BRANZ

ISSUE607 BULLETIN

PASSIVE VENTILATION

February 2017

- Ventilation brings fresh air into a dwelling, removes excess moisture and pollutants such as carbon dioxide and can cool the interior in summer.
- This bulletin outlines the design considerations for optimising passive ventilation in New Zealand domestic buildings.
- The bulletin replaces Bulletin 430 of the same name.

1.0 INTRODUCTION

1.0.1 Everyday household activities such as cooking, space heating, clothes drying and showering/bathing release moisture and pollutants such as carbon dioxide (CO_2) or carbon monoxide (CO) into the air inside a home. New construction, new decoration or new furnishings can introduce volatile organic compounds (VOCs) to the air.

1.0.2 Potential impacts of contaminated indoor air range from poor health of occupants to mould growth, condensation on windows and, in extreme cases, damage to the building. Numerous studies have shown that health problems, mould and condensation are common in New Zealand dwellings.

1.0.3 Ventilation brings fresh air into a dwelling, which removes and dilutes pollutants and moisture-laden air. It can also cool a dwelling in summer. Natural (passive) ventilation, such as opening windows, has traditionally been the main way New Zealand dwellings have been ventilated. Where mechanical ventilation has been used, it has largely been for specific purposes such as venting cooking steam from above a cooktop or extracting moist air and odours from a bathroom.

1.0.4 The most cost-effective way to add ventilation to a dwelling is to get the passive measures right. Passive ventilation can improve indoor air quality and reduce overheating in the same way as mechanical ventilation but without the energy use and environmental impacts. Some heat will also be lost as a result of ventilation.

1.0.5 Passive ventilation should be designed at the same time as other passive design features in a building, such as orientation on site, room layout and window design. Potential solutions can be tested and optimised with the use of modelling software.

1.0.6 Although passive ventilation can be very effective, active ventilation should still be used to remove moisture and pollutants at source. In particular, install rangehoods over kitchen cooktops and extract fans to remove steam from bathrooms and laundries. Both must be vented to the outside. All clothes dryers (except condensing dryers) must be vented to the outside (which requires planning in apartments and the like).

1.0.7 This bulletin outlines the key design considerations for effective passive ventilation in domestic buildings. It replaces Bulletin 430 of the same name.

2.0 WHAT IS PASSIVE VENTILATION?

2.0.1 Passive ventilation is when air is exchanged in a building through openings in the building envelope using wind pressure and/or the stack effect (Figure 1).

2.0.2 Wind (pressure-based) ventilation makes use of openable windows and doors on the external walls of a house, allowing airflow to pass through the house interior as layout permits. Fresh air enters the windows/doors on the windward side, where the outside air pressure is greater, and stale air leaves through windows/doors on the leeward side, where there is lower air pressure outside the building.

2.0.3 Stack (buoyancy-based) ventilation uses temperature differences to move air. Hot air rises (hot air has a lower density than cold air at the same pressure) and is expelled from the house through high-level windows/doors or a stack ventilator through the roof. Fresh air is drawn into the house at lower levels to replace the air expelled.

2.0.4 Passive ventilation is made up of two parts:
- Controlled, deliberately introduced ventilation through openable windows and doors or purpose-built vents.
- Uncontrolled ventilation by infiltration through gaps around windows and doors and between building components. This is much more likely with older buildings – especially pre-1960 – than with newer, more-airtight homes.

3.0 HOW MUCH VENTILATION IS REQUIRED?

3.0.1 All types of ventilation must meet the requirements of New Zealand Building Code clause G4 *Ventilation*. This includes ensuring that spaces within buildings have:
- adequate ventilation, with outdoor air that will provide an adequate number of air changes to maintain air purity
- means to remove moisture, products of combustion, fumes, odours and other airborne contaminants.

3.0.2 Acceptable Solution G4/AS1 provides a means of demonstrating compliance. This includes (for most household units) that, in occupied spaces, the net openable area of windows or other openings to the outside and other openings must be at least 5% of the floor area. Net open area must take account of restrictors and the like that may be fitted to windows to restrict unlawful entry. (Where restrictors are fitted as part of the design, it may be necessary to increase the number of opening sashes.)

3.0.3 G4/AS1 also provides means of compliance for removing moisture and contaminants from kitchens, bathrooms and laundries and for using active ventilation.

3.0.4 NZS 4303:1990 *Ventilation for acceptable indoor air quality* specifies minimum ventilation rates and indoor air quality that will be acceptable to human occupants and avoid adverse health effects. A minimum 0.35 air changes per hour (ach) are required. There are a range of international guidelines, typically spanning 0.3–0.5 ach. British standards specify 0.5 ach for their climate.

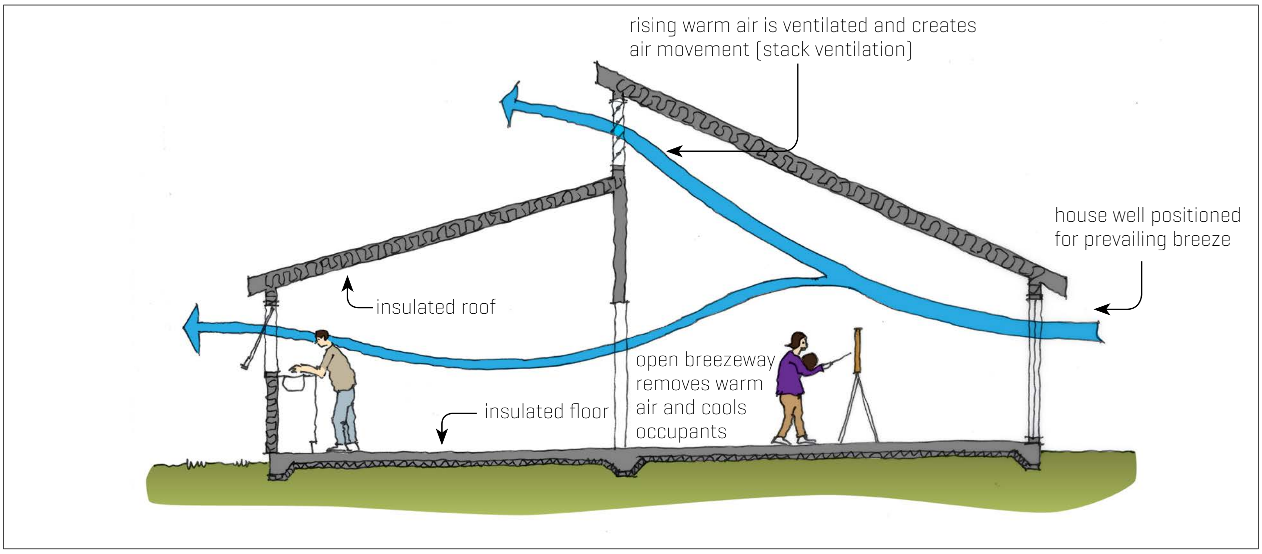


Figure 1. Passive ventilation.

4.0 PASSIVE VENTILATION DESIGN

4.1 PASSIVE VENTILATION AS PART OF PASSIVE DESIGN

4.1.1 There is little or no additional cost to designing effective passive ventilation into a new building. It will work best when it forms part of a wider consideration of passive design. This should start at the earliest stages of planning. The key elements of passive design that work together to optimise comfortable temperatures and good indoor air quality are:

- building location and orientation on site
- building layout
- window size/placement/specification (awning windows have a relatively small opening area and may therefore be less effective as ventilators, for example)
- thermal insulation (including glazing)
- thermal mass
- heating options (warmer air can hold more moisture, therefore, whatever the level of ventilation provided, it is more effective at removing internal moisture)
- sun shading and wind protection
- ventilation features such as high-level windows or vents that allow stack ventilation.

4.1.2 With existing buildings, some passive design features can be incorporated during upgrades. For example, new windows with trickle ventilators could be installed. But there are limits – for example, it is not practical to turn a completed house around on the site to take better advantage of cooling breezes.

4.2 GENERAL DESIGN CONSIDERATIONS

4.2.1 When designing a natural ventilation system, the long façade of the building should face the prevailing wind direction, with doors and opening windows providing the ventilation openings.

4.2.2 Ensure that openings (inlet and outlet) are:

- not obstructed
- reasonably sized
- able to control the flow
- located in opposing pressure zones to increase the potential airflow.

4.2.3 Other ventilating features include:

- maintaining a vertical distance between two openings to create a stack effect, i.e. hot air rising and thereby enhancing airflow
- shafts to promote airflow
- maximising airflow by designing open-plan spaces (while considering the implications of this for winter heating)
- maximising airflow by having openings at different levels or near the ceiling on opposite sides of the space
- using architectural and landscape features to direct and control airflow – for example, using casement sashes on the windward façade, as these can be more efficient than other types of sashes, and including opening windows on the leeward face.

4.2.4 For all the substantial benefits that passive design offers, there are potential drawbacks that must also be addressed at the early stage of design. These include:

- safety and security concerns – many homeowners are uncomfortable with leaving windows open (even windows with restrictors), sometimes even if they are at home, and especially with windows of a size and placement that may allow human entry
- heavy traffic noise
- dust
- draughts and wind noise
- the limited control of external environmental factors (such as reliance on temperature differential and wind pressure, which may not be present)
- the inability to respond to short, high-moisture events in the kitchen/bathroom
- in winter, the loss of heated air and its replacement with cold outside air, which may be costly to heat
- more thought is required for the design in the early stages
- there are some limitations associated with dwellings in warmer parts of New Zealand in terms

of siting where summer wind obstructions are minimal
- the need for a narrow building for passive ventilation to effectively distribute through all areas and allow for adequate internal airflow between rooms.

4.2.5 Designers should be aware that New Zealanders may not leave windows open in the same way they did several decades ago. Clause G4 assumes that windows will be open during normal household operations, and occupants need to be informed of the role open windows play in ventilating dwellings.

4.2.6 Passive ventilation design can be optimised with the use of modelling software. Modelling different scenarios in a computer allows a designer to explore design options and understand the implications of design and specification choices and compromises. One example is CoolVent (http://coolvent.mit.edu), developed by MIT's Building Technology Program. It is regularly updated and verified and has various comfort models available, as well as being a free download. Also see BRANZ Bulletin 602 *Thermal modelling tools for houses*.

4.3 CALCULATING AIRFLOW RATES

4.3.1 The optimum airflow rate for a particular location and building will depend on temperature and humidity. The higher the temperature and humidity, the more airflow is needed to maintain comfortable temperatures.

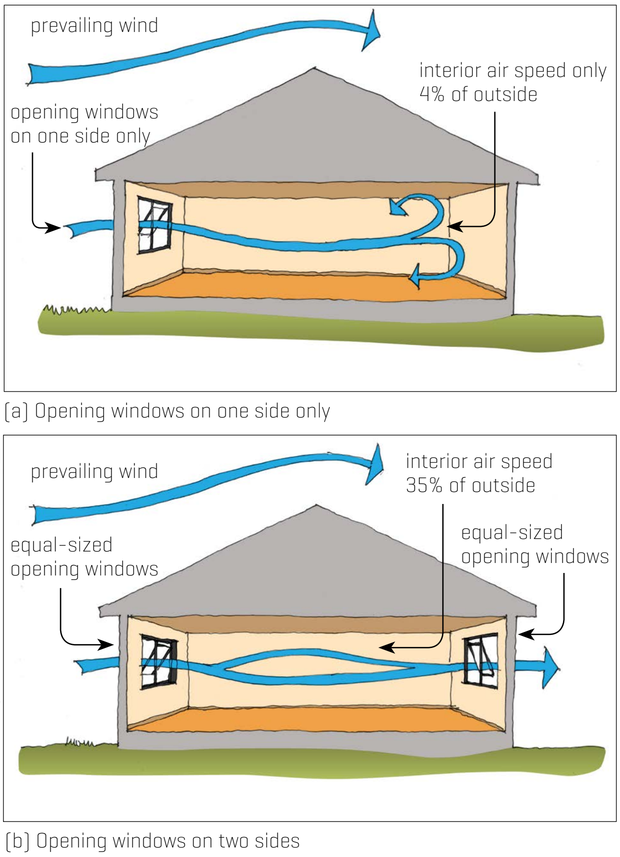


Figure 2. Interior air speed improves with cross-ventilation.

4.3.2 Airflow rates depend on:
- prevailing wind direction
- average wind speeds (as a guide, use half the average seasonal speed, as wind speeds rarely fall below this value)
- how the site is influenced by daily and seasonal variations in wind such as onshore/offshore winds and how these may change during the day
- building form – whether it enhances or restricts airflow
- surrounding landforms and planting – whether they will obstruct airflow
- orientation and position of windows, doors, roof ventilators, skylights and vent shafts
- surface pressure coefficients around the building.

4.3.3 The configuration of windows and vents as well as the coefficient of their effectiveness have a large bearing on airflow. *CIBSE guide B: Heating, Ventilating, Air Conditioning and Refrigeration*, pages 2–57 has further information on these calculations.

4.4 USING PASSIVE VENTILATION FOR COOLING

4.4.1 In warmer regions, the cooling role of passive ventilation should be carefully considered:
- Determine a location and orientation on site and form design that optimise exposure to cooling breezes.
- Design airflow paths through the building (Figure 2). For rooms with only one wall with windows, occupants should be advised to leave doors open or incorporate grilles in doors to facilitate cross-flow of air.
- Specify windows that allow good airflow but minimise unwanted heat gain.

4.4.2 Although air movement is useful for cooling people, it is less effective during periods of high humidity. An air speed of 0.5 m/s physiologically equates to a 3°C drop in temperature at a relative humidity of 50%, resulting from faster-evaporating perspiration.

4.4.3 Air speeds up to 1.0 m/s can increase evaporative cooling. Air speeds above 1.0 m/s usually cause discomfort.

4.4.4 Designs that optimise summer cooling should also be tested in simulation for their performance in winter. Fresh air requirements should be achievable on cold days without draughts or excessive heat loss.

5.0 PASSIVE VENTILATION FIXTURES AND DEVICES

5.1 OPENABLE WINDOWS

5.1.1 Openable windows can meet the bulk of ventilation requirements in most New Zealand houses. Their style and method of opening can have a significant effect on the volume of air changes provided (Figure 3). Casement windows can catch prevailing winds or shield against them. Awning windows can catch warm, rising air currents. Tall windows with open spaces at the top and bottom can allow cool air

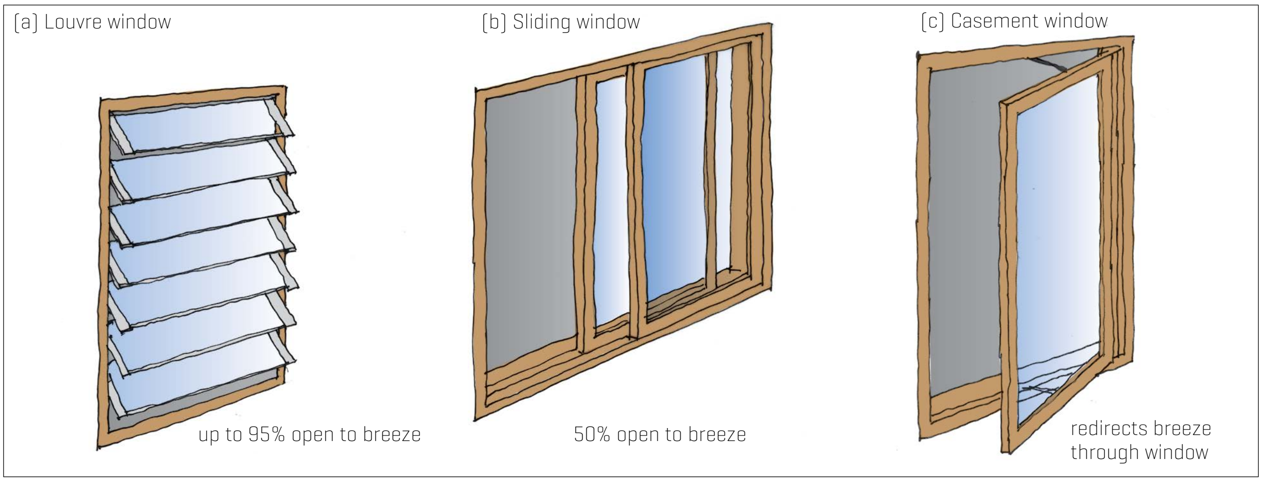
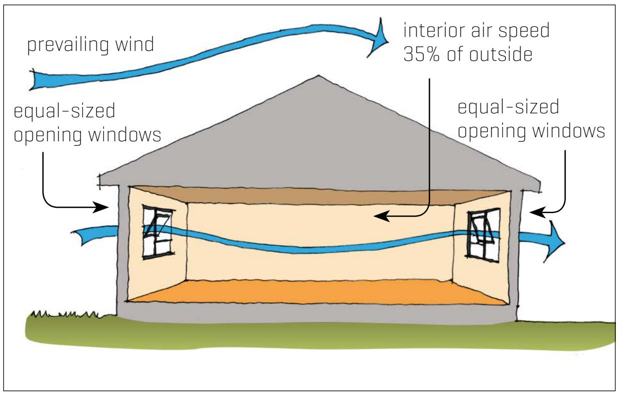


Figure 3. Window style and method of opening have a large effect on airflow.

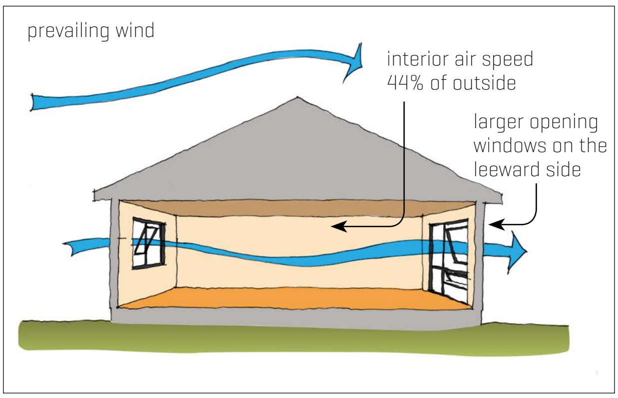
to enter at the bottom and warm air to be drawn out of the top (through convection as well as wind). Narrow (100–150 mm wide) opening glass or cedar louvres/ shutters incorporated into the window or door design allow ventilation while maintaining security.

5.1.2 The locations of openable windows will also have a significant effect on the level of air change they produce. The best option is to have windows on opposite walls (but not directly facing each other). The next best option is adjacent walls, with the least-preferred option being several ventilation openings on the same wall.

5.1.3 Having window openings of approximately the same size on both walls is recommended – where this is not possible, doors with grilles can assist the cross-flow ventilation. Where windows on different sides are different sizes, it will generally be preferable to have larger openable windows on the inlet (windward) side as the total rate of airflow is likely to be higher. Airflow speed is likely to be higher where inlet openings are small and outlet openings are larger (Figure 4). (This is partly due to the wind force acting on a small area and partly due to the funnelling Venturi effect.)



(a) Equal-sized opening windows



(b) Larger opening window on leeward side

Figure 4. Interior air speed varies with opening window proportions.

5.2 TRICKLE VENTILATORS

5.2.1 Trickle ventilators are controllable openings in the external building envelope, often built along the top or bottom of a window frame, that provide background ventilation as a result of air pressure differences. Positive air pressure on one side of a house pushes outside air in through the ventilators, while stale air is pushed out through ventilators on the leeward side of the building. These ventilators do not replace opening sashes but offer an extra option. They are designed to prevent insect and rain entry.

5.2.2 The main benefit of trickle ventilators over opening windows is their security. They can be left open even when house occupants are not at home.

5.2.3 Trickle ventilators are given as an option for ventilation in Acceptable Solution G4/AS1. Section 1.3.9 of G4/AS1 places specific requirements on trickle ventilators, including that they must:

- have an opening of no less than 2000 mm^2 equivalent aerodynamic area
- be located to minimise draughts
- keep pests and insects out

Trickle ventilator set in a window.

- be controllable and closable in all conditioned spaces
- have the sum of the equivalent aerodynamic area greater than the sum of the equivalent area of the passive stack ventilator(s), if installed in a household unit
- have the equivalent aerodynamic area, based on the number of occupants, for the space as given in Tables 1 and 2 in the Acceptable Solution.

5.2.4 Under G4/AS1, high-level trickle ventilators are required in:

- houses where kitchens, bathrooms or laundries do not have an external wall (section 1.3.3)
- habitable spaces that have an external wall and are open to a kitchen, bathroom, toilet or laundry with a passive stack ventilator (section 1.3.4)
- habitable spaces that have an external wall and no opening to a kitchen, bathroom, toilet or laundry with a passive stack ventilator (section 1.3.5)
- habitable spaces with both one external wall and a permanent opening to a kitchen, bathroom, toilet or laundry, within which a continuous mechanical extract system is installed (section 1.4.2)
- habitable spaces with one external wall and a permanent opening to a kitchen, bathroom, laundry or toilet, within which an intermittent mechanical extract system is installed (section 1.4.3).

5.2.5 Habitable spaces without openings to the exterior that are ventilated via another habitable space must have both high-level and low-level trickle ventilators (G4/AS1 section 1.3.6).

5.3 PASSIVE STACK VENTILATOR

5.3.1 A passive stack ventilator is a vertical or near-vertical ventilation shaft that uses continuous air movement to ventilate a space, typically a wet room such as a bathroom. Moist warm air is drawn up the ventilator, and the air being expelled moves out through a vent above the roofline. (The vent should be near the ridge to reduce the effect of wind gusts.)

Fresh air is drawn into the building through open windows, trickle ventilators or air leakage.

5.3.2 Stack effect ventilation is an especially effective strategy in winter, when indoor/outdoor temperature difference is at a maximum. Stack effect ventilation may not work as efficiently in summer as it requires that the indoors be warmer than outdoors, which is undesirable in summer.

5.3.3 Stack effect can be enhanced by the use of solar chimneys (Figure 5). These provide additional height and direction for air to increase performance. Solar chimneys heat the rising air to increase the temperature differential between the intake and exhaust air.

5.3.4 An expression for the airflow induced by the stack effect is:

$Q_{stack} = 0.65A\sqrt{19.6h\frac{T_i - T_o}{T_i}}$ where:
Q_{stack} = volume of ventilation rate (m³/s)
A = free area of inlet opening (m²), which equals area of outlet opening.
h = vertical distance between inlet and outlet midpoints (m)
T_i = average temperature of indoor air (Kelvin), note that 27°C = 300 K
T_o = average temperature of outdoor air (Kelvin).

5.3.5 G4/AS1 mentions a passive stack ventilator in the kitchen/bathroom/toilet/laundry as part of the solution. Section 1.3.7 of the Acceptable Solution outlines the requirements.

5.4 LOUVRES

5.4.1 Louvres are frames containing a series of parallel blades, usually glass, set in metal holders. They may be fixed or openable to allow air to pass through and may take the place of windows. Many houses built in the mid-20th century had small fixed louvres on the outside wall above a toilet, providing effective natural ventilation.

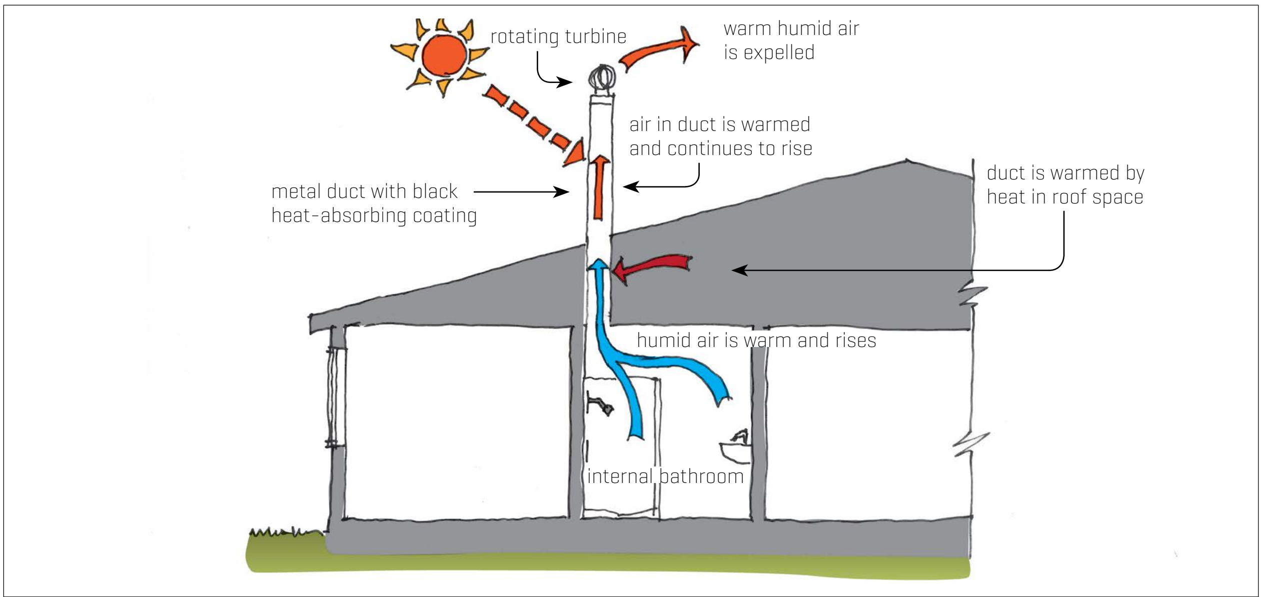


Figure 5. Principle of a solar chimney.

Modern louvres installed in a new house.

5.4.2 Louvres can give much more airflow into a home than many conventional window designs where the sash only opens a small way (Figure 3). Tilted appropriately, they may be left open in light rain. When open, they don't provide the obstacle to anyone walking by that some casement or awning windows do. A range of proprietary window louvres is available on the New Zealand market. Some can be electronically controlled by a remote control or a building management system.

5.4.3 Openable louvres should meet the requirements of NZS 4211:2008 *Specification for performance of windows*. They can be tested against AS/NZS 4740:2000 *Natural ventilators – Classification and performance*. Unlike trickle ventilators, they do not appear in G4/AS1.

5.4.4 Louvres are more appropriate for locations with warmer climates such as Northland, Auckland and the Bay of Plenty. They are not recommended in very cold climates as they may not fully seal when closed.

5.4.5 Wide louvres are not recommended for buildings in very high or extra high wind zones or where there is a security risk. The installation of proprietary louvres in these wind zones may void the product warranty.

5.4.6 Louvres with glass or timber blades can also be installed on internal walls to allow natural airflow between rooms. Grilles or louvres can also be incorporated into doors to facilitate airflow through the building.

6.0 WHERE MECHANICAL VENTILATION IS RECOMMENDED

6.0.1 Passive ventilation alone is unlikely to provide enough air exchange to remove large amounts of moisture generated in a very short space of time in bathrooms, kitchens and laundries. Localised air extraction systems such as kitchen rangehoods and bathroom extractor fans should be specified to remove the moisture at source. Extract systems must vent to the outside, which requires careful planning in buildings with restricted lengths of exterior walls.

6.0.2 Table 2 of NZS 4303:1990 *Ventilation for acceptable indoor air quality* sets out the mechanical extract airflow rate requirements. In houses, the minimum extract airflow rate is:

- for kitchens – 50 litres per second (l/s) intermittent, 12 l/s continuous
- for bathrooms and toilets – 25 l/s intermittent, 10 l/s continuous.

6.0.3 Consider the use of fans for topping up stack and wind-driven ventilation. Ceiling fans can provide up to 3°C effective temperature drop for one-tenth of the electrical energy consumption of mechanical air-conditioning systems. Look for fans with an airflow efficiency of at least 200 m^3/hr/W, and locate them immediately above each activity area within a room – this might not be necessarily at the centre of the room.

6.0.4 Other forms of mechanical ventilation (such as heat-recovery ventilation) may be useful or necessary if a building is very airtight or security or other concerns rule out a passive solution. (Heat-recovery ventilation is a ducted ventilation system consisting of two fans, one to draw air in from outside and one to remove stale internal air. An air-to-air heat exchanger recovers heat from the internal air before it is discharged and uses it to warm incoming air.)

7.0 MORE INFORMATION

7.1 NEW ZEALAND BUILDING CODE AND STANDARDS

- New Zealand Building Code clause G4 *Ventilation* and Acceptable Solution G4/AS1
- NZS 4211:2008 *Specification for performance of windows*
- NZS 4303:1990 *Ventilation for acceptable indoor air quality*
- AS/NZS 4740:2000 *Natural ventilators – Classification and performance*

7.2 BRANZ

www.branz.co.nz/wave – WAVE research, ventilation strategies
www.level.org.nz – the BRANZ website for sustainable building
Building Basics *Internal Moisture*
Good Repair Guide *Improving Internal Ventilation*
Level Sustainable Building Series *Windows*
Level Sustainable Building Series *Passive Design*
Bulletin 581 *Residential mechanical ventilation systems*
Bulletin 602 *Thermal modelling tools for houses*.

7.3 OTHERS

www.wanz.org.nz (search on "passive ventilation")
www.ashrae.org – a global body focusing on sustainable technology, especially in heating, ventilation and air conditioning
www.yourhome.gov.au/passive-design/passive-cooling
CIBSE guide B: Heating, Ventilating, Air Conditioning and Refrigeration

BRANZ

INSPIRING THE INDUSTRY TO PROVIDE BETTER BUILDINGS FOR NEW ZEALANDERS

BRANZ ADVISORY HELP LINES

FOR THE BUILDING INDUSTRY

0800 80 80 85

FOR THE HOME OWNER AND PUBLIC ENQUIRIES

0900 5 90 90

Calls cost $1.99 per minute plus GST. Children please ask your parents first.

HEAD OFFICE AND RESEARCH STATION
Moonshine Road, Judgeford
Postal Address – Private Bag 50 908, Porirua 5240, New Zealand
Telephone – (04) 237 1170, Fax – (04) 237 1171
www.branz.nz

BRANZ Find www.branzfind.co.nz

Standards referred to in this publication can be purchased from Standards New Zealand by phone 0800 782 632 or by visiting the website: www.standards.co.nz.

Please note, BRANZ books or bulletins mentioned in this publication may be withdrawn at any time. For more information and an up-to-date list, visit BRANZ Shop online: www.branz.nz or phone BRANZ 0800 80 80 85, press 2.

Disclaimer: The information contained within this publication is of a general nature only. BRANZ does not accept any responsibility or liability for any direct, indirect, incidental, consequential, special, exemplary or punitive damage, or for any loss of profit, income or any intangible losses, or any claims, costs, expenses, or damage, whether in contract, tort (including negligence), equality or otherwise, arising directly or indirectly from or connected with your use of this publication, or your reliance on information contained in this publication.

ISSN 1170-8395
Copyright © BRANZ 2017. No part of this publication may be photocopied or otherwise reproduced without the prior permission in writing from BRANZ.