predictive weather files for two locations (Auckland and Christchurch). Modelling suggests that there will not be a very significant effect on the number of overheating hours up to 2030. Modelling results using the 2080 weather files indicate a much more marked effect, with greater reliance on mechanical cooling to limit overheating. Given that the typical life expectancy of school heating and cooling systems is 10-20 years, general reliance on active cooling can be deferred, and should be regarded as a short-term climate change mitigation strategy.

CO_2 concentrations and associated ventilation provisions

Although carbon dioxide is naturally occurring and is not itself a contaminant, it is a proxy for the concentration of other contaminants and for the rate of outdoor air supply.

CO_2 modelling has been used to inform CO_2 concentration limits and improve the indoor air quality within learning spaces. In particular, where natural ventilation is the primary source of CO_2 control, modelling showed that CO_2 levels remained under 2000 ppm in the large learning spaces; only the breakout spaces exceeded this level, and only in the absence of ventilation. This was consistent with actual measurements of CO_2 concentration in learning spaces.

Table 11, below, summarises modelling results with different levels of background ventilation.

Table 11: CO_2 concentration modelling results
winter CO_2 concentrations, occupied hours, average across all spaces

Summary of modelling results with different levels of background ventilation			
Background Ventilation Rate	**Average CO_2 Concentration (ppm)**	**75th Percentile CO_2 Concentration (ppm)**	**Maximum CO_2 Concentration (ppm)**
0 l/s/person	724	859	2394
3 l/s/person	712	854	1617
5 l/s/person	694	845	1271
10 l/s/person	645	766	1121

This modelling has been supplemented by actual monitoring of a range of school buildings. Results support the use of natual ventilation together with CO_2 monitors and good management of windows by staff and students for warm climate zones. This supports the more stringent CO_2 requirements in Section 1, above:

- 1,250 ppm average CO_2 concentration
- 2,000 ppm short term peak concentration

Heat recovery ventiation has also been mandated for cooler climate zone locations.

Carbon dioxide levels in schools

Carbon dioxide is typically used as an indicator of ventilation effectiveness and as a proxy for indoor air quality. For a typical learning space with 30 students and 2 staff, an outdoor air ventilation rate of between 5 to 8 l/s/person corresponds to a CO_2 level of around 1,000 – 1,500 ppm under steady state conditions. Atmospheric CO_2 levels measured at Baring Head in 2021 by NIWA are about ~410 ppm.

It is expected that due to normal respiration rates of occupants, CO_2 levels inside learning spaces will increase above outside levels. In European Standard EN16798-1:2019, the CO_2 levels of 550 ppm (Category I), 800 ppm (Category II) and 1350 ppm (Category III) above the outdoor concentration, correspond to high, normal, and moderate levels of expectation with respect to indoor air quality. The

DQLS design criterion of 1250 ppm average CO_2 concentration in **Section 1.1.2** above, is 840 ppm above the atmospheric carbon dioxide level, taken as 410 ppm, and corresponds to the EN16798-1:2019 Category II criterion.

Most New Zealand school buildings are naturally ventilated, which means that adequate ventilation by opening windows is essential. The CO_2 concentration design criteria in Section 1 above, has been informed by measurements of actual CO_2 levels in learning spaces. **Figures 22 to 26**, below, present CO_2 data collected from Internal Environmental Monitoring (IEM) devices in a number of climatic locations. This data was analysed to assess the winter CO_2 concentrations in occupied learning spaces.

Five typical school days in winter (26th to 30th July 2021) were analysed in five schools, in four different climate zones (two warm zones and three cold zones). From the five schools, a two-day on-site observation of space usage was carried out in three schools, and a pre-designed template was used to record the building characteristics such as window orientation, type of ventilation, window operation, heating systems, and spot measurements of temperature and CO_2 levels. Winter data were analysed because cold winter draughts make it less likely that occupants will open windows to control ventilation.

The graphs below show how CO_2 levels can vary over the course of a day in naturally ventilated learning spaces with manually openable windows during the heating season. The overall trends indicate that across the cold and warm climate zones and in all five school days, the average CO_2 levels were largely less than1250 ppm and temperature levels were within the acceptable 18°C to 25°C for the school hours of 9 am to 3 pm. In schools, occupants are the primary source of CO_2 generation, and CO_2 concentrations within buildings will fluctuate depending on the number of occupants, type of activities, the amount of time spent in the room, and the ventilation rate. The graphs and on-site observations indicated that:

- there is a spike in CO_2 levels when occupants arrive in the morning, and shortly after the lunch break;
- as the space warms up during the course of the day, and occupants begin to open the windows, there was a significant drop in CO_2 levels; and
- opening windows during winter maintained CO_2 levels less than1,250 ppm, without lowering temperature levels below the acceptable threshold.

This suggests that if windows are properly operated, naturally ventilated schools can typically achieve the air change rates necessary to meet the acceptable CO_2 concentration criteria, even during winter. Based on this, natural ventilation is preferred in warmer climates, while a mixed mode system (natural ventilation and mechanical ventilation with heat recovery) is preferred in the colder climates.

Where natural ventilation is the primary means of CO_2 control, CO_2 and internal/external temperature display must be provided in a central location within each learning space, with instant visible feedback to local users, and the ability to store and download accumulated data. Windows must be designed to ensure that occupants flexibility in opening and closing windows in response to their environment.

Climate Zone One (Warm) CO_2 Analysis

The graphs in **Figures 21 & 22**, show how CO_2 levels rise and fall in a naturally ventilated learning space with manually openable windows over five school days during winter. A similar pattern may be discerned at both the Whakatāne and Auckland locations. The CO_2 level rises from a base of about 410 ppm (external atmospheric CO_2 concentration) to a peak of about 1,200 ppm.

During the two-day on-site visit to the Auckland school, it was observed that the fluctuations in CO_2 levels were due to the number of occupants, and to occupants opening and closing doors and windows. When students arrived in the morning there was a sharp increase in CO_2 levels, but when windows were opened, the CO_2 levels significantly decreased. This pattern repeats after the lunch break. When the students finished for the day, CO_2 levels decreased to ~410 ppm throughout the night. Similarly, the indoor temperature increased in the morning when the heating system was switched on, and generally remained within the acceptable range from 9 am to 3 pm.

These patterns suggest that provided windows are opened as intended, acceptable CO_2 and temperature levels can be maintained in naturally ventilated learning spaces in warm climates during winter. It is important that occupants have the flexibility to control their indoor environment, with a variety of openable windows on different sides and at different levels. Occupant training and the use of CO_2 monitors may also improve natural ventilation control.

Figure 21: Average CO_2 concentration and temperature levels, in Whakatāne District over five winter days, between 12am – 12pm in a primary school learning space

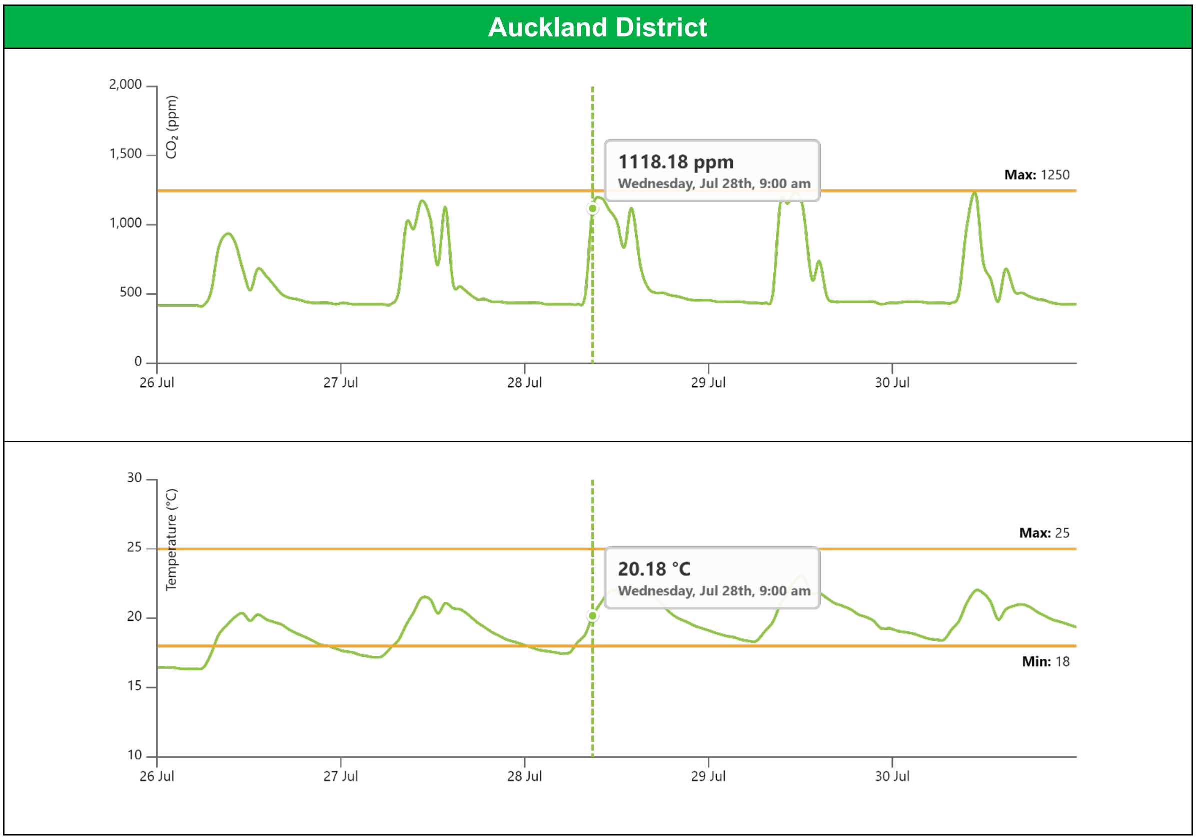
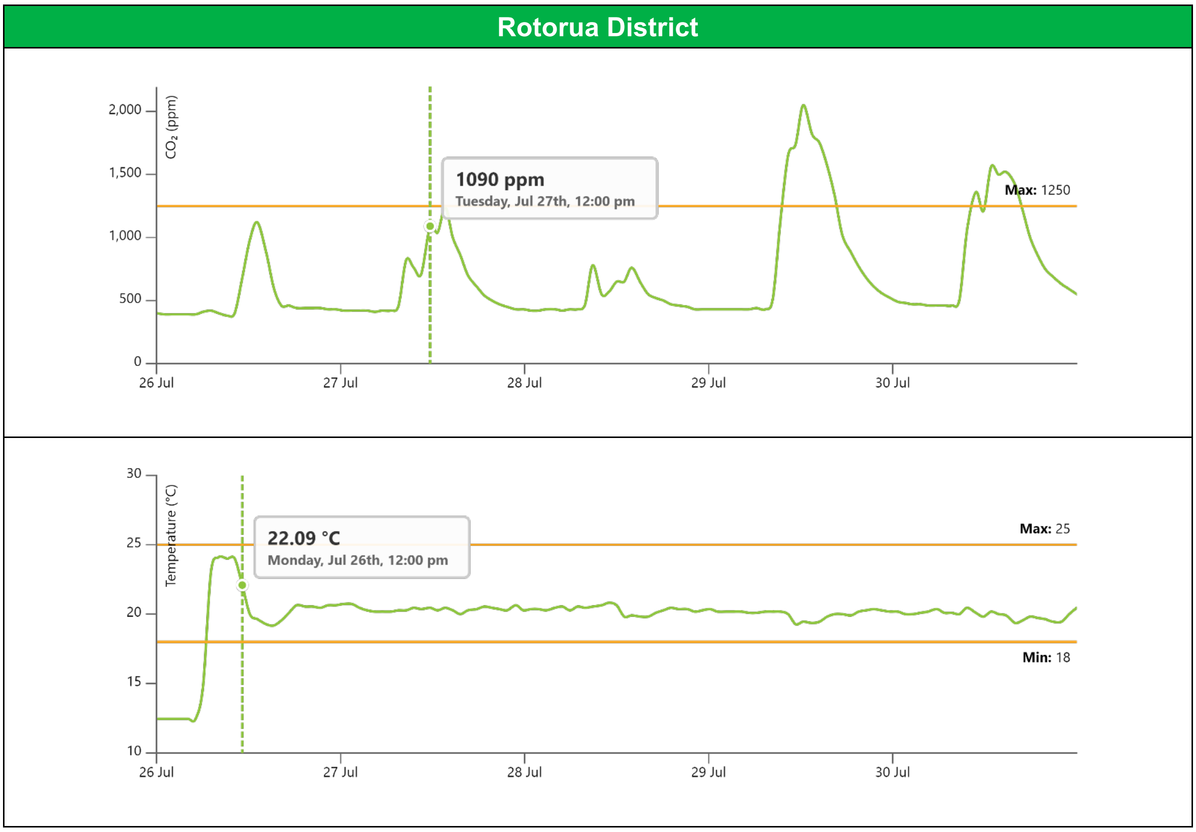


Figure 22: Average CO_2 concentration and temperature levels, in Auckland District over five winter days, between 12am – 12pm in a primary school learning space

Climate Zone Four, Five and Six (Colder) CO_2 Analysis

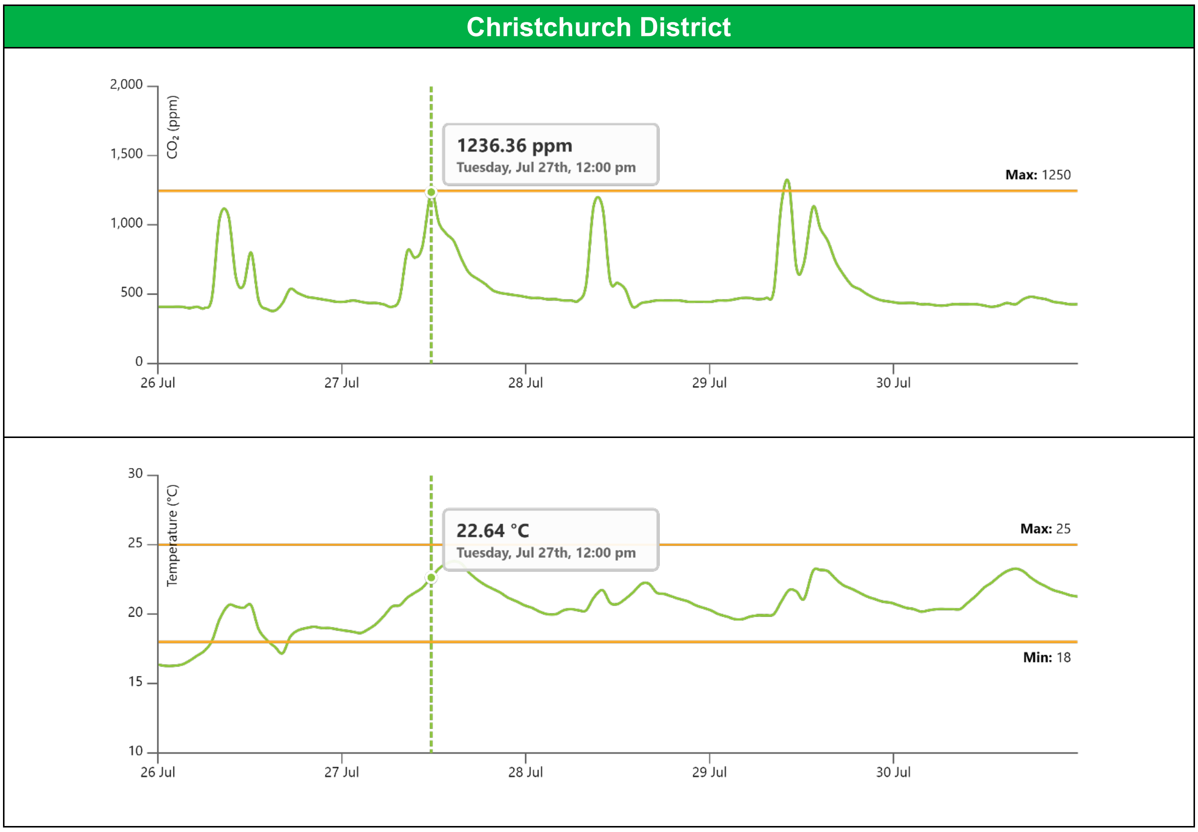
Figures 23 to 25 show how CO_2 levels rise and fall in naturally ventilated learning spaces in colder climates during winter. Over the course of a typical day, CO_2 concentrations rise from a base of 410 ppm to a midday peak of around 1000 ppm. CO_2 concentrations then drop during the lunch break, before rising again during the afternoon. During winter in the colder climates, windows and doors are generally closed early in the morning to conserve heat. Over the course of the day windows and doors are opened as occupants move between indoor and outdoor learning environments, or in response to feelings of stuffiness as CO_2 concentrations and temperature increase. During the two-day on-site observation in the schools at Christchurch and Queenstown, the occupants opened some windows, and the heating systems helped to keep the spaces warm.

These patterns generally suggest that even in the colder climates, on most winter days natural ventilation can be effective in maintaining adequate air flow in learning spaces, and the temperature variation from opening windows may not be excessive. However, there would likely be some days when weather conditions deter occupants from opening windows (e.g., strong winds, precipitation and particularly low temperatures). In the colder climate zones, mixed mode ventilation systems would ensure acceptable indoor conditions despite extreme external conditions and would improve energy efficiency.



Rotorua District

Figure 23: Average CO₂ concentration and temperature levels, in Rotorua District over five winter days, between 12am – 12pm in a primary school learning space



Christchurch District

Figure 24: Average CO₂ concentration and temperature levels, in Christchurch District over five winter days, between 12am – 12pm in a primary school learning space

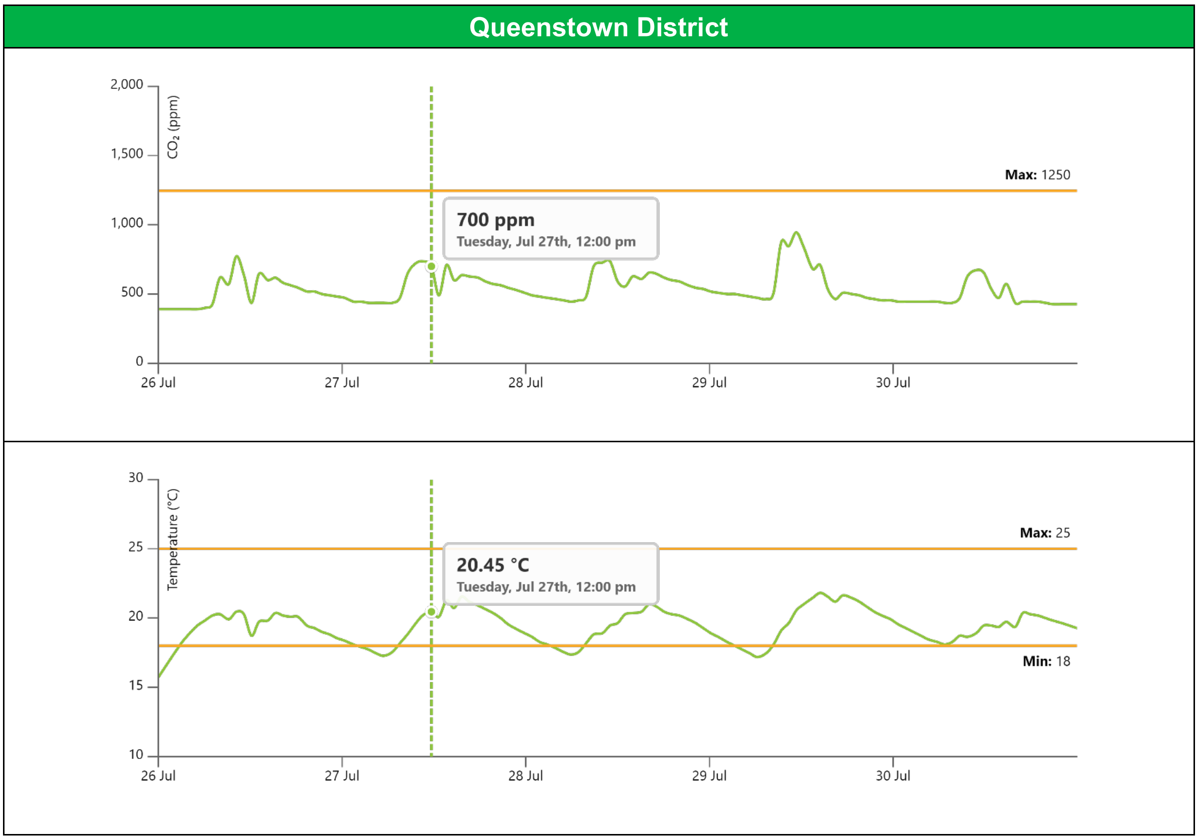


Figure 25: Average CO_2 concentration and temperature levels, in Queenstown District over five winter days, between 12am – 12pm in a primary school learning space

Summary

The CO_2 concentration limits set out in **Section 1.1.2** above are intended to serve as a limiting proxy for respiration derived pollutants (including airborne pathogens and anthropogenic odours). The available evidence indicates that even the highest CO_2 concentrations likely to be encountered in learning spaces in schools would not in themselves constitute a risk to health, but rather a temporary impediment to cognitive performance, particularly in relation to speed. According to ASHRAE Standard 62.1:2016, “the CO_2 concentration commonly found indoors, is not a direct health risk and in most buildings, concentrations rarely rise to very high limits (e.g., greater than 5000 ppm)”. To ensure good indoor air quality and thermal comfort, learning spaces must have temperature and CO_2 monitors that are easy to understand and alert occupants to change the conditions (open windows) in their learning spaces during the course of the day.

Rationale for the Ministry’s Ventilation Strategies

Ventilation may be provided through either natural, mixed mode, or mechanical means. The strategy employed will depend on the climate zone, the form of the school building, its size, occupancy density, acoustic considerations, and other site-specific requirements.

In warmer climate zones (Figure 6) natural ventilation is preferred by the Ministry, wherever practicable, provided minimum requirements in terms of indoor air quality and thermal comfort and control, are met. Where spaces are naturally ventilated, provision of ceiling fans and night purge ventilation (especially high level automated windows) should be considered, to reduce over-heating.

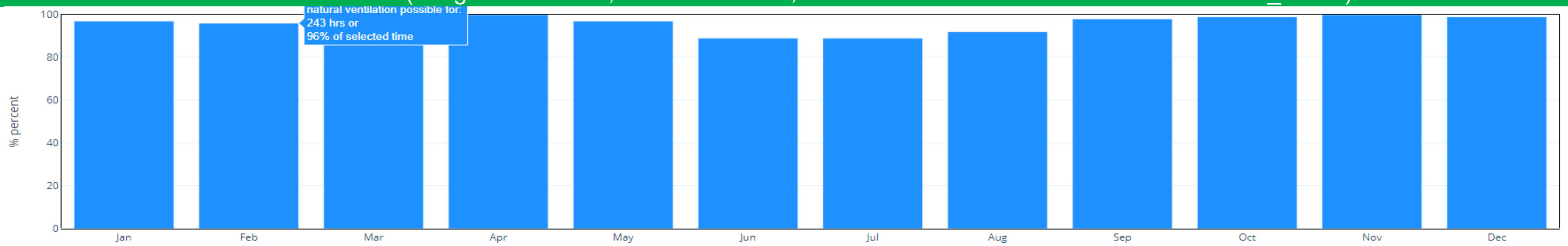
In colder climate zones (Figure 6), mixed-mode or mechanical ventilation, with heat recovery systems, is preferred by the Ministry. Mixed-mode and wholly mechanical ventilation are generally suited to larger, spatially complex enclosures in cooler climate zones with moderate to high occupancy levels. Where a mechanical heat recovery ventilation system is used in cooler climate zones, heating loads can be reduced by recovering the heat from internal gains. In summer, heat recovery ventilation systems use conditioned exhaust air to cool the incoming fresh air, or expel internal heat by operating a summer bypass around the heat exchanger.

Mechanical ventilation may also be appropriate for internal rooms in deep plan buildings, or where acoustic and structural constraints preclude the use of natural ventilation, or where outdoor conditions necessitate tempering or other treatment of outdoor air.

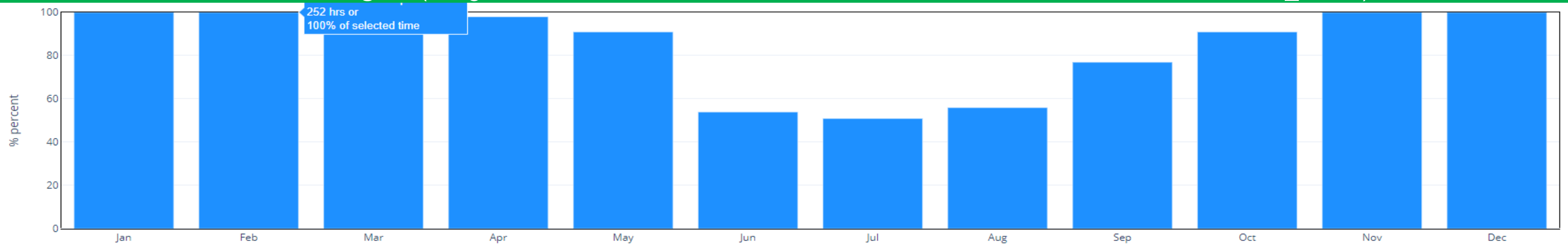
The Ministry's ventilation strategies have been informed by outdoor temperatures in warm and cold climate zones. **Figure 26** below, presents dry bulb temperature data for major urban centres across New Zealand. The CBE Clima Tool was used to analyse NIWA temperature data and calculate the percentage of hours the dry bulb temperature is in the range 10°C to 25°C between the months of January and December, and during the school hours of 8:00 am and 3:00 pm. The CBE Clima Tool is a free online tool for thermal comfort calculations and visualizations, which complies with the major international thermal comfort standards (ASHRAE 55–2017, ISO 7730:2005 and EN 16798–1:2019).

The graphs below show that for most of the time, natural ventilation is possible in warmer climate zones. However, maintaining good indoor air quality in naturally ventilated buildings is more difficult during cold weather in colder climate zones. This is consistent with measurements of indoor temperature in naturally ventilated learning spaces, presented in **Figures 21 to 25** above, which show that indoor temperature levels were maintained within the acceptable range 18 °C to 25 °C for five typical school days in winter, noting that this includes the use of heating systems.

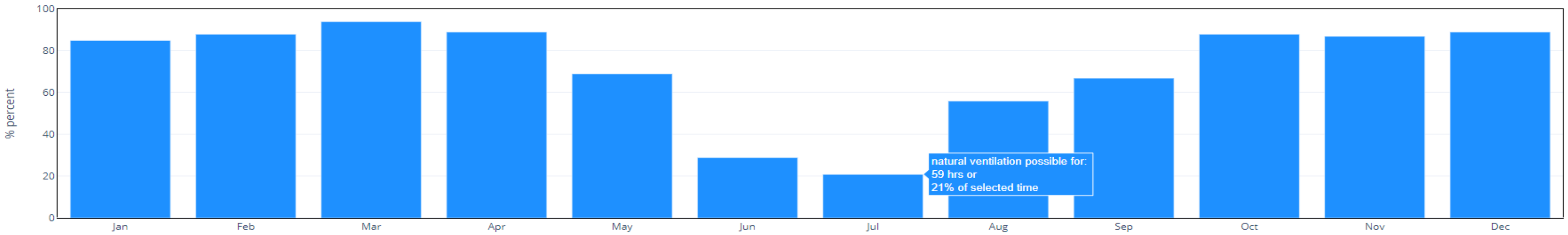
Auckland (Longitude: 174.79, Latitude: -37.01, Elevation above sea level: 33 – AK.931190_NIWA)



Wellington (Longitude: 174.87, Latitude: -41.41, Elevation above sea level: 79 – WN.934360_NIWA)



Christchurch (Longitude: 172.54, Latitude: -43.49, Elevation above sea level: 37 – CC.937800_NIWA)



Queenstown (Longitude: 168.74, Latitude: -45.02, Elevation above sea level: 354– QL.938310_NIWA)

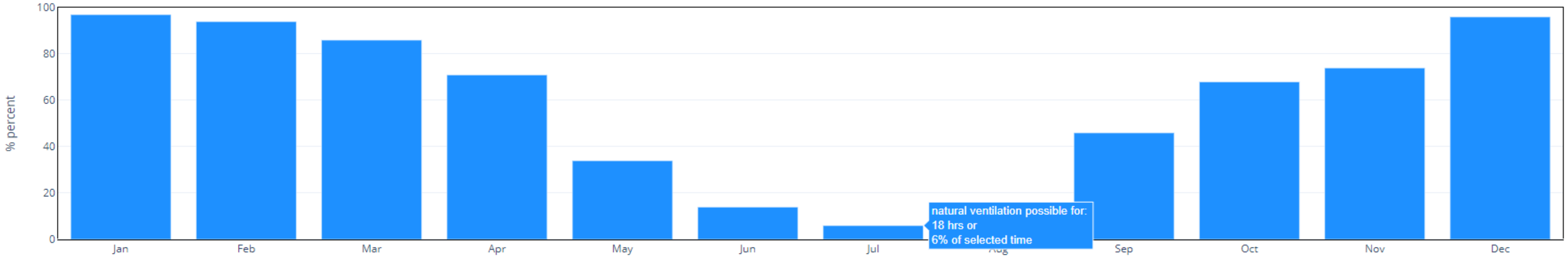


Figure 26: Percentage of hours the outdoor dry bulb temperature is in the range 10°C to 25°C between the months of January and December, between the hours 8:00 am and 3:00 pm

Effects on energy use

Heating & cooling energy use was found to be low in the model simulations, primarily due to the wide range of acceptable internal temperatures (18°C to 25°C), the use of a predominantly passive design approach in the modelled building, and the beneficial heat gains from occupants in cooler weather.

In order to ensure that new school buildings have similarly low heating & cooling energy use, the following design imperatives must be adhered to:

- correct orientation, and/or shading
- a modest window wall ratio (WWR)
- appropriate levels of thermal insulation for the school climate zone and location
- predominant use of natural ventilation, with supplementary mechanical heat recovery ventilation in cooler climates, and extract ventilation with trickle vents in warmer climates where passive ventilation is constrained by site characteristics

Daylighting

Modelling in support of this DQLS has demonstrated that thermal and energy modelling needs to be carried out in an integrated multi-variable way, so that the requirements of both this document and the DQLS – Lighting & Visual Comfort document can be achieved, or at least optimised.

Key aspects

The modelling and post-occupancy evaluation studies by the Ministry in support of this new DQLS – IAQTC Version 2.0 demonstrate how the document can be used to improve school building performance. New features in this version include:

1. The identification of new and distinct winter heating and summer overheating zones. Winter heating zones are based on the MBIE Building Code Clause H1 Update 2021, whereas the summer overheating categories are based on NIWA maximum summer temperature data. This allows appropriate indoor environmental control solutions to be matched more closely with particular climatic conditions.
2. Refinement of the modelling to reflect different types of learning spaces (viz. larger open plan learning spaces, which can be passively controlled more effectively, and smaller break out spaces which may require more active control solutions).
3. The reduced number of overheating hours for both 25ºC and 28ºC will require design teams to work harder and more collaboratively in optimising the passive control features of the building.
4. The new requirement for CO_2 controlled heat recovery ventilation with a summer bypass facility in Climate Zones 4, 5 and 6.
5. The short-term effects of climate change are not considered to be too detrimental to the DQLS – IAQ & TC recommendations, given the anticipated life of environmental control systems. However, with the current acceleration of these effects, future reviews of this Document may need to adapt the current requirements and recommendations further.
6. Provided that building performance is optimised and meets the requirements of this DQLS using predominantly passive design features, then the energy use for heating, cooling and

ventilation will be low and consistent with the stated requirements of a ‘Carbon Neutral Government’ by 2025. This DQLS also precludes the use of fossil fuels as a heat source for new School buildings and in major upgrades of existing buildings.

7. Thermal, energy & daylight modelling needs to be carried out in an integrated way so that the requirements of the DQLS suite can be met.

Glossary

Active cooling	Cooling provided by a mechanical system. Also called air conditioning.
Air pollutant	Any substance (dust particulates, chemical compounds, or other airborne materials) that may be harmful or irritating to occupants when present in sufficiently high concentrations.
Airtightness	An indirect measure of the collective size of gaps/openings in the shell of the building. Airtightness is usually expressed as a number of air changes per hour at 50 Pa pressure difference (n50). It may also be expressed in terms of permeability - $m^3/m^2/hr$ at 50 Pa (q50). Testing is undertaken via fan pressurisation techniques ("a blower door"). Pressurisation test results should not be construed as the building leakage rate in service.
Cross ventilation	Ventilation whereby air is introduced into a space on one side by positive air pressure and then drawn across the space and vented from the other side by negative air pressure. Natural cross ventilation utilising wind and local air movements is a common and effective ventilation strategy, particularly in small, spatially simple enclosures.
Fresh or outdoor air	External air as used for ventilation, filtered or otherwise treated where necessary. Not always fresh, so more accurately referred to as outdoor air.
Glazing system	The glass and framing of windows and doors; these may be specified to achieve a variety of temperature control, acoustic, lighting and ventilation outcomes. The glazing system may be an integral part of a heating, ventilation, acoustic or lighting design strategy.
Heat Pump	A mechanical unit designed to transfer heat from one environment to another, opposite to the spontaneous direction of heat flow. A heat pump uses the refrigerant cycle, just like a refrigerator or freezer. Most are reversible, which means they can both heat or cool a space. They require electrical power but are typically 3 to 4 times more energy efficient than conventional electrical resistance heaters. The efficiency of a heat pump is frequently express as a coefficient of performance (COP) rating. Disadvantages include relatively high capital costs, and life spans limited to around 15 years.
HVAC	A generic term for a system that provides heating, ventilating, or air conditioning (HVAC) in various combinations.

Insulating glazing unit (IGU)	A double or triple glazed unit, together with the spacer material that separates the panes, and any reflective or tinted coatings. IGUs are typically designed and specified to improve the acoustic and thermal insulation performance of the building. The term 'glazing system' is typically used to refer to IGUs together with their framing.
Interstitial condensation	Condensation occurring inside the envelope of the building, as opposed to on the interior or exterior surfaces. This results from a complex dynamic interaction between the various properties of the components making up the assembly (thermal resistance, vapour permeance, heat capacity etc.) and the environment either side. Modelling tools are available to help predict and mitigate the risk of interstitial condensation occurring.
Internal Environmental Monitoring (IEM) Device	Also, called dataloggers, IEM are devices used to monitor the internal environment by measuring lighting levels, sound levels, temperature, humidity, and CO_2 levels. These are small electronic devices which are installed into classrooms and collect data over a span of time.
Learning Space	Learning space is defined by the space required for one teacher and a 'classroom' group of students. The number of students per teaching space varies with the year level of the student. The term is used interchangeably with 'Teaching Space'. Teaching spaces is a term that better describes the broader range of learning space configurations than classrooms does. However, a classroom is a teaching space. Classroom is a traditional term still used but is not our preferred term when speaking generically. When discussing size and quantity of teaching spaces, one teaching space is equivalent to one classroom.
Make up air	Air that is introduced into a space to replace air that has been removed through either passive or mechanical means. This means that minimal outside air is able to infiltrate the building when doors, windows and other vents are closed. If mechanical ventilation is then used to remove contaminated air, fresh air will not be able to infiltrate the building, which will instead depressurise, potentially causing issues with back-drafting of gas appliances etc. In the absence of a make-up air source, natural ventilation systems will also fail. Make up air may be provided through simple vents, or through pressure-sensitive or extract-triggered dampers.
Mechanical ventilation	Ventilation whereby air is moved through an enclosed space by a mechanical device such as a fan.
Mixed mode ventilation	Ventilation whereby a mixture of complementary mechanical and natural ventilation means is included.

Natural ventilation	Ventilation provided by natural means, such as openable windows, doors or vents. Natural ventilation relies on internal/external air pressure differentials, or on vertical thermal differentials within building spaces (the stack effect), to drive air movement. Natural ventilation stands in contrast to mechanical ventilation, which relies on motor driven fans to distribute air within a building space.
Passive ventilation and cooling	See *Natural ventilation*, above.
Relative humidity (RH)	The water vapour concentration present in a sample of air, expressed as a percentage of the concentration the air could hold if fully saturated (i.e., at a particular temperature and pressure).
R-value	See *Thermal resistance* below.
Sash	The frame holding the glass in a window. There may be multiple sashes within the window frame.
Solar gain	Heat gain within an enclosure as a result of passive accumulation of solar energy through windows, by building components, or by deliberately deployed thermal masses. Solar gain may be beneficial when internal spaces require heating, or it may be problematic if internal spaces are prone to overheating.
Thermal comfort	The sensation of feeling neither too hot nor too cold; a condition of thermal neutrality. It will depend on metabolic rate, clothing, and factors such as air movement, radiant temperatures, humidity, and the prevailing external conditions. Due to the variation in thermal comfort expressed among individuals, it is rarely possible to achieve this ideal for all occupants.
Thermal resistance	A measure of a material or composite construction's ability to resist heat flow. The SI unit of specific thermal resistance is K□m/watt – this refers to the resistivity of a particular material, independent of its quantity or thickness. The thermal resistance of a material or composite construction is often expressed per unit area and is quoted as its R-value (m$^{2\circ}$C/watt); this value is dependant on the thickness of the material or construction. Good insulators have high R-values.

Volatile organic compound (VOC)	Volatile organic compounds are substances which easily evaporate into the surrounding air at normal ambient air temperatures and pressures. Some VOCs are dangerous to human health, or cause harm to the environment. They may not be acutely toxic, but chronic exposure at even low concentrations may be harmful over prolonged periods. The diversity and ubiquity of VOCs make them difficult to monitor and regulate. They are widely used in materials such as paints, adhesives, sealants, varnishes, synthetic fabrics, particle and plaster boards and insulation materials. Notably toxic VOCs include benzene, formaldehyde, naphthalene, perchloroethylene, methylene chloride and methyl tert-butyl ether (MTBE). VOC emissions from building materials and furnishings are typically highest when they are new. Elevated air temperatures and direct exposure to sunlight may increase VOC emissions from materials.

Tables

Figures

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