ISSUE 698 BULLETIN

RESIDENTIAL MECHANICAL VENTILATION SYSTEMS

March 2025

- Ventilation is crucial for introducing fresh air from outside to replace stale indoor air.
- Ventilation is essential for building occupant wellbeing and building material durability.
- This bulletin covers extract, supply and balanced heat recovery ventilation systems. It updates and replaces BU581 of the same name.

1 INTRODUCTION

1.0.1 Ventilating homes by extracting stale air, pollutants and excess moisture and bringing in fresh air from outside plays a major role in maintaining good indoor air quality and moisture management. It is crucial for the comfort, health and wellbeing of the occupants and for the performance and durability of building materials.

1.0.2 Much of the excess moisture and/or many of the pollutants in indoor air come from:

- occupants breathing, cooking, showering or bathing, drying clothes indoor or using clothes dryers that are not vented to the outside or using unflued gas heaters
- combustion in wood burners and gas appliances that produce harmful gases such as carbon monoxide and carbon dioxide
- wood burners and some types of cooking that can increase particulates in the air
- new building materials that can give off volatile organic compounds (VOCs) such as formaldehyde or other gases
- some pollutants enter from outside.

1.0.3 Our existing housing stock includes a significant proportion of homes that are poorly ventilated. The 2023 Census found that 18% of private occupied dwellings experienced dampness at least some of the time, and 14% (1 in 7 homes) had mould over A4 size always or sometimes. Dampness and mould are a sign of insufficient ventilation and heating in a home. Other contributing causes can include single-glazed windows and poor or missing insulation, inappropriate occupant behaviour such as drying washing inside, leaks in the building envelope and moisture rising from the ground under a house. There is a wealth of evidence that dampness and mould contribute to health problems such as respiratory infections and rheumatic fever, especially in children.

1.0.4 In Aotearoa New Zealand, we have traditionally assumed that acceptable ventilation in our homes is achieved via windows or other openings that are the equivalent to 5% of the floor area of occupied spaces. That is the minimum requirement in Acceptable Solution G4/AS1 today and is unchanged from regulations that existed in 1947. The ventilation requirements assume a certain amount of ventilation by infiltration.

1.0.5 Older dwellings had infiltration – uncontrolled air movement through gaps and openings in the building envelope – just because of the way we built. While relying on this fortuitous air leakage and opening windows for ventilation appears to have worked in the past, it is no longer sufficient because of the way we and our homes have changed:

- Many people are reluctant to open windows or leave them open because they perceive security risks or noise problems or are worried about heat loss and the costs of reheating indoor air.
- New homes today are considerably more airtight than homes such as villas and bungalows. Older homes were subject to ventilation through levels of infiltration that are much less likely today and were more likely to have chimneys, which provided some stack effect ventilation.
- New homes are considerably better insulated than older homes. Well-insulated homes offer less drying potential in the structure because of the reduced energy flow through the different assemblies that make up a building. This means an increased risk that excess moisture moving from living areas into roof spaces or wall assemblies, where less drying is taking place, may lead to condensation, mould or even rot. There is therefore greater need to consider ventilation for moisture management of indoor air.

1.0.6 International guidelines recommend that, to maintain good indoor air quality, homes have a ventilation rate of 0.35–0.5 air changes per hour (ach). In other words, one-third to one-half of the volume of air in a home is replaced each hour. BRANZ recommends that mechanical ventilation is the default option to achieve this.

1.0.7 Passive ventilation systems that include elements such as trickle vents in windows or passive stack ventilation are possible but need careful, well thought out design and modelling to ensure they achieve the required results. Building consent applications for entirely passive ventilation (with no mechanical element) will need to use an Alternative Solution. G4/AS1 includes the comment: "Within this acceptable solution, natural ventilation ... on its own is not adequate to remove moisture generated from cooktops, showers and baths."

1.0.8 Specifying and designing an appropriate mechanical ventilation system is not enough. It is critical that ventilation systems are properly commissioned and well maintained.

1.0.9 For new builds, ventilation systems should be seen as part of the whole home, including home heating and thermal insulation. They should be considered from the very start of the design process rather than being a later add-on.

1.0.10 If mechanical ventilation is being considered as a response to excess moisture in a home, first identify the sources of the problem and address those. If a ventilation system is being retrofitted in an older house, also look at the existing levels of insulation and heating and any gaps in the thermal envelope.

1.0.11 Some people have the mistaken belief that heat pumps provide ventilation. While heat pumps have indoor and outdoor units and piping between them, they do not bring fresh air into a home and do not provide ventilation. A house with space heating provided by heat pumps still needs effective ventilation.

2 AIRTIGHTNESS AND VENTILATION

2.0.1 The airtightness of a building is a measure of how much air flows between indoors and outdoors through the structure itself under a sustained pressure difference of 50 pascals (Pa). It is an indirect way of measuring how big the gaps in the envelope are. The level of airtightness in a building can have a significant effect on its energy efficiency, thermal comfort and indoor air quality.

2.0.2 BRANZ has tested the airtightness of houses built in different periods and also apartments (Figure 1). New Zealand homes have become much more airtight over recent decades as a result of changing building materials and construction methods.

2.0.3 There is no requirement to meet a particular target level of airtightness in our Building Code or standards. Specific airtightness requirements with testing of new homes to demonstrate compliance already exist in some other Western countries. Airtightness testing is usually carried out in New Zealand on homes that are trying to achieve a certain environmental or performance certification.

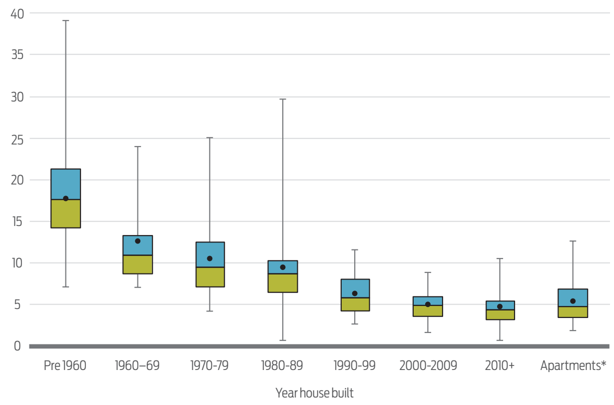

Figure 1. The average New Zealand home infiltration rate broken down by year of construction, showing that our homes have become considerably more airtight in recent decades.

2.0.4 Areas that may need attention to enhance airtightness include:

- bottom plate/floor junction – apply sealant before installing the skirting board
- window and door edge – take care with sealing details
- plumbing penetrations – seal using boots (also called grommets)
- detailing behind bathtubs – ensure there is full wall lining and seal all junctions and penetrations
- recessed downlights – use sealed types that do not allow movement of air from living spaces to the roof space.

2.0.5 An airtightness measurement is a fundamental characteristic of the building envelope and is unknown at the design stage. In contrast, ventilation rates are a measure of how much fresh air we are intending to supply to a building. BRANZ supports an approach of "build tight and ventilate right", with a recommended ventilation rate of 0.35–0.5 ach. This is achievable for industry with minimal additional construction cost.

3 BUILDING CODE AND STANDARDS REQUIREMENTS

3.0.1 Building Code clause G4 *Ventilation* has these performance requirements:

- Spaces within buildings must have means of ventilation with outdoor air that will provide an adequate number of air changes to maintain air purity.
- Mechanical air-handling systems must be constructed and maintained to prevent harmful bacteria, pathogens and allergens from multiplying within them.
- Buildings must have a means of removing pollutants, including:
    - cooking fumes and odours
    - moisture from laundering, utensil washing, bathing and showering
    - odours from sanitary and waste storage spaces
    - airborne particles
    - bacteria, viruses or other pathogens
    - products of combustion.
- Contaminated air must be disposed of in a way that avoids creating a nuisance or hazard to people and other property.
- The quantities of air supplied for ventilation must meet the additional demands of any fixed combustion appliances.

3.0 2 The first performance requirement – that ventilation uses outdoor air – makes it clear that systems that draw air from the roof space cannot be used to demonstrate compliance with G4.

3.0.3 The last performance requirement for fixed combustion appliances applies to gas appliances and solid fuel burners that draw supply air from the room. If there is insufficient ventilation, the risk is that there can be a dangerous build-up of carbon monoxide in the room. The combustion can also be starved of air. Ventilation is required to avoid a build-up of noxious gases and ensure sufficient make-up air is provided for efficient combustion. This is especially important where a continuous extract ventilation system is installed that produces negative air pressure in the home.

3.0.4 Some appliances operate with room-sealed combustion where supply air for the fire is drawn from outside through a bi-directional flue. Manufacturers say this system means that their appliances do not require the room to be ventilated as others do for the safe operation of combustion. Ventilation for improved air quality is still recommended.

3.0.5 G4/AS1 references NZS 4303:1990 *Ventilation for acceptable indoor air quality*. This requires a minimum rate of 0.35 ach for living areas in private dwellings, which is equivalent to approximately one-third of all the air in the house being changed every hour. The standard says that the "ventilation is normally satisfied by infiltration and natural ventilation". However, the standard is 25 years old (and was itself based on a standard from 11 years earlier) and this statement is unlikely to be the case for homes being built today.

3.1 HEALTHY HOMES STANDARDS

3.1.1 The healthy homes standards apply to rental properties and boarding houses. Landlords must ensure that their properties comply with the standards within 90 days of any tenancy that starts or is renewed after 1 July 2021. All Kāinga Ora homes and registered community housing provider houses have been required to comply since 1 July 2024. All private rental homes must comply by 1 July 2025. Landlords must take all reasonable steps to ensure the rental property complies with the standards to the greatest extent reasonably practicable. There are some exemptions from the requirements.

3.1.2 There are ventilation and anti-draught requirements for rental housing. There must be openable windows in the living room, dining room, kitchen and bedrooms. Owners must also stop any unnecessary gaps or holes in walls, ceilings, windows, floors and doors that cause noticeable draughts. All unused chimneys and fireplaces must be blocked.

3.1.3 These are the requirements for extractor fans:

- For kitchens, new fans or rangehoods installed after 1 July 2019 must have a minimum diameter (including ducting) of 150 mm or an exhaust capacity of at least 50 litres per second.
- For bathrooms, new fans installed after 1 July 2019 must have a minimum diameter (including ducting) of 120 mm or an exhaust capacity of at least 25 litres per second.

3.1.4 Alternatively, the standard can be met with continuous mechanical ventilation. In this case, the system must be designed to provide ventilation for multiple rooms and to continuously extract air to the outdoors and extract air directly out of the kitchen and bathroom, with an exhaust capacity of at least 12 l/s in the kitchen and 10 l/s. in the bathroom. The actual flow rate may be varied (manually or automatically) in response to the demand for ventilation.

3.1.5 Systems that recirculate air or do not extract to the outdoors do not meet the requirements.

3.1.6 There is a ventilation tool for guidance on the Tenancy Services website.

4 MECHANICAL VENTILATION SYSTEMS

4.0.1 Mechanical ventilation systems give greater control over the supply of fresh outside air into a building and the removal of excess moisture and pollutants from indoor air. Components of a mechanical ventilation system typically include:

- a fan or fans
- an air intake
- an air filter to remove particulates
- ductwork
- room diffusers
- duct silencers and fire dampers and collars (in multi-unit housing).

4.0.2 Ventilation system size should be calculated to ensure required airflows are provided without undersizing or oversizing a system. Manufacturers and HVAC engineers could be consulted.

4.0.3 A very basic approach is to calculate the internal volume of the house or part of the house that is required to be ventilated and multiply the volume by 0.35 to get the minimum volume of air changes required per hour. For example:

- for a house with a floor area of 120 m² and internal volume of 288 m³ – multiply 288 x 0.35 = 100.8 m³/h
- for a house with a floor area of 250 m² and internal volume of 675 m³ – multiply 675 x 0.35 = 236.3 m³/h..

4.0.4 When calculating requirements and designing a ventilation system, pay careful attention to the different measures l/s and m³/hour – we are aware of cases where these have been confused. One l/s is the equivalent of 3.6 m³/hour. There are online calculators that make the conversion easy.

4.0.5 Extracted air should always be expelled outside and never expelled into the roof space, which can lead to condensation, mould growth and other problems.

4.0.6 There is a wide range of air filters available, sometimes labelled with a letter and a number. F filters typically remove smaller particles than G filters, and a higher number indicates a more effective filter. F7 is therefore much finer than G4. Carbon filters can remove odours, and high-efficiency particulate air (HEPA) filters can take out particles as small as 0.3 microns (less than one-hundredth the thickness of a human hair). This means they will trap some allergens such as pollen or dust mites. Do not overspecify filtration – there is a trade-off between installing high efficiency filters and ventilation system air pressure and energy efficiency (which both drop). Filters also increase maintenance requirements.

4.1 EXTRACT VENTILATION

4.1.1 Air extraction systems remove moist or polluted air, typically from kitchens and bathrooms, to the outside. While overall house ventilation rates are expressed as the number of air changes per hour, mechanical ventilation systems such as extract systems move particular volumes of air per unit of time – usually the number of litres per second (l/s) or m³/hour. Higher-flow extractor fans with larger diameters for better and quieter airflow are often recommended.

4.1.2 G4/AS1 includes extractor fans as a Code-compliant way to ventilate bathrooms and kitchens. The Acceptable Solution says: "1.3.3 Spaces in household units and accommodation units that contain cooktops, showers and baths must have mechanical extract fans installed to remove moisture generated by these fixtures. Mechanical extract fans (including associated ducting) must have a flow rate not less than a) 25 L/s for showers and baths, and b) 50 L/s for cooktops."

4.1.3 NZS 4303:1990 Table 2 also sets out the mechanical extract airflow rate requirements. In houses, the minimum extract airflow rate is:

- 25 l/s intermittent, 10 l/s continuous for bathrooms and toilets
- 50 l/s intermittent, 12 l/s continuous for kitchens.

4.1.4 The best location for the extract grille where air is being extracted in a bathroom or toilet is:

- as high as possible such as in the ceiling or high on the wall
- as close as possible to the source of the steam, moisture or smell such as above a shower
- opposite the point in the room where replacement air may enter (such as a window temporarily opened

or under a door) so that the maximum amount of contaminated air is replaced by fresh air.

4.1.5 G4/AS1 requires that, where an exhaust fan is installed to remove moisture and other contaminants from a kitchen or wet area, the fan must exhaust air to the outside. Locate the exhaust air outlet so that the discharged air:

- does not re-enter the home's fresh air supply
- is not drawn inside through a window or door
- does not enter another dwelling.

4.1.6 For rooms used infrequently or intermittently such as bathrooms or toilets, an extract fan linked to the operation of the light switch means the fan will run automatically while the room is occupied. A timer switch can ensure that it runs for a short time afterwards. The wiring and switching should also allow the ventilation to be used even when the light is not and vice versa. A humidity sensor is also an option.

4.1.7 Rangehoods can be installed over a kitchen cooktop in ducted or recirculating mode. With ducted rangehoods, steam and smells are extracted to the outside. Where recirculating mode is specified, air passes through a filter before being released back into the kitchen. This does not extract moisture from the kitchen and does not meet the requirements of G4/AS1.

4.1.8 Although less commonly installed, continuous extract ventilation systems are also available. These extract air and create negative pressure that results in air being drawn into a house from outside. When installed in a new relatively airtight home, they will require vents (such as trickle vents in windows or proprietary vents in exterior walls) to provide the make-up air. This system may not be a good choice for some villas or bungalows if damp subfloor air may be drawn up through gaps in floors.

4.2 SUPPLY VENTILATION

4.2.1 A supply system (positive pressure or forced air system) brings air into living areas typically through ceiling-mounted diffusers (Figure 2). This creates a slight positive pressure inside the home that forces stale, indoor air out through gaps and air leakage paths. For this system to be effective, the building envelope must enable sufficient air to leak out to match the supply airflow rate. In very airtight homes, windows may need to be left slightly open or vents installed.

4.2.2 Proprietary systems take either roof space air or outside air, and some that usually take roof space air may include a bypass allowing outside air to be taken from the eaves of the building in the warmer months. Some systems have electric resistance heaters that pre-heat air (including roof space air) that is cold. Due to heat losses through ducting, placing heaters directly in rooms is typically more efficient.

4.2.3 As noted above, drawing air from the roof space does not comply with Building Code clause G4, which requires ventilation with outdoor air. Airflow control based solely on temperature difference can potentially mean insufficient fresh air being brought inside during colder weather and result in inadequate ventilation and high moisture loads. Some systems have a minimum calibrated airflow that exceeds 0.35 ach and can be instructed not to turn off. Some systems incorporate humidity measurement sensors.

4.2.4 Ventilation systems should never draw air from roof spaces under claddings where asbestos materials have been identified.

4.3 BALANCED HEAT RECOVERY VENTILATION

4.3.1 These systems have two fans and ducts – one to draw in fresh air from outside and one to remove stale internal air. An air-to-air heat exchanger, generally installed in a roof space, recovers heat from the internal air before it is discharged to the outside and warms the incoming air with the recovered heat (Figure 3). In summer, the unit can often be bypassed to cool the home with fresh air. Some manufacturers of these systems state that, during colder weather, the incoming air will have to be heated to create a comfortable indoor temperature.

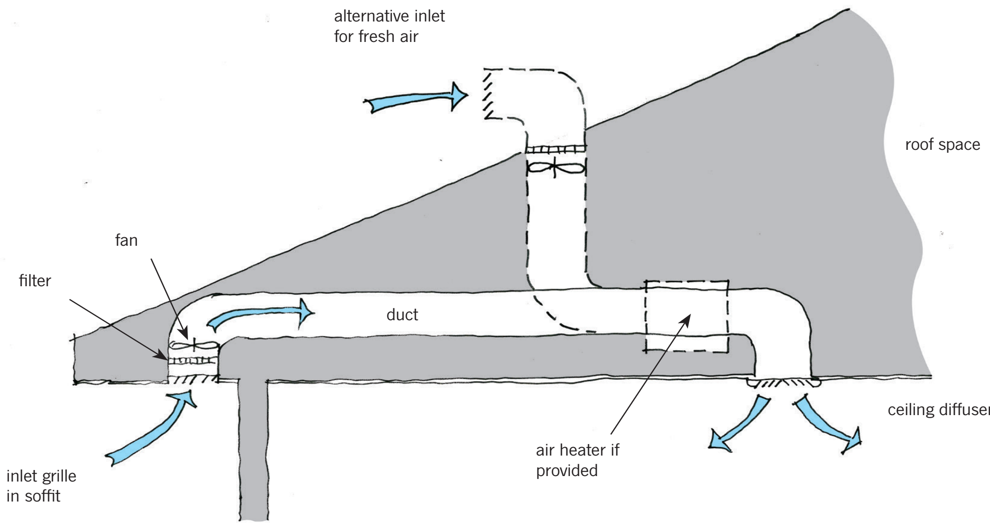

Figure 2. Schematic drawing of a supply-only system sourcing fresh air from outside. Note that the alternative inlet (the roof penetration) presents weathertightness risks unless extremely carefully detailed.

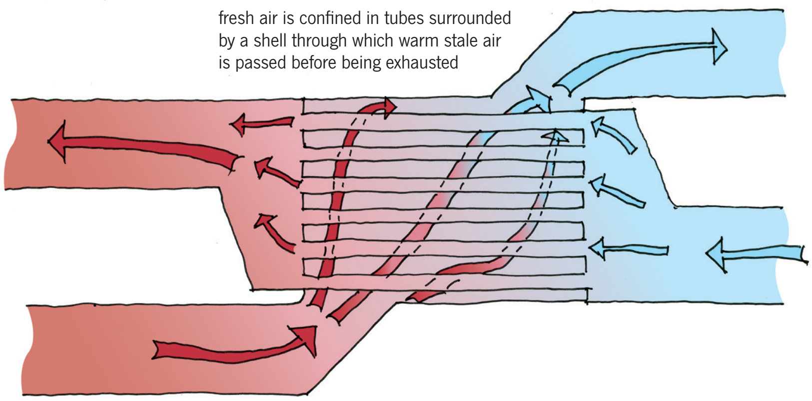

Figure 3. A counter-flow heat exchanger. A system that does not include a heat exchanger is not a heat recovery ventilation system.

4.3.2 For whole-house ventilation, a well-designed and commissioned balanced heat recovery system is the best option. In the right circumstances, it has the potential to provide a healthy indoor environment while also reducing home heating bills. The energy recovered from the warm outgoing air can be higher than the energy required for the operation of the fans. However, these systems have the highest upfront purchase and installation costs.

4.3.3. Balanced heat recovery ventilation is best for colder climates and houses with at least a moderate level of airtightness where all spaces served by the unit are heated.

4.3.4 While the heat exchange unit can potentially achieve an efficiency of around 90%, BRANZ testing indicates that energy efficiency of the whole system is more likely to be at a lower level than this.

4.3.5 To achieve optimal efficiency, ventilation ducting for heat recovery systems should have these features:

- Designed and installed with a balanced extract and intake airflow. (BRANZ testing of a deliberately unbalanced system found that an efficiency of 70% in the core dropped to around 40% for the system overall.)
- Ideally installed within the thermal envelope such as under a warm roof (Figure 4). When installed inside the thermal envelope, the supply and exhaust ducts need to be insulated for the sections between outdoors and the heat exchanger. Where installation within the thermal envelope is not possible, the ducting must be well insulated (>R1.5) to reduce heat loss as the air in uninsulated roof voids can be much colder than the air in the ducting.
- Whole-of-home permanent mechanical ventilation systems generally have lower flow rates in ducting and smaller diameter ducts are generally used.
- A condensate drain for the exhaust ducting to allow removal of moisture created when the heat is removed from the air and around 2% fall to the drain where condensation is a risk.

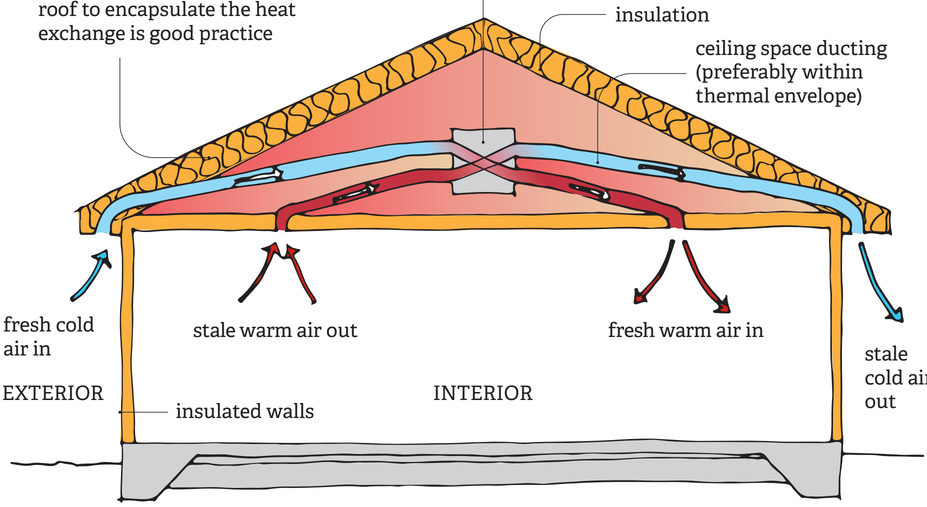

Figure 4. Schematic drawing of a balanced heat recovery ventilation system with ducting mostly inside the thermal envelope created by a warm roof.

4.3.6 These systems may be a solution for those homeowners reluctant to ventilate their homes – either by opening windows or using ventilation systems – because they believe that too much heat is lost when they do that and the cost of reheating their home will be expensive. (When it comes to ventilation, windows are a blunt instrument.)

4.3.7 BRANZ scientists modelled a balanced heat recovery system in a building where airtightness was varied (Figure 5). With the same ventilation rate, the cost of maintaining a temperature of 20°C is approximately halved for the more airtight configurations with heat recovery system efficiency of around 55%. For efficiency of 90% – technically possible with optimal specification, design and installation – the cost is just one-quarter or less of having no heat recovery system.

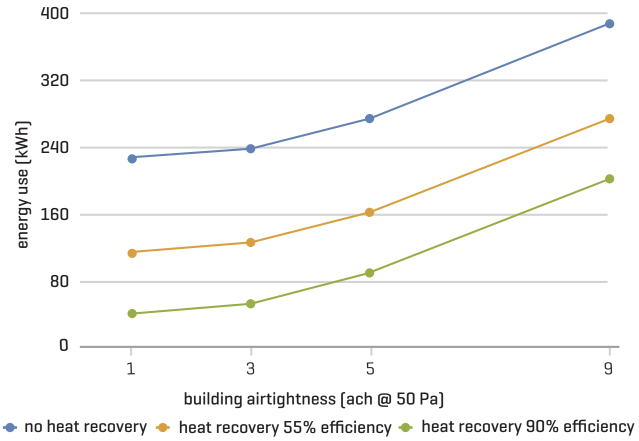

Figure 5. Modelled energy use to maintain 20°C in a 90 m² Wellington house for July at different airtightness levels.

4.4 DUCTING

4.4.1 For all mechanical ventilation systems, there are certain recommendations that apply to the specification and installation of ducting:

- Run lengths as short as possible – longer duct runs allow more opportunity for heat to escape and are harder for the fans to drive air through.
- Smooth internal surfaces to minimise airflow resistance.
- The minimum number of bends possible. Where bends are unavoidable, they should have as large a radius as possible.
- Hangers holding the ducting should be well fixed to the building structure and spaced to minimise sag in flexible ducting. Ducting may also sit on ceiling joists.

4.5 SOLAR AIR PREHEATING VENTILATION

4.5.1 Solar air preheating systems draw outdoor air through flat panels or tubes to warm it before it is blown into a building. As they use the sun's heat to warm the air, these systems can have relatively low operating costs. Solar panels can be used to power the fans.

4.5.2 Solar preheating systems only operate efficiently when the sun is shining so they are not well suited for housing, particularly on long winter evenings. (School hours of around 9am to 3pm align much better with the hours of solar radiation. A study of 12 Palmerston North classrooms retrofitted with solar ventilation found that they maintained required thermal comfort with less use of heaters, reducing energy use, and that carbon dioxide levels were reduced.)

5 COMMISSIONING AND MAINTENANCE

5.0.1 The appropriate commissioning and maintenance of mechanical ventilation systems is crucial to their performance. What is required in commissioning should be tailored to the specific system installed but typically involves the following:

- Ensuring that the whole system is installed properly, complying with the plans and specifications and manufacturer's requirements.
- Testing to check the system meets design and performance requirements. Ducting must be properly connected and sealed with no air leakage. With heat recovery systems, air inflow and outflow rates must be checked to see that they are balanced. Specialised equipment and experience are required for measuring airflow – the way testing equipment is placed and used can greatly affect the accuracy of results.
- Adjusting flow rates to the optimal level.

5.0.2 Ideally, commissioning will be conducted by a third party rather than the person who carried out the installation.

5.0.3 Proper operation and maintenance is also crucial. This involves giving homeowners documentation as to what is required and ensuring that they understand the maintenance tasks, which typically include:

- replacing air filters as the manufacturer recommends
- cleaning outside hoods and screens – typically 12 monthly
- where and as required, cleaning condensate drains/pans to remove mould, bacteria and fungi
- checking ducts in the roof space are undamaged – every 2 years.

6 SMART APPLIANCES, SMART HOMES

6.0.1 Ventilation systems can include smart appliances and can be part of a smart home:

- Smart appliances can be interconnected, automated, managed and monitored remotely, typically through a smartphone via WiFi or Bluetooth. They can receive, react and respond to signals so they are operating (and using electricity) at periods of lower demand. This is a different thing to systems that switch on or off depending on readings from temperature or humidity sensors.
- Smart homes link appliances and devices together into a network with the specific goal of achieving greater energy efficiency. This is often done through a home energy management system installed by an electrician.

- Demand control ventilation is a system that automatically adjusts airflow and indoor climate based on the internal air quality and occupancy of the building. For example, the system may reduce ventilation intensity during off-peak hours and increase it when someone takes a shower or cooks dinner. If sensors indicate that carbon dioxide or humidity levels are rising, the system will bring more fresh air into the building. These systems aim to improve indoor air quality and reduce energy use. Domestic versions are available.
- Load shed (sometimes also referred to as demand control in this country), covered by an agreement between householders and an electricity supplier, means that non-essential load such as ventilation is switched off when energy costs are high. EECA talks about smart appliances that have the capacity to communicate with the grid and react to demand and pricing signals, dialling energy use up or down in line with user preferences. This reduces pressure on the grid at peak times and means lower energy bills for consumers.

7 FURTHER INFORMATION

BRANZ

Bulletin 607 *Passive ventilation*

Bulletin 687 *Introduction to smart homes*

Build article *Airtightness and ventilation*

IAQ Research Centre New Zealand (BRANZ and partners)

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