Submission to MBIE on:

The Need to Update Clause G4 for Residential Construction

Abstract

Our code lacks clarity on what adequate ventilation is or, more useful perhaps, specifics on when loss of amenity and health occurs due to lack of fresh air. Industry experts have met to discuss the challenges faced in residential construction based on the current code as it relates to ventilation. This document covers those discussions of the current standards, the effect of changing lifestyles and construction on housing and health outcomes and concludes with recommended improvements to code that contributors would like to see implemented. Specific concerns included the reliance on natural ventilation in increasingly high-density construction, performance of intermittent fans in airtight construction and limitations of relying on humans in a modern world. Recommendations on how these concerns could be addressed through code improvements included updates to the definition of openable area and applicability of natural ventilation options, inclusion of continuous ventilation and defined air pathways and reviews of definitions and tables in the acceptable solution. The clear message was that a change is needed, and that The Collab would like to see this considered with some urgency.

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1. Background

A cooperative of ventilation suppliers, mechanical consultants, building experts, academics and other industry stakeholders have come together to discuss the current serviceability and applicability of the NZ Building Code Clause G4 for modern residential construction as it applies to ventilation. Self-titled the Ventilation Collab ("The Collab"), the group's objective was to: "help our industry improve Indoor Air Quality in NZ Homes, with an urgency that reflects what we see as a growing and significant problem." Since July 2023, the Collab met regularly to discuss what they meant by this statement and how an acceptable outcome could be achieved.

1.1. Collaborators

Made up of 31 individuals across 23 businesses, The Collab undertook to arrive at a well-balanced solution involving contributors with varying interests in and perspectives on ventilation. The goal was to deliver science-led recommendations starting from a minimum level, not driven by individual business interests. The results reported here may not represent one individual's opinion in full, instead favouring research and the opinion of the majority.

Collaborators	Company	Collaborators	Company
J. Bennett Associate Professor	University of Otago	T. Ujjainwala	BDT
B. Dick	BDVAir	T. Sandes	DVS
C. Kilgour	Fantech	W. Delport	THCi
C. Masterton	HRV	Unnamed Collaborator 1	Unnamed Org. 1
D. Gear	Simx	Unnamed Collaborator 2	Unnamed Org. 1
D. Martin	BEO	Unnamed Collaborator 3	Unnamed Org. 1
G. Anderson	Stiebel Eltron	Unnamed Collaborator 4	Unnamed Org. 2
I. Borley	Simx	Unnamed Collaborator 5	Unnamed Org. 2
J. Davies	Pro Clima	Unnamed Collaborator 6	Unnamed Org. 2
J. Selkirk	SCPNZ	Unnamed Collaborator 7	Unnamed Org. 3
M. Cutler-Welsh	NZGBC	Unnamed Collaborator 8	Unnamed Org. 4
N. Woods	HRV	Unnamed Collaborator 9	Unnamed Org. 5
P. Shaw	Smooth Air	Unnamed Collaborator 10	Unnamed Org. 6
R. Mannes	22 Degrees	Unnamed Collaborator 11	Unnamed Org. 7
R. Zettler	BDT	Unnamed Collaborator 12	Unnamed Org. 8
S. Harpham	Simx		

1.2. Impact of Air Quality

The HAPINZ3 2016[1] research provided an estimate of the human cost of air-pollution, with more than 3,300 deaths and $15.6 billion in social costs being associated. While these measures weren't specifically tied to the indoor environment the link is reasonably simple given the amount of time we spend indoors and the reliance on outside air to provide our indoor air quality.

In 2024 FMANZ undertook an independent study[2] considering the economic impact of poor indoor air quality. They focused specifically on offices and schools and the health and productivity costs of poor indoor air quality in these spaces. The current standard in these spaces for ventilation rates was 8-10l/s/pp, if they increased this to 14l/s/pp the potential economic impact from offices and schools was a saving of $776m-$1.15bn for a cost of less than $253m. While simply increasing air volume is not the only solution, particularly when we factor in energy costs, it does emphasise the importance of caring for indoor air quality.

1.3. Scope

Determine the need for and the direction to update G4 legislation and AS1 for residential construction.

[1] https://ehinz.ac.nz/projects/hapinz3/key-findings-from-hapinz/
[2] https://www.fmanz.org/wp-content/uploads/2024/09/FINAL-20240917-IAQ-Report-FMANZ.pdf

1.4. Specific Concerns

Condensation in New Builds

Over the past few years, many of the collaborators, or their industry colleagues and researchers have seen or been provided evidence of condensation in new builds. Including many which have been constructed within the last 5 years. Left unchecked, there is the potential for this to have serious and long-lasting implications regarding both the integrity of the building, and the ability for the occupants to maintain their health and lifestyle in the manner that has become the norm in society

Figure 1: Waikato - Double Glazed Non-Thermally Broken Joinery

Lifestyle Changes and Ventilation Education

Reduced home time affected by work-life balance, increased neighbourhood densities, security, noise, and personal comfort all affect our disposition towards opening windows at the right time – and yet building code relies on it. There are also social and cultural factors at play. Expecting individuals to grasp the nuances of the current code which were designed for a different time and society doesn't account for what may be usual or palatable to New Zealand's current multicultural society.

Intermittent Isn't Enough and Humans Are Unreliable

The need for specific contaminant removal is crucial to maintaining a healthy atmosphere in the home. Currently there are two assumptions underpinning the basis for the existing acceptable solution. Firstly, that the bulk of indoor air pollutant generation happens in bathrooms, kitchens and laundries; secondly that we will use the provided fans sufficiently to remove them. With more compact living, over-crowding and the lifestyle changes mentioned previously we are both increasingly less likely to open windows and more frequently generating pollutants or generating the same volume of pollutants in a smaller more airtight space resulting in poorer air quality overall.

The reliance then on intermittent fans is problematic for several reasons. The first is that as we are building increasingly airtight homes and the ability of the fan to overcome the resistance of a building envelope is reducing. Electricians regularly report being called back to installations that aren't removing steam, although they can show the fan is working and the installation is correct. The reason is the space lacks make-up air, be it from door undercuts or availability of outside air.

This assumes that the fan is being turned on in the first place. Landlords, most notably Kainga Ora, are increasingly adding humidity sensors to their bathrooms so that the option of turning on the fan is no longer reliant on the human element. The second issue with intermittent fans is of course the reliance on occupants to use them; especially where that fan may be loud, or the occupant is in fuel poverty, or the fan is tied to a light switch and light is not needed, or simply because they forgot. The third challenge is that the air volume removed by an intermittent fan does not provide air replacement throughout the home and is sometimes insufficient to even remove the moisture generated in the one space (run-on timers are another of the landlords answers to this problem).

Figure 2: Auckland Residence - Homeowner actively attempting to use natural (window) ventilation while maintaining indoor air temperatures, still resulting in mould

Changing Construction

More New Zealanders living in townhouses and apartments reduces the ability for windows to provide good crossflow ventilation due to single sided construction or proximity to neighbouring buildings. Compounded by the presence of restrictors in the safety from falling requirements prescribed in Acceptable Solution F4/AS1 2.0[3] and that windows for natural ventilation must be able to be "fixed" open, it becomes almost impossible for sufficient natural ventilation to be achieved based on the current code's "5% openable area" (a number calculated on the overall area and not the effective area). The impossibility is evidenced by the influx of news articles documenting homeowners' inability to offset solar gain by opening windows in modern homes.

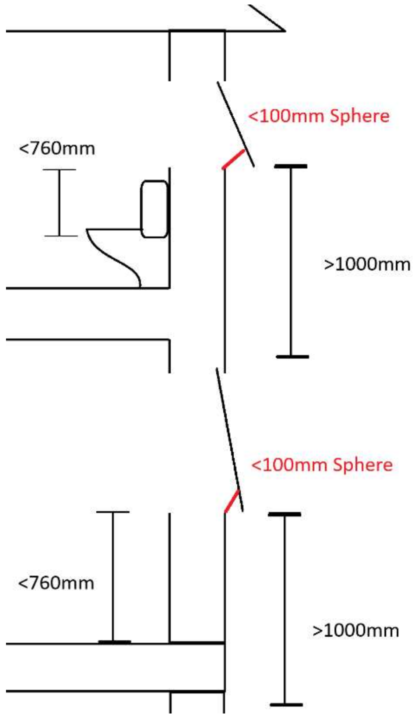

Figure 3: F4/AS1 Interpretation

The most recent update to H1 was also considered in this section and, while it was concluded that the increased need for ventilation was not caused by the H1 changes[4] it has brought into public focus the issues related to unwanted moisture and temperature buildup. The general trend towards more airtight builds with an emphasis on energy efficiency brings to the forefront a need for well-considered ventilation improvements. BRANZ[5] data shows NZ homes have been increasing in airtightness since pre-1960. Airtightness contributes significantly to energy efficiency and so should be encouraged but need to be considered alongside more structured ventilation solutions; it should be noted the unwanted infiltration due to poor airtightness that previously moderated the vapour load in the home did not guarantee high indoor air quality and so a reversal of any airtightness improvements would not be considered a positive outcome.

It should also be considered that solutions implemented to achieve airtightness affect the vapour permeance of the building envelope as well. Buildings with rigid air barriers have a far higher vapour resistance than building wraps or traditional tar paper. RAB Systems that are well fitted with all joints taped with vapor tight tapes provide further resistance to drying and moisture removal by significantly limiting diffusion pathways as well as bulk air movement pathways.

Warmer homes thanks to insulation and airtightness are also not synonymous with drier or healthier homes. Wu and Wong [6]in their 2022 investigation compared mould growth at 19 vs 28°C and 40, 60 and 80% RH, they found that "spores showed similar levels of viability at 19 and 28°C" in comparison to "substantially lower survival" at 40%RH, versus 60% and 80% RH. The result is warm but humid conditions with stagnant air will result in mould growth as an Australian school found during summer 2024[7]. Warmer surfaces and warmer air, when it results in lower RH, may decrease the likelihood of condensation and mould overall but does not produce drier air; this requires new air sources or active dehumidification to reduce the absolute humidity. Otherwise, prolonged

[3] F4/AS1 2.0. Opening Windows reproduced in part: "2.1 … where the possible height of fall from an open window is more than 1000 mm. The possible height of fall shall be measured from the inside floor level adjacent to the window. 2.1.1 In housing … a window … shall have either: a) the lower edge of the opening at least 760 mm above floor level, or b) a restrictor fitted to limit the maximum opening so that a 100 mm diameter sphere cannot pass through it..."
The result is most second storey windows and higher, as well as houses built on piles or other elevated foundations require window restrictors (restricting openings to <100mm)
[4] Design is a far larger factor and shading, orientation, airtightness and ventilation all need to be considered
[5] Branz Build 166-90 Airtightness Trends : https://www.buildmagazine.org.nz/assets/PDF/Build-166-90-Research-Airtightness-Trends.pdf
[6] Wu, H.; Wong, J.W.C. Temperature versus Relative Humidity: Which is More Important for Indoor Mold Prevention? J. Fungi 2022. 8, 696
[7] Australian School Mould Issues: https://www.theguardian.com/australia-news/2024/mar/19/nsw-school-to-be-demolished-after-extensive-mould-outbreak-in-carpet-chairs-and-plasterboard

exposure to high humidities can lead to a build-up of moisture over years and in turn increase the likelihood of mould.

That same moisture buildup is exacerbated by increased condensation on the now more concentrated area of thermal bridges when the rest of the surfaces are kept warmer. This coupled with other items discussed can lead to aluminium joinery crying more than previously and much more liquid water developing in concentrated spots, creating havens for mould. The main point to hold in mind is that a certain quantity of vapour is produced by living that cannot be reduced. If it cannot escape it will eventually condensate on the thermal bridges of an insulated building.

Mould in Roof Spaces

H1 may not be culpable for many of the evils ascribed to it but as roof spaces have cooled, thanks to better heat retention in the home, we have created the perfect breeding ground for mould. As moisture is carried up with the rising warm air, water vapour migrates through our ceilings into the roof spaces where it meets cold surfaces, particularly overnight, and condenses. These surfaces stay damp as the roof space is no longer heated by lost heat from the home.

Mould growth is further supported by insufficient roof venting from a combination of: insulation blocking ventilation pathways and poor design. However, even with better attention provided to roof space ventilation not all roof moisture issues will be able to be resolved without managing indoor humidity levels better. The “cold roof” issue is elevated once more by light toned roofing (that lacks sufficient solar gain during the day to reliably assist with heating and evaporating moisture), as well as smaller footprints to floor areas which typically have a smaller roof to occupancy ratio.

The prevalence of downlights is another aggravating factor as they typically allow far greater bulk movement of air into ceilings than traditional surface mounted or hanging luminaires. This is mitigated in bathrooms with the use of IP rated lights that seal to the ceiling better than non-rated elements. Quality of install affects both locations.

Filtration

There are some portions of code that mention ventilation separate to G4 (specifically E3 and G5) and loosely address its relationship to indoor environment (moisture and temperature) without clearly specifying the level of ventilation, nor the quality of the indoor environment[8]. While the outdoor air’s typical gaseous composition is defined the definition has remained unchanged since the Building Regulations inception in the 1990’s. This definition gives no consideration for variation in outdoor air quality between populous and unpopulous areas looking only at the gas composition of the air and not the potential pollutants in the air. Nor does our current construction consider the potential of worsening outdoor air quality over the next 50+ years of our building life. With increasing pollution, rising base CO_2 levels, higher density central city accommodation and development in more industrial and marginal areas a clearer definition of outdoor air and indoor air quality is needed to help ensure future protection from illness.[9]

Changing Climate and Overheating

Condensation and pollution are not going to be the only challenges facing us in the next 50 years, the minimum timeframe a new home must last for although many homes will persist and contribute much longer. With increasing temperature extremes and weather events, consideration will need to be given to the potential for homes to overheat in summers. As it’s not possible to easily control for building orientation or wind factors; shading and ventilation are going to become critical to dwelling thermal performance and occupant safety.

While ventilation alone does not prevent overheating it greatly mitigates the effect of solar gain and poor design relative to the outdoor air. With the improvements to air tightness and insulation, our homes are liable to be hotter

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[8] NZS4303 provides some IAQ guidance but the IAQ section is not referenced by G4/AS1, favoring instead Table 2.3 in G4/AS1.5.1a.

[9] There is much still to be learnt of the contribution of indoor air quality to long term health, while this document does not explore the specifics there is sufficient evidence to support that improving indoor air quality contributes to better health and social outcomes.

than outside and the ability to provide good ventilation is a key element (paired with shading and orientation) to reduce this. Further improvements can be found from intelligent ventilation systems, night purge and thermal mass, heat or energy recovery systems and other passive solutions. The ventilation systems should be designed to last 5-15 years (depending on accessibility and may vary by component) and designs should consider the ability for key components to be replaced at end of life.

Variations Nationally

There are occasions where natural ventilation is not acceptable, these are typically found within district and regional plans and requirements vary by region. The most common occurrence is as a response to unacceptable outdoor noise levels rendering openable windows unsuitable. Councils, NZTA, as well as some airports have taken different paths for determining how to achieve acceptable indoor environments, many simply accept G4 (0.35ACH/7.5l/s/pp) as a suitable outcome although from these it varies whether supply air systems sourcing roof air are acceptable or not. Other locations require 6-10+ ACH to deliver high volumes of air change through a mechanical system which are historically based on achieving the experience of open windows on a windy day. Some allow the capacity to be reduced by installing air conditioning systems to mitigate overheating, instead of high levels of air change.

This highlights one discrepancy found nationally and the need for greater consistency between the required and desirable outcomes when natural ventilation is not acceptable.

1.5. Method

The Collab undertook to gather evidence to support the urgency of this request to update G4 and review the legislation and Acceptable Solution to identify weak points. The results are the suggested updates in line with the evidence collected to better safeguard people from illness or loss of amenity due to lack of fresh air, having regard to how changes may affect other parts of the building.

2. Research

2.1. Validation of Concerns

News From Around NZ:

Overheating in new townhouses (Auckland): https://www.rnz.co.nz/news/national/511585/the-big-bill-to-cool-new-auckland-townhouses

> Over the summer of 2023/2024 owners of new townhouses found their top floor bedrooms impossible to cool. Lack of shading, high sun-exposure to the west, insulation without consideration to overheating and inadequate ventilation were all referenced as causes. Remedying this after the fact was expensive if not impossible.

50deg+ in townhouses (Christchurch): https://www.1news.co.nz/2024/12/15/a-sauna-without-the-fun-calls-grow-for-action-on-overheating-townhouses/

> December 2024 it's 20 degrees outside in Christchurch and yet internal temperatures are already reaching 53 degrees. Large glazing levels is identified as the typical culprit and ventilation and insulation part of the solution. The article identifies the lack of any specific overheating element to our residential building code.

25% of Apartments and 50% of townhouses uncomfortable (Auckland): https://www.knowledgeauckland.org.nz/media/jfqbf2nm/tr2024-06s-life-in-medium-density-housing-in-t%C4%81maki-makaurau-auckland-summary.pdf

> A 2024 Auckland Council Medium Density Residential study found "the combination of large windows, small window openings, solar orientation , reduced natural ventilation and minimal shade provision (e.g. eaves, established trees) are resulting in homes that are too hot in summer." Of those surveyed over 25% of apartment dwellers and 50% of townhouses and duplexes suffered from uncomfortable temperatures. The study also raised the concern that heat pumps as a solution contributed to the heat island affect.

30deg+ apartments and heatwaves expected (Wellington): https://thespinoff.co.nz/society/09-12-2024/too-hot-to-handle-how-climate-friendly-housing-is-becoming-unliveable

> This Wellington based author measured their apartment at over 30degrees in autumn of 2024, while they referenced historic studies including the BRANZ study in 2007 that found newer homes more likely to exceed a comfortable 20degrees, their biggest concern was that heatwaves are coming, and local apartments aren't designs for these.

Poor Air Quality Getting Inside (Invercargill): https://niwa.co.nz/news/some-homes-contain-3-times-more-air-pollution-niwa-finds

> While our air quality is good in many areas; a lot of the time poor air quality, particularly over winter and when the wind is low, occurs as pollution settles in localised areas and finds its way into our homes. This outdoor air quality presents a risk of causing headaches, asthma and other respiratory issues. Improving air quality overall through electrification of heating was a key focus, but for individual homes the answer was air filtration.

Research and Modelling:

Nodal Modelling of Air Flow with Trickle Ventilation, Continuous Extract and CO_2: https://www.sciencedirect.com/science/article/pii/S0378778823010587?via%3Dihub

While the research conducted was aimed at establishing a simpler modelling method the comparison was built upon the Australian National Construction Codes provision for continuous ventilation rates and CO_2 as a basis to validate their models. The result was that continuous extract coupled with trickle vents did not sufficiently achieve CO_2 management despite being modelled with internal doors open and closed. The limitations of the research included the single sided design of the model, vent placement relative to floor plan and wind loading. The paper also did not provide a comparison to a solution without any vents.

Healthy and affordable housing in New Zealand: the role of ventilation (Kara Rosemeir):

The paper compared survey results to simulations to determine the thermal and air quality outcomes in 15 homes built since the year 2000, confirming the modelled concerns were accurate and delivered air quality and thermal comfort were generally poor. The report also points out that simply increasing air changes in New Zealand's typically underheated homes exasperates a heating challenge particularly for those in fuel-poverty and increasing load on the grid, clearly suggesting that good air quality is critical but should not be allowed to lead to negative thermal outcomes and the associated health problems.

Interestingly this research did not find a correlation between the air-leakiness of the building envelope and better air quality outcomes, suggesting that air quality due to lack of ventilation has been a problem for a lot longer than the early 2000.

Comparing International Ventilation Standards TN72 (AIVC): https://www.aivc.org/resource/tn-72-ventilation-requirements-and-rationale-behind-standards-and-regulations-dwellings

Research showed that New Zealand ventilation volumes were in the lower quartile for fresh air supply volumes and the lower 50% for continuous extract volumes. They acknowledged the main drivers for ventilation guidelines were based on health, energy and comfort. They did not establish a recommended ventilation standard however recognising that the variation by country is too large instead recommending any group making proposals should review the basis for their recommendations including climate zone, philosophy and rationale along with any background material, the role of occupants, special conditions for sensitive groups, exceptions and any energy consequences.

2.2. Current Clause and Acceptable Solution

The Current NZ Codes and Standards

The New Zealand building code references ventilation limited times in the legislation, and only G4 and E3 expanding in the acceptable solutions. The code does recognise the importance of ventilation in "safeguard[ing] people against illness, injury or loss of amenity that could result from the accumulation of internal moisture" (NZBC E3.1) and of course "safeguard[ing] people from illness or loss of amenity due to lack of fresh air." (NZBC G4.1). But both standards refer to "adequate" ventilation to achieve such an outcome, with G4.3.1 adding that this air should be outdoor air which is defined only as "air as typically comprising by volume. (i) oxygen 20.94% (ii) carbon dioxide 0.03% (iii) nitrogen and other inert gases 79.03%" (NZBC A2 Interpretation).

Air Quality

NZS4303's approach to outdoor air is notably different from G4/AS1 (although NZS4303 is referenced by G4/AS1 as it pertains to fresh air supply G4/AS1:1.5.1a), instead of defining the gaseous composition of outdoor air it instead specifies "air taken from the external atmosphere and, therefore, not previously circulated through the system"[10] and provides an ambient-air quality table (NZS4303:1990 Table 1[11]) referenced by a more detailed three-step procedure (NZS4303 6.1.1) for determining outdoor air acceptability, this procedure at the time of writing in 1990 was considered not applicable in NZ due to the high local ambient air quality. The result is once NZS4303 is used to provide compliance the definition of outdoor air takes on an additional constraint but is otherwise ignored.

NZS4303 also provides following definition for *acceptable indoor air quality*:

> "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

Within the 6.2 Indoor Air Quality Procedure (distinct from 6.1.1. Acceptable Outdoor Air) both a qualitative and a quantitative pathway are provided, instead of the earlier prescriptive Ventilation Rate Procedure. NZS4303:1990 Table 1 is again referenced, as well as Table 3[12] to provide limits for contaminants in the air with other potential contaminants discussed in NZS4303:1990 Appendix C. It is noted that the inclusion of CO_2 at 1000PPM is primarily to satisfy odour control when moderated through dilution.

No additional guidance on harmful concentrations is provided elsewhere in the New Zealand code or the acceptable solutions. Also, the guidance this standard was built on at the time has changed in the intervening period and is under review in NZ.

Moisture Considerations

The following are the specific sections of E3 that deal with ventilation. The result is that in ventilated spaces we are typically safe from "illness, injury or loss of amenity" if interior temperatures are 5-7°C above exterior temperatures. While mainly a requirement to maintain temperatures at a level to avoid condensation (if ventilation is installed) it does remind users that ventilation shall be provided to comply with G4/AS1.

> **E3.1 Objective** "The objective of this provision is to– (a) Safeguard people against illness, injury, or loss of amenity that could result from the accumulation of internal moisture;"
>
> **E3.2 Functional Requirement** "Buildings must be constructed to avoid the likelihood of– (a) Fungal growth or the accumulation of contaminants on linings and other building elements; and (b) Free water overflow penetrating to an adjoining household unit; and (c) Damage to building elements being caused by the presence of moisture."

[10] There is one unresolved discussion surrounding the question "is roof space air considered to be at external atmosphere" that parties would like MBIE guidance on.

[11] NZS4303:1990 Table 1 covers: Sulfur Dioxide, Total Particulate, Carbon Monoxide, Ozone, Nitrogen Dioxide and Lead with short- and long-term limits for most.

[12] NZS4303:1990 Table 3 covers: Carbon Dioxide, Chlordane, Ozone and Radon with continuous limits on the first three and an annual average on the last.

E3.3.1 Performance "An *adequate* combination of *thermal resistance*, **ventilation**, and space temperature must be provided to all *habitable spaces*, bathrooms, laundries, and other spaces where moisture may be generated or may accumulate."

Acceptable Solution:

E3/AS1 1.0.2 "The New Zealand Building Code does not specify minimum heating requirements except for old people's homes and early childhood centres. Occupants will determine their own methods and levels of heating. Typically it is necessary and sufficient, for condensation control in winter, to keep interior temperatures 5°C to 7°C above exterior temperatures **in a ventilated space.**"

E3/AS1 1.2.1 "Ventilation shall be provided naturally or mechanically **to comply with G4/AS1."**

Temperature Requirements

The Indoor Environment section of the standard provides guidance for indoor temperatures in old people's homes and early childhood centres but not for general residential properties. Even in these spaces the focus is primarily on heating with the acceptable solution providing wattage guidance for heating with no mention of overheating. There is an expectation of adequate ventilation, but the acceptable solution does not consider the thermal loading of this ventilation or any guidance beyond "adequate".

G5.2.1 Buildings shall be constructed to provide: (a) An adequate, controlled interior temperature…
Requirement G5.2.1 (a) shall apply only to habitable spaces, bathrooms and recreation rooms in old people's homes and early childhood centres.

G5.3.1 *Habitable spaces*, bathrooms and recreation rooms shall have provision for maintaining the internal temperature at no less than 16°C measured at 750 mm above floor level, while the space is *adequately* **ventilated**.
Performance G5.3.1 shall apply only to old people's homes and early childhood centres.

Ventilation Codes

Adequate ventilation is prescribed in G4/AS1. An oversimplification of G4/AS1 can be found in the below table alongside, referenced alternative standards and the Healthy Homes requirements which were implemented to provide guidance on acceptable living conditions for rental properties including retrofitting ventilation.

The table does not deal with gas or solid fuel appliances, garages, or fire requirements. Current prescribed acceptable pathways for NZ have not been greyed out.

	Fresh Air	**Shower/Bath**	**Cooktops**	**Laundry**	**WC**
G4/AS1[13]	5% Openable Area + able to be fixed open AND/OR[14] Trickle Ventilators, or **NZS4303:1990 Table 2**	25l/s (intermittent) OR **AS1668.2:2002 Table B1**	50l/s (intermittent) AND[15] **AS1668.2:2002 Table B1**	5% Openable Area OR Trickle Ventilators AND <6m deep, OR **AS1668.2 Table B1**	5% Openable Area OR Trickle Ventilators AND <6m deep, OR **AS1668.2 Table B1**
NZS4303:1990	Table 2: 0.35ACH / 7.5l/s/pp (greater of), normally satisfied naturally,	25l/s (int.) or 10l/s (cont.) or	50l/s (int.) or 12l/s (cont.) or openable windows[16]		25l/s (int.) or 10l/s (cont.) or openable windows[10]

[13] Additional comments: Building interiors with mechanical ventilation incorporating filtration shall be maintained at a positive pressure and those that are used to collect or remove contaminants should be at a negative pressure (relative to other spaces in the building).
[14] Household and accommodation units with only one external wall using natural ventilation must be <6m deep and for units with only one external wall: habitable spaces with permanent openings to kitchens (ie. Open plan layouts), bathrooms, toilets or laundries (spaces requiring mechanical extraction) must have both trickle vents and openable windows and be either <6m (int.) or <10m (cont.) deep.
[15] AS1668.2 AND 50l/s intermittent only when intermittent is used to remove moisture and other contaminants from cooktops.

	OR 6.2 IAQ Procedure	openable windows[16]			
AS1668.2:2002	5% Openable Openings (effective area or as required to achieve minimum flow rates)[17,18], OR exhaust + natural relief vents, OR Greater of (5l/s/pp OR 0.35ACH[19] AND 6l/s/pp IF >27°C under normal conditions) OR >3.5 Dilution Index	Table B1: 25l/s/room using Mechanical extraction OR supply air + relief vents OR natural ventilation	No residential flow rates given. Use 5% Openable Openings	Table B1: 20l/s/room using Mechanical extraction OR supply air + relief vents OR natural ventilation	Table B1: 25l/s/room using Mechanical extraction OR supply air + relief vents OR natural ventilation
Healthy Homes Standards	5% Openable Area + able to be fixed open	25l/s OR 120mm diameter OR qualifying ventilation (post 2019, runs continuously @10l/s)	50l/s OR 120mm diameter OR qualifying ventilation (post 2019, runs continuously @10l/s)		
AS1668.2: 2024[20,21]	Greater of 10l/s/pp[22] OR 0.35ACH[23] AND 15l/s/pp IF >27°C under normal conditions (2.9.1) OR >3.5 Dilution Index	Natural Ventilation (5% Openable Area under AU NCC) OR 25l/s/room[24] (cont. OR auto.), OR for dwellings	Natural Ventilation (5% Openable Area under AU NCC) OR 40l/s/room, OR for dwellings <1.0m³/hour.m² @ 50Pa under	Natural Ventilation (5% Openable Area under AU NCC) OR 40l/s OR 110% dryer airflow[25] , OR for dwellings	Natural Ventilation (5% Openable Area under AU NCC) OR 25l/s/room[24] (cont. OR auto.), OR for dwellings

[16] Assumes air supplied through adjacent living areas provides sufficient makeup air.

[17] Taken from AS1668.2:2002 Table 3.1 for a Class 1, 2 or 4 building as per the Australian Building Code (1, 2 or 4 are most residential buildings).

[18] This comes from a dedicated natural ventilation section including provisions for "Natural supply with natural relief" which has been since removed along with the Natural Ventilation acceptability guidance at AS1668.2:2002 Clause 2.2. The guidance expects specific air volumes still to be met and provides prescriptive guidance at Clause 3.4, alternatively can be achieved through empirical calculations or computer modelling (which references supplementary guidance on the standard). Where a Dilution Index is calculated Clause 3.2 i), ii) and iii) provide design criteria for wind speed and temperature differential use. This leads on to flowthrough (cross flow) use and guidance at 3.3.4 if necessary. Clause 2.2: provides these additional conditions for natural ventilation acceptability: **outdoor air should need no treatment**, **air movement within the enclosures is unimpeded**, there is **provision for wind and thermal effects**, there is some **tolerance to transient lower airflow rates** and an additional aside at C2.3 where there is not unfavourable external conditions such as **excessive noise, pollution or dust**.

[19] 5l/s/pp is the contaminant rate per occupant for <160Watts/occupant metabolic rate and 0.35 is the factor for building material and other not occupant related contaminants in residences.

[20] All ventilation system combinations have both supply and return pathways using a combination of mechanical and natural, there is no solution with natural on its own (AS1668.2:2024 C1.5) which was present in the 2002 edition.

[21] Under AS1668.2:2024 dissimilar exhaust enclosures cannot be combined (ie. Kitchen and bathroom/WC/laundry) to avoid contamination when not in operation

[22] Occupancy rates for systems serving multiple areas where the occupants may move between enclosures may be calculated based on the distribution of occupancies that gives the highest outdoor air rate. It would be worth querying the residential application of this if adopted.

[23] AS1668.2:2024 provides a reduction rate for fresh air if there is supply air recirculation and filtration, or further possible reduction if using the detailed procedure (2.8.3 and Appendix D). There is also a ventilation effectiveness rate applied throughout of 0.8 effectively bringing 10l/s/pp down to 8l/s/pp closer to the NZ 7.5l/s/pp

[24] Concern was raised on the initial publishing of this that the phrasing requires 25l/s continuous as a minimum. AS1668.2:2024 has also implemented demand control with no intermittent/user controlled option based on AS1668.2:2024 Table B.1

[25] Should be interlocked with appliance, when in a bathroom use the greater of the two airflows, also greater of 40l/s or 110%.

		<1.0m^3/hour.m^2 @ 50Pa under AS/NZS ISO9972 AND there is supply air THEN 10l/s (cont.)	AS/NZS ISO9972 AND there is supply air THEN 15l/s (cont.)	<1.0m^3/hour.m^2 @ 50Pa under AS/NZS ISO9972 AND there is supply air THEN 8l/s (cont.) IF a condensing dryer is installed	<1.0m^3/hour.m^2 @ 50Pa under AS/NZS ISO9972 AND there is supply air THEN 10l/s (cont.)
NCC 2022 + ABCB Housing Provisions 10.6, 10.8.2 and 13.4.5 Note: NCC has additional Energy Efficiency, Air Tightness, Comfort and Air Movement requirements that also affect ventilation	H4: ABCB10.6 - 5% Ventilating Area (Openable sash area) ABCB 13.4.5 - IF an exhaust fan is serving a conditioned space or habitable room in AU Climate Zones 4—8 a “sealing device” must be provided H6: PLUS IF Air Sealed to < 5 m3/hr.m2 at 50 Pa a mechanical ventilation system must provide air flow (Q (l/s)) calculated based on Q=(0.05×A+3.5×(N+1))/p, where A = Area, N = bedrooms and p = fraction of 4hours operating (minimum 25%)	H4: ABCB10.6 - 5% Ventilating Area (Openable sash area, not allowed if opening on to kitchen or pantry) OR ABCB10.8 - mechanical exhaust fan @25l/s AND EITHER ((5% ventilating area) OR BOTH (light interlock + 10min run-on timer (unless continuous) AND (make-up air via internal openings 14,000m^2 [26]OR in accordance with **AS1668.2**)))	H4: ABCB10.6 - 5% Ventilating Area (Openable sash area, not allowed if opening on to kitchen or pantry) OR ABCB10.8 - mechanical exhaust fan 40l/s	H4: ABCB10.6 - 5% Ventilating Area (Openable sash area, not allowed if opening on to kitchen or pantry) OR ABCB10.8 - mechanical exhaust fan 40l/s AND any venting clothes dryers must duct directly to outside	H4: ABCB10.6 - 5% Ventilating Area (Openable sash area, not allowed if opening on to kitchen or pantry) OR ABCB10.8 - mechanical exhaust fan @25l/s AND EITHER ((5% ventilating area) OR BOTH (light interlock + 10min run-on timer (unless continuous) AND (make-up air via internal openings 14,000m^2 OR in accordance with **AS1668.2**)))

A few notable differences are:

- The Australian standards (in both 2002 and 2024) make use of a “ventilation effectiveness” rate of 0.8.
- The removal of natural ventilation from the Australian Standard between 2002 and 2024 (the 2012 edition was not reviewed for this exercise) and the retention of it in the NCC have left some gaps in guidance.
- NZS4303 provides and IAQ procedure, Australian standards have set IAQ figures in the NCC while AS1668.2 provides a Dilution Index calculation method.
- NZ building code does not accept natural ventilation for bathrooms, kitchens and laundries while the ABCB housing provisions do.
- Continuous extract ventilation appears in NZS4303, AS1668.2:2004 and Healthy Homes Standards.
- Make up air/relief grille sizing is not prescribed clearly anywhere, although trickle vents are shown in G4/AS1 the sizing calculation and use for make-up air is not communicated. The ABCB does provide direction on make up air sizes for 25l/s airflows to bathrooms and sanitary compartments (WC).
- Prescriptive air volumes are comparable at around 7.5l/s/pp (Australian standards vary with some complexity from this) and 20/25l/s for bathrooms/WC and 40/50l/s for kitchens
- Both use openable area rather than equivalent area for windows/sashes.
- New Zealand does not yet address airflows or efficiencies in high performance air tight homes, nor comfort, energy usage or airtightness as Australia does although these requirements were outside the scope of this table.
- New Zealand code does not prescribe any demand control solutions as the ABCB do.

[26] 14,000mm^2 can be achieved by a 20mm undercut to a 700mm wide door.

Foundation of Natural Ventilation in Building Codes

In his 2023 research paper N P Isaacs[27] traced the historical sizing requirements of windows for lighting and natural ventilation tying the current NZBC guidance to an 1891 Wellington Council Bylaw "at least one-tenth of the area of the floor of such room; half of such window or skylight shall open and the opening must extend to the top of the window". With very few variations in the codes and bylaws that were published between then and now. While we no longer provide guidance on the height or location of openable area (although we do provide this guidance for high and low trickle ventilation in current codes) the bylaw remains equivalent to our current 10% glazed area for daylighting and 5% openable area for natural ventilation.

Issac's points out that the bylaw doesn't provide a foundation for why this level of glazing (and in turn ventilation was sufficient) and so tracked back further into international standards, starting in Great Britain. While standards varied over time to consider set minimum window areas (1.4m^2 (15ft^2) or 0.8m^2 (9ft^2), depending on reference), and window area by volume (1ft^2 per 100-150ft^3) instead of just by floor area; Isaacs found that in most cases the glazing area for daylight sat between 8.3%-14% and for ventilation typically half that of daylight. The oldest and seemingly consistent guidance was from the 1800's, although Isaac's research extends back further into the 1600's, Isaac's concluded that the first requirement identified using 10% (daylight) and 5% (ventilation was the 1859 Model By-laws of England under the Local Government Act 1858, this is only just slightly after the end of the window tax in 1851. New Zealand's 1891 Wellington Council By-law closely match that of 1859 England.

While in these studies it seemed clear there was an understanding of importance of daylighting and variably fresh air there doesn't appear to be much scientific basis for our codes reliance of a 5% openable area beyond it historically satisfying requirements and so has been maintained. Significant lifestyle changes have occurred since the mid 1800's including the use of windows for refuse disposal and smoke control from fireplaces. One other change is the form of windows used since the 1800's. Many of the references referred to hinge or pivot type casements or double-hung sashes; allowing for high and low opening of the windows, something not commonly available or installed today.

International Codes

In 2023 the AIVC (Air Infiltration and Ventilation Centre) published their report[28] on ventilation requirements and the standards behind them across 29 different countries. They found large differences, in some cases more than a factor of five, between prescriptive ventilation requirements for the same application between different countries. Their research established that most of the current standard air volumes were written in the 1990's. The rates are defined with varying calculations from per person to per floor area or simply as a volumetric rate with wide ranging outcomes as below:

- Kitchens: using continuous extract rates as a basis resulted in a range from 8.3l/s to 42l/s (NZ 12l/s NZS4303)
- Bathrooms: again using continuous ranges from 7l/s to 22l/s (NZ 10l/s NZS4303)
- Toilets/WC's: from 6-13.9l/s (NZ NA)
- Whole house: working on a basis of ACH had a very large range from 0.15ACH to 1 ACH although most sat between 0.3ACH and 0.7ACH. (NZ 0.35)
- Living room: comparisons were provided but not in a tabulated form, and were done for multiple living room sizes as some countries appear to have combined both area and occupancy, the results are a range from ~2-10l/s in a 40m^2 living room with 4 people and from ~2-5 for a 20m^2 living room with 4 people (excluding one country that maintained 8l/s across all living room sizes). (NZ 3l/s and 1.5l/s respectively)

New Zealand typically sits in the lower third for these results when it appears.

For habitable rooms, apart from the so-called wet rooms, almost all countries mention CO_2 as an indicator for bio effluents as a rationale. For bathrooms; human activities and moisture production are the most important drivers.

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[27] https://journals.sagepub.com/doi/epdf/10.1177/14771535231225363?src=getftr&utm_source=readcube&getft_integrator=readcube
[28] https://www.aivc.org/resource/tn-72-ventilation-requirements-and-rationale-behind-standards-and-regulations-dwellings

For toilet rooms; rationales are related to the spreading of germs and odour to other rooms. For kitchens, diluting products from cooking processes (such as nitrogen dioxide from gas cooktops and steam from boiling water) are, as can be expected, the most important rationale. The AIVC contributors identified the following drivers:

- Health – although not common typically resulted in higher air flows
- Energy use – contributes to limiting air flow rates, they provide the 1973 oil crisis and ASHRAE as an example shifting from 7l/s to 2.5l/s per person
- Comfort – the most common driver driven by comfort and odour with Pettenkofer 1858 stating that CO_2 was a good driver (a similar timing to the window area developments see Foundations of Ventilation Code section), recommending 10l/s. Most standards using bio effluents as a driver arrive at around 5-10l/s; for reference they provide “an adult person with medium activity and 7l/s results in an equilibrium CO_2 of a bout 1200 ppm”.
- Moisture – key as it relates to mould and condensation control and the importance of extraction to achieve it

Typical rationales have been summarised in the AIVC report and is quoted below:

Explanation for Table 6 (for a total of xxx countries):

Color Black	Black	*1 to 3 countries*
Color Grey	Grey	*4 to 7 countries*
Color Yellow	Yellow	*8 to 10 countries*
Color Blue	Blue	*more than 10 countries*
White	White	*not mentioned or specified*

Table 6: Reported rationales for several types of rooms

Rationales reported	**Room type**					
	Living Bedroom	**Kitchen**	**Bath room**	**Toilet room**	**Office room**	**Class room**
Odour, Bioeffluents	Blue	Black	Black	White	Blue	Blue
Odour/smells cooking products	White	Blue	White	White	White	White
Moisture/Dampness	Blue	Blue	Blue	Blue	Blue	Blue
Moisture/ Cooking	Blue	Blue	White	White	White	White
Moisture/Washing/showering/laundry	White	Blue	Blue	Blue	White	White
Preventing spreading of contaminants	White	Yellow	Yellow	Yellow	White	White
Emissions from building materials and furniture	Grey	Grey	White	White	Grey	Grey
Formaldehyde	Black	White	White	White	Black	Black
Other VOC's	Grey	Grey	Grey	Grey	Grey	Grey
Airborne particles	Black	Black	White	White	Black	Black
CO	Black	Black	White	White	Black	Black
Viruses	Black	Black	Black	Black	Black	Black
Sick Building Syndrome	Black	Black	Black	Black	Black	Black

Figure 4: AIVC TN72 Table 6 - Reported rationales for several types of common rooms

The report also identified the important of design, commissioning and maintenance. In 2023 most countries had no obligation for handing over and commissioning but it appeared a the time that some countries were working on this and that there is growing interest in development of rules. Although this may be predominantly for larger systems. Ventilation systems with medium intensity maintenance sit within 92.2-97.4% reliability.

Natural ventilation systems were mentioned in passing, primarily in relation to the Netherlands that have the requirement that flow rate must be attained at least 83% of the time. Details weren’t provided on how this was measured but it is acknowledged that due to the reliance on weather natural ventilation systems have a lower reliability than mechanical systems.

2.3. Collab Review

The group reviewed the current code and acceptable solutions and identified the following specific areas that required improvement. During the process we acknowledged that the legislation avoids defining specific solutions because it is harder to change, instead focusing on the performance of the building which is subject to interpretation.

Legislation

Ref#[29]	Comments	Recommendation
G4.1	The definitions in the objective left room for interpretation. In general "**illness**" was well understood, "**loss of amenity**" was harder to understand but the Human Rights Commission in their 2-year housing inquiry published in 2023 defined "habitable" using rates of damp, mould, overcrowding and cold. Ventilation has a role to play in resolving or reducing the prevalence or negative effects of these.	Better educate the construction market on what ventilation is for and what should be considered "adequate".
G4.2 & G4.3.1	**Outdoor Air** was unusually specific: Clause A2 "(i) oxygen 20.94% (ii) carbon dioxide 0.03% (iii) nitrogen and other inert gases 79.03%", but did not cover "air purity" or indoor air quality. It was acknowledged that these can be hard to monitor and that on a national scale outdoor air is recorded but on a per house scale no measure is frequently taken (outdoor or otherwise). This becomes more relevant as the air quality in our cities worsens.	Clearer guidance on indoor air quality rather than outdoor air alone would be desirable and consistency between quoted standard definitions (ie NZS4303) and legislation is necessary.
G4.3.2	While there was no specific concern for this section it was referenced as being used to avoid mechanical ventilation due to maintenance requirements. It also raised the question – who is responsible for ensuring maintenance occurs.	Education and controls are required.
E3	E3 provides a "typically sufficient" temperature difference with interior temperatures 5°C - 7°C above exterior for condensation control in winter. This is not required but reads as a recommendation only for ventilated spaces.	Provide an indoor environment definition to be used throughout code based on health requirements for different groups which can provide a bearing on ventilation.
G5	G5 provides a specific requirement for the internal temperature of 16°C for retirement and ECE while *adequately* ventilated.	

Acceptable Solution

Topic	Comments	Recommendation
General	The combination of commercial and residential ventilation in one place is challenging.	Provide residential ventilation requirements broken out from commercial by (or similar): -Standalone housing -Single faced accommodation -Opposing faced accommodation -Commercial buildings

[29] Any sections without comment were considered clear and sufficient

Standards	Referenced standards refer to non-current versions and references are not all publicly available. The use of external and partial references has led to some confusion for example: - Under G4/AS1:1.5.1a) AS1668.2 (excluding Table A1 and Section 3 and 7) is used for the design and install alongside NZS4303 but only NZS4303 Table 2 is used when referencing specific air flow rates for occupied spaces. - Then under G4/AS1:1.5.1c)ii) AS1668.2 Table B1 is used for extract volumes (NZS4303 is not referenced at all) and should be used in conjunction with the minimum for cooktops in 1.5.1c)iii) (shower and bath minimums aren't explicitly called out in section 1.5, although they are present elsewhere and in AS1668.2:2002 Table B1). Most people don't require these as the minimums are so easy to comply with, this would change if other recommendations are adopted.	Create current residential ventilation air volume tables to be provided in the Acceptable Solution, basis of tables to be determined using a performance based model.
Natural Ventilation	Natural ventilation was considered the most concerning element of the Acceptable Solution. While natural ventilation provides a ventilation pathway not requiring power the implementation is affected by typical housing styles and lifestyle choices. It is most affected by human variables and does not provide for good control of outside inputs. Natural ventilation is also affected by occupant behaviour inside the home including the opening and shutting of internal doors. Demand control was discussed and favoured but challenging to implement. The focus was turned instead to specific elements of natural ventilation.	Consider making natural ventilation only compliant under a verification method with considerations given to wind, effective area and crossflow ability. Also requires improved education.
Natural Ventilation: Openable Area	Almost unchanged from the 1891 Bylaws and 1947 Housing Improvement Regulations in NZ it should be recognised that effective window openable area varies by window type and is also affected by the incidence of security stays on new builds.	Change openable area to mean effective area only and provide calculation guidance for windows (including where safety stays are required) and passive/trickle vents effective areas by wind zone with and without opposite building faces.
Natural Ventilation: Opening Placement	Consideration should be given to construction types: standalone houses, townhouses with two opposing faces, single faced or corner housing. Consideration should also be given to height of opening both on a single floor and between floors.	Provide different Acceptable Solutions pathways depending on construction type (see Acceptable Solution topic: General) and provide guidance on fenestration/ penetration height placement (high/low on wall), buildings over a specific height include height from ground.

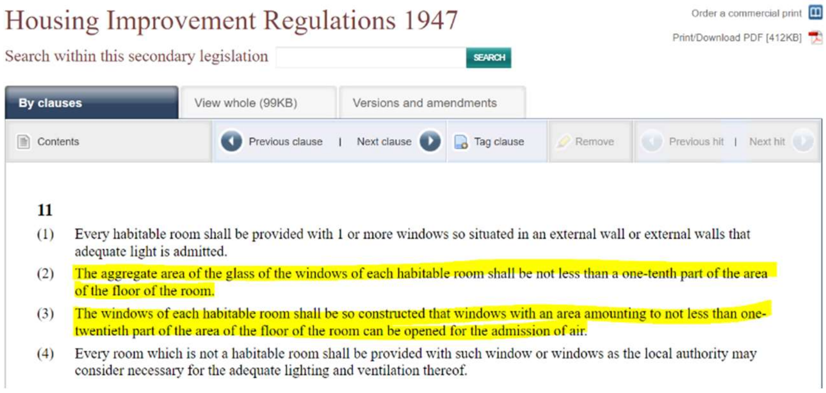
Natural Ventilation: Trickle Ventilators	While not covered in depth there was both confusion and frustration on the basis of the sizing as well as how to determine the effective area. Some parties also felt that it also insufficiently covered available solutions on the market. The question was raised covering whether trickle vents still provide a complete ventilation solution or should only be accepted when used for make-up or relief air. If maintained for natural ventilation in general should consider effect of internal obstructions (ie. Doors being open or closed).	Deserve a deeper review covering – sizing and noise, flow rates, design validation and filtering. Should remain included for make-up and relief vents as a minimum with clear guidance of compatible air flows to effective area, calculations for effective area and consideration for wind zone.
Natural Ventilation: Outside Conditions	The likelihood of windows being opened is inversely proportional to the occupant's perception of noise, security, air temperature and air quality. No reference is made to acceptable outdoor conditions beyond "Outdoor Air" and outdoor conditions according to one study[30] are only acceptable 8% of the time. Councils provide guidance in the district plans, but rules vary by region. Foundation for these localised rules is hard to source.	Provide guidance on acceptable conditions to reduce variation by region except where appropriate or required for climate, as it affects efficiency of the home.
Air Volumes and Airtightness	The current Acceptable Solution considers supply and extract independently. Based on BRANZ air tightness data[31] our homes are getting more airtight, it's understood homes under 5 air tightness/permeability may not be suitable and under 3 are not suitable for unbalanced air flows and so allowance should be made in code for this. Well-sealed spaces affect the performance of ventilation fans, a casual survey of electricians demonstrate this on a single space basis with intermittent bathroom extract fans not performing without door undercuts.	Provision should be made for homes above or below a specified airtightness level. Definition will be required for how to judge this, alternatively an airtightness standard and testing expectation.
Independent Extract	The biggest gap for extract was that continuous extract was only referenced externally and the minimum volumes are not explicitly for intermittent ventilation. This means validation is required with most residential submissions and typically requires an engineer for building consents that should otherwise be relatively basic. Intermittent rates in G4/AS1 and continuous rates in NZS4303 are generally acceptable to remove moisture from bathrooms and kitchens. A performance/demand standard is desirable. There was a question around if boosting to intermittent rates with continuous was necessary.	Include continuous extract in the air flow tables. Include expectation of make-up air for both intermittent and continuous. Provide demand controlled pathway based on humidity or run-on timers if not continuous. Suggest (only) boost airflow rates for continuous solutions.
Independent Supply	Supply air ventilation source for fresh air proved the most contentious element and advice on determining acceptability is desired. A secondary concern was the possibility of interstitial moisture condensing, particularly in more modern constructions. Specific airflow calculations were discussed and investigated, and it appears 7.5l/s remains appropriate as well as 0.35ACH, while on the lower end it is considered closer to acceptable energy efficient outcomes. Additional consideration should be given to filtration to make use of recycling air, along with purge ventilation to compensate for overheating. Living space calculations need to provide clearer guidance.	Retain but include expectation of relief vents. Make clear occupancy rate of living space at equivalent of bedroom occupancy for air flows. Provide a demand controlled alternative solution based on CO_2 or similar.
Supply and Extract	Balanced solutions in air tight homes are considered better. It would be useful for this to come across in documentation.	Provide guidance on broader solution options.

[30] A quote based on the studies of one member organization of The Collab.
[31] https://www.buildmagazine.org.nz/assets/PDF/Build-166-90-Research-Airtightness-Trends.pdf

Space Pressurisation	While it was generally accepted that the guidance on positive and negative spaces was correct it was felt that section 1.5.3 was not sufficiently clear.	1.5.3 building interiors possibly should read habitable spaces, note 1.5.4 is already referencing spaces in which contaminants are collected
Air Pathways	Most agreed air pathways should be included in the acceptable solution, although some wondered if we could assume this was now required in all new homes.	For homes under 5 air permeability or using certain construction styles, require assumed air pathways be shown in services plans.
Commissioning	Based on G4/AS1:1.5.1h) commissioning should be performed to the specified stand only if it is done. This is an example where commercial overlaps residential, if included in residential it should be clear when commissioning should be expected. As many fans are installed by electricians working to consented plans they are unlikely to check the fans or have sufficient gear or training to do so. It was suggested that the equipment required for testing is not burdensome and a BCA could purchase and train it's inspectors on it. Currently it is possible for fans to significantly underperform unchecked if makeup air is not provided or the installation quality is poor. This change would be similar to how BCAs test the moisture co tent of framing in a pre-line inspection.	For developments of more than 10 residences or homes under 3 air permeability, require air flow commissioning be undertaken. Alternatively provide for air flow testing to be undertaken by BCA.
Recirculated Air	While not considered a major concern its definition under G4/AS1:1.1e) was discussed and its purpose was clarified as: not to provide an acceptable supply or extract pathway but to set a standard for when these are installed. This is covered in detail in the AS1668.2 standards.	Should be considered in future code improvements to assist with energy efficiency alongside filtration.
Purge Ventilation	As part of the overheating discussion purge airflow volumes to assist with overheating should be determined with both natural and mechanical pathways.	Determine purge airflows needed in warming conditions proportional to unshaded northerly window area affecting openable effective area or mechanical ventilation to make up for insufficient openable area.
Air Movement	While not discussed in detail it was identified that Australia has an air movement portion to their building code and the suggestion was raised that New Zealand should consider this to assist with possible overheating in some climates.	Consider adding air movement devices (eg. Sweep fans) to standard with a consider for glazing or overheating potential.
Comfort	Increase used of mechanical ventilation without user input or comfort guidance made lead to complaints. There are references elsewhere in the building code to temperatures, it would be worth considering how to relate or restrict ventilation outcomes to avoid providing discomfort. As results will vary by climate zone this would need to consider whether heat recovery or air tempering was required in some zones.	Ensure that there is a provision to prevent the installation of systems that produce droughts in a space that would be unpleasant to occupants. This could be a maximum velocity constraint on supply grilles and a maximum temperature difference by climate zone.

Garages	Not discussed in detail but main concern is around pollutants and increasing use of garages as living spaces. Suggested simple guidance for garages of limited depth only suitable for entering and exiting not turning.	Provide requirements for a garage attached to a dwelling including measures to prevent intrusion of unwanted pollutants.
Missing Reference	G4/AS1:1.5.3 references 1.4.4 which does not exist in the current document. It may be meant to reference 1.5.4 as these two sections talk about positive vs negative pressure spaces.	Fix reference.

Other Topics

	Action
Airtightness and Energy Efficiency Discussed why we were having this conversation "now", the concern was more that ventilation hasn't been done well for a long time and is based on outdated standards.  Housing Improvement Regulations 1947 Order a commercial print Print/Download PDF [412KB] Search within this secondary legislation SEARCH By clauses | View whole (99KB) | Versions and amendments Contents | Previous clause | Next clause | Tag clause | Remove | Previous hit | Next hit 11 (1) Every habitable room shall be provided with 1 or more windows so situated in an external wall or external walls that adequate light is admitted. (2) The aggregate area of the glass of the windows of each habitable room shall be not less than a one-tenth part of the area of the floor of the room. (3) The windows of each habitable room shall be so constructed that windows with an area amounting to not less than one-twentieth part of the area of the floor of the room can be opened for the admission of air. (4) Every room which is not a habitable room shall be provided with such window or windows as the local authority may consider necessary for the adequate lighting and ventilation thereof. All agreed how we live and design our houses are more major factors that have changed rather than H1. **Air tightness and Air permeability Relevance:** Varying response to this topic live vs written. Live response felt this had less relevance to G4, but questionnaire responses felt there was still a relationship for air pathways. Conclusion was airtightness and air permeability need to be addressed under H1 (or similar) and that a higher volume of blower door testing should be undertaken (suggest 10% of homes) **Education:** Critical to address difference between buildings being too airtight vs buildings being adequately ventilated – need to shift the conversation from criminalising airtightness to promoting IAQ.	Suggest addition of an air tightness standard and increased monitoring of new construction performance.
Overheating: Also in questionnaire, generally supported as fits with objective of G4 (loss of amenity). Should provide section in code to address including useful air flows, shading and orientation may help if better design improves expected air volumes to incentivise likelihood of compliance (ie purge volumes reduce if northerly glazing reduces). Would need to also include provisions to avoid encouraging to much south glazing.	Introduce overheating to building code, include provision for purge ventilation and air movement as well as shading and orientation.
Noise: open windows in some areas are noisy but internal fans can be noisier so should be addressed/considered	Add in space noise constraint for fan performance. Provide guidance for ventilation outcomes when windows are not suitable to improve national consistence.
Moisture: Using dry bulb temps as in E3 is not particularly useful moving towards dew point would provide stronger outcomes for E3. Also only addresses some residences and high-risk occupancy types. Also no standard install detail in clause E2 for through wall large diameter penetrations on profiled metal.	Transition E3 to dew point and link to all homes. Add E2 detail for ventilation wall penetrations

Education reappeared as a topic, specifically on **maintenance** – not the place of code but should be considered in what we recommend as typical pathways (eg. Mechanical solutions require more maintenance).	Provide education on recommended maintenance periods for filters, fans and ducting.

3. Options

These changes are suggestions only, the collaborators are available for comment and future feedback on elements discussed below.

Australia and Europe (specifically Ireland and UK Documents F) have been used to prepare this response although it should be noted that varying climates impact the suitability of outdoor air to provide indoor dilution and the effect on typical ambient conditions.

3.1. Urgent Changes

The group propose one minor but effective change to the current acceptable solution to assist with improving suitability of current code, that being Openable Area be changed to Effective Openable Area or specific exclusion be made to windows with security stays or clear openings less than 15-30degrees.

While it does not resolve all concerns it allows windows for natural ventilation to deliver more than they currently are.

Also allow NZS4303:1990 Table 2.3 to be used for extract air flow as well as fresh air. This would resolve the lack of definition for continuous extract rates which are referenced in G4/AS1 but have no volume defined elsewhere within the current Acceptable Solution (they aren't covered in AS1668.2:2002).

3.2. Further G4 Legislation and Acceptable Solution Changes

Definitions

Update or include legislation definitions for: Outside air (to align with NZS4303), pollutants (add pollutants or indoor air quality guidance as they appear in NZS4303 or an acceptable international standard)

Provide in Acceptable Solution expanded definition for: loss of amenity (clearer definition as it applies to air)

Outdoor Air and Indoor Air Quality

Update "Outdoor Air" to[32]: air taken from the atmosphere external to the building or proven to contain less than XX pollutants and comprising typically of i) oxygen 20.94%, ii) carbon dioxide 0.03%, iii) nitrogen and other inert gases 79.03%.

Add "Acceptable Indoor Air Quality" as: air in which there are no known contaminants at harmful concentrations and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.[33]

air, outdoor: air taken from the external atmosphere and, therefore, not previously circulated through the system.

Figure 5: NZS4303:1990 Outdoor Air Definition

Outdoor air Air as typically comprising by volume:

i) oxygen 20.94%

ii) carbon dioxide 0.03%

iii) nitrogen and other inert gases 79.03%.

Figure 6: NZBC Outdoor Air Definition

[32] The exact composition may be better addressed elsewhere to moderate and control mass pollution, likely local/regional councils will be better placed to define if air quality is acceptable or not acceptable for a local area.

[33] Would likely need consideration given to the qualification of the people and the measurement of this condition.

acceptable indoor air quality: air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.

Figure 7: NZS4303 Indoor Air Quality Definition

Pollutants

Include table for the guideline on contaminant concentration similar to NZS4303:1990 Table 3 or Australian NEPM Ambient Air Quality Standards. The Australian NCC provides an Indoor Air Quality Handbook which includes guidance on potential contaminants that can be addressed and their affects[34].

TABLE 3
GUIDELINES FOR SELECTED AIR CONTAMINANTS OF INDOOR ORIGIN

Contaminant	Concentration	ppm	Exposure Time	Comments
Carbon Dioxide	1.8 g/m^3	1000*	Continuous	See Appendix D
Chlordane	5 ug/m^3	0.0003	Continuous	Reference 27
Ozone	100 ug/m^3	0.05	Continuous	Reference 28
Radon gas	100 Bq/m C3(EEC)**		Annual Average	Reference 42 and 43

*This level is not considered a health risk but is a surrogate for human comfort (odor). See Section 6.1.3 and Appendix D.
**EEC = Equilibrium Equivalent Concentration

Figure 8: NZS4303 Indoor Air Contaminant Guidelines

Table 3.7 NEPM Ambient Air Quality Standards (Source: NEPC 1998, amended 2003)

Air contaminant	Concentration and averaging period
Carbon monoxide	9.0 ppm (parts per million) maximum measured over an eight-hour rolling average period
Nitrogen dioxide	0.12 ppm averaged over a one-hour period
Nitrogen dioxide	0.03 ppm averaged over a one-year period
Ozone	0.10 ppm of ozone measured over a one-hour period
Ozone	0.08 ppm of ozone measured over a four-hour rolling average period
Sulphur dioxide	0.20 ppm averaged over a one-hour period
Sulphur dioxide	0.08 ppm averaged over a 24-hour period
Sulphur dioxide	0.02 ppm averaged over a one-year period
Lead	0.5 μg/m^3 (micrograms per cubic meter) averaged over a one-year period
Particles as PM_{10}	50 μg/m^3 averaged over a 24-hour period
Particles as $PM_{2.5}$	Advisory reporting standard: 25 μg/m^3 over a one-day period; 8 μg/m^3 over a one-year period

Figure 9: NCC IAQ Guidance

Amenity

Define "Loss of Amenity" as: where undue degradation of structure, materials or belongings may occur due to unsatisfactory trapped air while building systems are able to be maintained and used at an acceptable level.

B1.3.2 *Buildings, building elements* and *sitework* shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use.

Figure 10: NZBC Loss of Amenity

[34] https://www.abcb.gov.au/sites/default/files/resources/2022/Handbook-indoor-air-quality.pdf

Durability

Introduce residential guidance on durability of ducting for non-accessible spaces. Suggest flexible ducting not suitable for installations in mid-floor spaces, use instead rigid or semi-rigid options in apartment or multistorey townhouse applications.

Referenced Standards

Bring externally referenced residential tables into the Acceptable Solution: AS1668.2:2002 Table B1 (note include kitchens in table), NZS4303:1990 Table 2. Alternatively include a new table using updated air volumes, discussed later.

Tables shown below are current relevant items only, it is recommended NZS4303:2002 Table 2.3 be used for exhaust air also, alternatively see additional comments in Continuous Extract section.

TABLE 2.3[a]
OUTDOOR REQUIREMENTS FOR VENTILATION OF RESIDENTIAL FACILITIES
(Private Dwellings, Single, Multiple)

Applications	Outdoor Requirements	Comments
Living areas	0.35 air changes per hour but not less than 15 cfm (7.5 L/s) per person	For calculating the air changes per hour, the volume of the living spaces shall include all areas within the conditioned space. The ventilation is normally satisfied by infiltration and natural ventilation. Dwellings with tight enclosures may require supplemental ventilation supply for fuel-burning appliances, including fireplaces and mechanically exhausted appliances. Occupant loading shall be based on the number of bedrooms as follows: first bedroom, two persons; each additional bedroom, one person. Where higher occupant loadings are known, they shall be used.

[a] In using this table, the outdoor air is assumed to be acceptable.
[b] Climatic conditions may affect choice of ventilation option chosen.
[c] The air exhausted from kitchens, bath, and toilet rooms may utilize air supplied through adjacent living areas to compensate for the air exhausted. The air supplied shall meet the requirements of exhaust systems as described in 5.8 and be of sufficient quantities to meet the requirements of this table.

Figure 11: NZS4303:1990 Table 2.3 Residential Outdoor Air Supply Only

TABLE B1

MINIMUM EXHAUST VENTILATION FLOW RATES

Enclosure type	Quantity	Unit	Comments
Kitchen			
Commercial	5	L/s.m² floor	
Laundry			
Commercial	15	L/s.m² floor	
Hospital	15	L/s.m² floor	
Residential	20	L/s. room	Rate is independent of enclosure size. Operation of the system may be intermittent

Bathroom Toilet	Private dwellings and attached to bedroom of hotels, motels resorts, private hospital rooms and the like	25	L/s per room	May include bath, shower, water closet and handbasin in one compartment. Rate is independent of room size (see Note 2)

NOTES:

1 Enclosure uses in Table B1 are typical. Omission of an applicable enclosure from this Table does not obviate the need to comply, in principle, with this Standard (see Section 5).

2 Where a bathroom is combined with a laundry, the higher of the two applicable ventilation rates may be used.

3 Unit 'L/s.m^2 floor' to be read as 'L/s per square metre of floor area'.

Figure 12: AS1668.2:2002 Table B1 Residential Exhaust Ventilation

Openable Area

Make the definition of openable area "Effective Openable Area" and provide guidance on these calculations. Alternatively provide guidance on openable angle considered acceptable to provide sufficient natural ventilation (see below example).

Table X: Ventilation Openings

Opening Type	Minimum total area of openings
Hinged or pivot windows with an opening angle of 15 to 30 degrees and greater than 100mm in height	10% of the floor area
Hinged or pivot windows with an opening angle of greater than or equal to 30 degrees	5% of the floor area
Opening sash windows	5% of the floor area
External doors	5% of the floor area

Make natural ventilation as set out above only permissible in household units with two opposing external walls which can facilitate cross-ventilation and include no more than two occupiable floor levels. Otherwise use alternative ventilation strategies. For units relying on cross flow ventilation permanently open internal air pathways should be provided.

Limit room depth of natural ventilation acceptability to 6m if using natural ventilation alone for any space (regardless of number of external walls) and 10m if used as make-up or relief vents in mechanical + natural solution.

Hinged or pivot windows with an opening angle of less than 15 degrees are not suitable for purge ventilation or if sill depth exceeds a set dimension based on standard window details make minimum opening 30degrees or greater. Also require at least some part of the opening to be above 1.7m from floor level.

Add provision for if unacceptable outdoor conditions occur (ie. High background noise zones, waste processing), including required ACH for filtered purge ventilation and air quality flow rates from mechanical ventilation if this occurs.

An improvement would be to include table variations for different wind zones.

Improve Definitions for Trickle/Passive Ventilation

Mechanical extract fans are intended to remove moisture from localised sources, and will not necessarily provide adequate ventilation for the whole occupied space and natural ventilation on its own is not adequate to remove moisture generated from cooktops, showers and baths.

General ventilation of *occupied spaces* where the house is not provided with both mechanical supply and mechanical exhaust must be achieved by providing background ventilators:

- Background ventilators should be installed at least 1700mm above floor level to reduce cold draughts, but still be easy for the occupant to reach, and
- The area of background ventilators on opposing sides of the dwelling should be similar to allow cross-ventilation.
- Background ventilators for fresh air supply are only suitable when provided for crossflow or in combination with a continuous mechanical exhaust fan.
    - Evidence of the suitability of crossflow should be tied to permanently open internal pathways, wind zones and exposed faces.
- The minimum total area of background ventilators in each room should follow the guidance in Table XX

Table XX: Minimum equivalent area of background ventilators for natural ventilation	
Room	Minimum equivalent area of background ventilators
Bedrooms	8000mm^2 for the first bedroom, 4000mm^2 for subsequent bedrooms.
Kitchen	8000mm^2
Bathroom	4000mm^2
Other Occupiable spaces	4000mm^2 per occupant

Background ventilators are intended to normally be left open, but retain the ability for the occupant to close them.

If an exposed façade is close to an area of sustained and loud noise (e.g. a main road), then a noise attenuating background ventilator should be fitted.

If fans and background ventilators are fitted in the same room, they should be at least 500mm apart.

Background ventilation alone is not sufficient if the dwelling has only one exposed façade or at least 70% of it's openings are on the same façade. Provision should always be made for internal air pathways.

Equivalent area to be measured in accordance with the method specified in I.S. EN 13141-1:2004. Information on equivalent area of ventilation products, e.g. trickle ventilators, should be supplied by the product manufacturer. Where this information is not available, the free area may be used to assess compliance, but the area of ventilator required should be increased by 25%.

Make Continuous Extract Acceptable

In the tables to be added as per above "Reference Standards" include continuous extract but also include a provision for openable area and relief ventilation sizing in conjunction with supply or exhaust rates and define level of acceptance as a supply air source if used in conjunction with exhaust fans.

If continuous systems are being used it's also important to define acceptable noise levels of the fans, this can be done either by a room rating (30-40dB(A)) or more prescriptively a fan rating which would need to be divided by type (surface mounted fans in rooms, duct mounted fans and system noise).

If a system is not to be run continuously then follow Australian AS1668.2:2004 example for bathrooms and provide lighting interlock and minimum 10-minute run on time or humidity sense demand control. Controls should also show faults if a continuous solution acts as a whole home system combined with make-up vents, failure of which would mean failure of the fresh air system.

Any implementation of continuous extract should make clear the relative need for boost rates (if any) and (if any) at a lower volume than current intermittent rates. It would also be valuable to ensure that the use of these systems was appropriate to the local climate (in other words provide an acceptable level of background airflow for each climate zone before a efficient heating or heat recovery solution would be required) to avoid increased energy use.

Define Living Room Occupancy Rates

For air flow calculations in living and communal spaces the total ventilation should be the greater of 0.35ACH and the sum of the possible household bedroom occupancy at n+1.

Introduce Internal and External Make-Up Air Guidance (Relief Vents)

Provide guidance on use of door undercuts, transfer grilles or similar effective openable area between spaces to coincide not just with suitable cross flow ventilation but also make-up and relief air paths for mechanical ventilation. Mechanical extract and supply ventilation should be provided with make-up air pathways suitable to the sizing of the airflow for the given space. If there is not a balanced mechanical supply and exhaust within the home (note these can be separate systems) then air movement should be tied to the ability of a given fan to overcome the air tightness in the home (if it has been measured) OR the system should be commissioned (with doors and windows closed) to demonstrate that it is achieving the required airflow.

Example effective area:

- For 7.5l/s (typical single bedroom) – 4000mm^2
- For 25l/s (typical bathroom, intermittent extract) – 14000m^2 equivalent door undercut would be 20x700mm

Note: If door undercuts used allow additional 10mm above FFL to account for changes in flooring thickness.

With this pathway intermittent fans and natural ventilation will still be considered compliant, but more evidence is required to demonstrate that they will deliver. It would also be valuable to account for wind zones.

Condensation Avoidance

G4/AS1 is expected by E3 to assist with indoor moisture, passive and active ventilation solutions need to be reviewed to address higher concentrations of internal moisture and more concentrated thermal bridging. Intermittent and user controlled natural ventilation solutions are not providing the condensation avoidance assistance required. One possible resolution can be found in measuring the performance of the house (airtightness) and tying it to the chosen solution (ie extraction alone, extraction with relief vents and internal flow paths identified, extraction and supply etc.) and varying the additional required air based on these, if any.

There is also a need to introduce insulation standards for ducting in or passing through unheated voids or roof spaces to avoid condensation from bathroom extract fans and air conditioning systems, minimum R0.6 and possibly increasing by climate zone.

Correct Minor Errors

G4/AS1 - 1.5.3 references 1.4.4 which does not exist in the document. Is this meant to reference 1.5.4 as these two sections talk about positive vs negative pressure spaces.

Compliance and Verification

Provide additional training to BCA’s and Inspectors to improve compliance with current code (disconnected ducts, continuous ventilation rates, poor installation).

Provide training and resources for airflow monitoring by inspectors and incorporate randomised air flow testing for key extraction points eg. rangehood and bathroom.

Define and/or provide an updated external standard that can be used as a NZ reference for alternative solutions including borrowed ventilation.

3.3. More Extensive Changes and Other Code Sections

These changes may not be relevant to include directly in G4 or the Acceptable Solution but consider the more holistic elements of a code update include the impacts on other sections.

Airtightness Standard

Introduce new building code section to address air tightness, tie air tightness to house energy efficiency and also include variable ventilation rates based on tested outcome of home. If home is untested assume air tightness compliance at 3-5ACH to protect from chance of using non-compliance to access lower compliance pathways for other elements.

Housing Efficiency Standard

Operational efficiency calculations (home energy rating tool), include provision for ventilation demand response or automation to affect air volumes, and include winter and summer comfort – maximum and minimum temperatures with energy efficiency tied to outcomes.

Implement Indoor Standard

Covering temperature and relative outdoor air quality, as well as pollutants.

Outdoor Air Quality

Establish zones for air quality. Likely this would need to be done on a territorial authority level due to the many local factors affecting it with some generalised zones such as city centre, industrial, rural (implement similar to earthquake zones).

Factors that could be considered could be:

1. Proximity to roads and their traffic volumes (ie motorways and arterials)
2. Proximity to industrial sites
3. Local factors such as cold inversions creating intense zones of pollution
4. General rate of air movement due to wind (ie higher wind in Wellington than central Otago)

Could be administered as a layer on GIS systems and would provide a layer that guides filtering requirements to determine filter type, grade and area as to provide a serviceable solution to prevent bringing in pollutants

The primary target would likely be PM2.5 and PM10 particulate matter.

Indoor Air Quality

Define current indoor air quality standards and contaminant limits for residential applications as discussed above as well as include formaldehyde limits for acceptable building materials to reduce off-gassing.

Review Air Volumes Suitability

Based on the AIVC TN72 report, New Zealand airflows are in the lower third of the 29 countries investigated. However, it is also acknowledged that ventilation for energy efficiency should employ a "minimum acceptable" policy, this means that unnecessarily increasing ventilation rates without strong founding should not be encouraged. Instead implementing the additional recommended design and compliance guidance alongside an air quality performance method will provide the best outcome. To reduce air volumes further demand controlled ventilation can be installed to respond to sufficient air quality sensors and attain the necessary indoor air quality to demonstrate compliance with the performance method.

Designers may wish to employ airflow to volume rates to achieve faster clearance of contaminants in accordance with occupant expectations, but unnecessary increases in airflow may lead to increased cooling effect in spaces. Exhaust and make-up vent positioning and surface heating will also play a part in achieving this efficiently.

Commissioning

If not undertaking commissioning require greater depths of calculations to be provided or modelled for ducted system performance.

For mechanical systems, a simple calculation method for working out pressure drops and flow rates would be useful. It would be valuable for allowing design of simple systems without the need to employ an expensive consultant to do work that is not adding value.

Include provision for:

- A standard issue "ductulator" covering the 3 types of ducting: rigid, semi rigid and ducting

- A standardised methodology for dealing with minor loss coefficients eg. Convert bends to additional metres of duct
- Although they are the same issue as above, minor loss coefficients in association with expansions and contractions, and cowlings may be confusing to add as extra meters so a standard table or graph for these could be introduced.

Realising that there is complexity here the scope of systems design able by this method could be limited to systems with a single pathway, or systems with symmetry to within 3m. Alternatively from the Irish standard:

Document F 1.2.4.7: "For bathrooms, axial fans may be acceptable for use with flexible ducting up to 1.5 m long and two 90º bends. Centrifugal fans can generally be used with flexible ducting of up to 3m and one 90º bend for extract rates of 60l/s (e.g. from kitchen) and up to 6m for extract rates of 15 l/s with two 90º bends (e.g. from bathrooms)."

For their part, fan and other equipment providers would have to publish fan curves to allow the calculation.

Occupiers Education

Modified from the Government of Ireland Building Regulations F 2019:

Occupiers of buildings should be provided with operation and maintenance requirements so that a home can be operated in an efficient and effective manner. Instruction should be directly related to the system installed in the dwelling without prejudice to the need to comply with health and safety regulations. The instructions should explain the important function of the system to provide adequate ventilation, how the system is intended to work, why the system should not be turned off, how the controls should be used and how and when the system should be cleaned and maintained. Boost and normal operation of the unit should be explained and the effects of opening windows. Guidance on the operation of controls and how a fault is indicated, location of fault alarms and their meaning should also be included.

4. Recommendations

Urgently implement the simple changes recommended in Section 3.1. Considered the more extensive changes as part of the ongoing revisions, particularly as part of a more holistic update.

Support industry in providing better education on the importance and use of ventilation particularly to BCA's and LBP's. Industry, for its part, will continue to undertake training of consumers and the wider construction industry.

Summary of References to Ventilation or Related Elements Throughout NZ Building Code:

D2.3.2 Mechanical installations for access shall be provided with:

(c) *adequate* lighting and ventilation for both normal and emergency use,

E2.3.6 Excess moisture present at the completion of *construction* must be capable of being dissipated without permanent damage to *building elements*.

E3.1 The objective of this provision is to—

(a) safeguard people against illness, injury, or loss of *amenity* that could result from accumulation of internal moisture;

E3.2 *Buildings* must be constructed to avoid the likelihood of—

(a) fungal growth or the accumulation of *contaminants* on linings and other *building elements*; and

(c) damage to *building elements* caused by the presence of moisture.

E3.3.1 An *adequate* combination of *thermal resistance*, ventilation, and space temperature must be provided to all *habitable spaces*, bathrooms, laundries, and other spaces where moisture may be generated or may accumulate.

F4.3.1 Where people could fall 1 metre or more from an opening in the external envelope or floor of a *building*, or from a sudden change of level within or associated with a *building*, a barrier shall be provided.

G1.3.2 *Sanitary fixtures* shall be located, constructed and installed to:

(e) avoid affecting occupants of adjacent spaces from the presence of unpleasant odours, accumulation of offensive matter, or other source of annoyance,

Objective

G4.1 The objective of this provision is to safeguard people from illness or loss of *amenity* due to lack of fresh air.

Functional requirement

G4.2 Spaces within *buildings* shall be provided with *adequate* ventilation consistent with their maximum occupancy and their intended use.

Performance

G4.3.1 Spaces within *buildings* shall have means of ventilation with *outdoor air* that will provide an *adequate* number of air changes to maintain air purity.

G4.3.2 Mechanical air-handling systems shall be constructed and maintained in a manner that prevents harmful bacteria, pathogens and allergens from multiplying within them.

G4.3.3 *Buildings* shall have a means of collecting or otherwise removing the following products from the spaces in which they are generated:

(a) cooking fumes and odours,

(b) moisture from laundering, utensil washing, bathing and showering,

(c) odours from sanitary and waste storage spaces,

(d) gaseous by-products and excessive moisture from commercial or industrial processes,

(e) poisonous fumes and gases,

(f) flammable fumes and gases,

(g) airborne particles,

(h) bacteria, viruses or other pathogens, or

(i) products of combustion.

G4.3.4 Contaminated air shall be disposed of in a way which avoids creating a nuisance or hazard to people and *other property*.

G4.3.5 The quantities of air supplied for ventilation shall meet the additional demands of any fixed *combustion appliances*.

G5.1 The objective of this provision is to:

(a) safeguard people from illness caused by low air temperature,

G5.2.1 *Buildings* shall be constructed to provide:

(a) an *adequate*, controlled interior temperature,

Requirement G5.2.1(a) shall apply only to habitable spaces, bathrooms and recreation rooms in old people's homes and early childhood centres

G5.3.1 *Habitable spaces*, bathrooms and recreation rooms shall have provision for maintaining the internal temperature at no less than 16°C measured at 750 mm above floor level, while the space is *adequately* ventilated.

Performance G5.3.1 shall apply only to old people's homes and early childhood centres.

G6.1 The objective of this provision is to safeguard people from illness or loss of *amenity* as a result of undue noise being transmitted between abutting occupancies.

Does not address outside noise which is covered in local council plans.

H1.2 Buildings must be constructed to achieve an adequate degree of energy efficiency when that energy is used for—

(a) modifying temperature, modifying humidity, providing ventilation, or doing all or any of those things; or

H1.3.1 The building envelope enclosing spaces where the temperature or humidity (or both) are modified must be constructed to—

(a) provide adequate thermal resistance; and

(b) limit uncontrollable airflow.

H1.3.3 Account must be taken of physical conditions likely to affect energy performance of buildings, including—

(a) the thermal mass of building elements; and

(b) the building orientation and shape; and

(c) the airtightness of the building envelope; and

(d) the heat gains from services, processes and occupants; and

(e) the local climate; and

(f) heat gains from solar radiation.

H1.3.6 *HVAC systems* must be located, constructed, and installed to—

(a) limit energy use, consistent with the *intended use* of space; and

(b) enable them to be maintained to ensure their use of energy remains limited, consistent with the *intended use* of space.

Performance H1.3.6 applies only to *commercial buildings*.