Controlling the interior environment

- **HC1: Winter Comfort**
- **HC2: Summer Comfort**
- **HC3: Ventilation**
- **HC4: Moisture Control**

Controlling the interior environment

New Zealanders spend around 70% of their time indoors, during which time they cook, shower, sing, breathe, and generally live! While they do this they are producing excess moisture and CO_2 and if the levels of either get too high this can cause health issues for people, and issues for the building fabric itself.

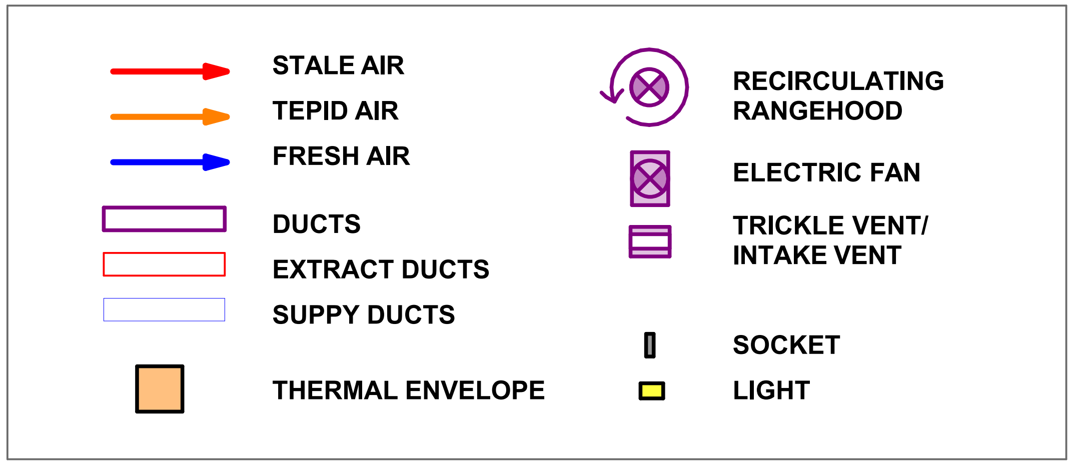
At the same time, many elements within our buildings are 'off gassing' as they age, leading to volatile organic compounds (VOCs) being released into the air - that new sofa smell, or the smell of paint for example. Many of these can become harmful to people if they reach certain levels.

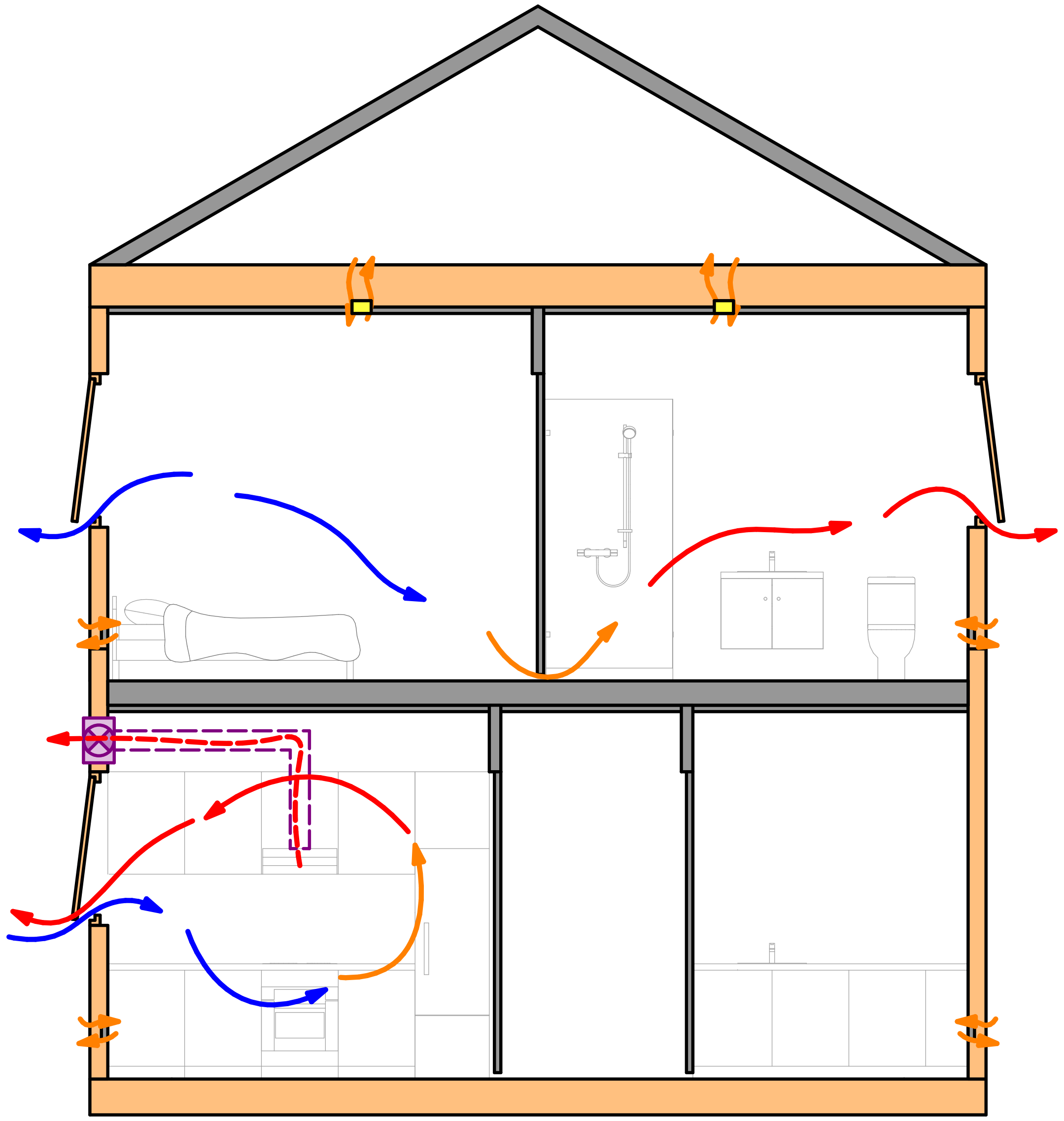
Studies have shown that relying solely on openable windows rarely, if ever, provides adequate ventilation to keep a building and its inhabitants healthy. To this end openable windows should only be utilised for user comfort, with the minimum required levels of ventilation catered for separately.

The best way to do this is to provide continuous mechanical ventilation, where one or more fans create airflow to remove the moisture, CO_2 VOCs and other pollutants in the air. For this reason, continuous mechanical extract ventilation is the minimum requirement for all Homestar levels.

The three main types of mechanical ventilation:

- Positive pressure
- Negative pressure
- Balanced pressure





Natural Ventilation

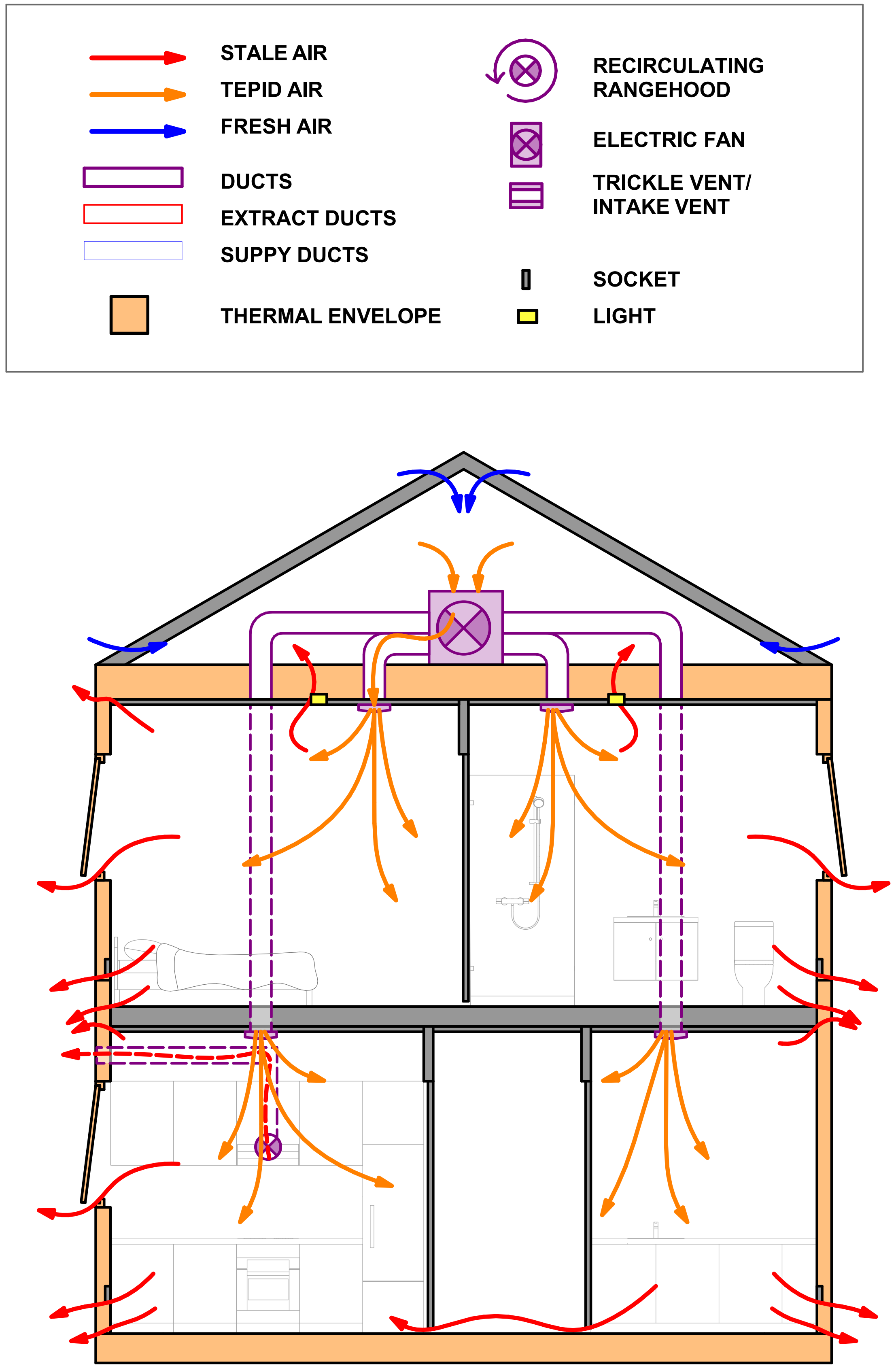
Positive pressure

These systems use fans to push air into the building, pressurising it. The air is then forced out of the building through any gap it can find – potentially an open window, but in an air leaky building this could be plug sockets, light fittings and walls, windows, ceiling and floor junctions. Moisture is forced into the building fabric, creating potential interstitial condensation risks.

While previously accepted in other countries, positive pressure systems are slowly being phased out, with Britain, for instance, no longer accepting them as an acceptable solution.

With many of the systems available in New Zealand, the air is also extracted from the roof space, with no guarantee of air temperature or quality.

Positive pressure systems do not satisfy the ventilation requirements in Homestar and BRANZ recommends air is sourced from the outside for ventilation purposes.



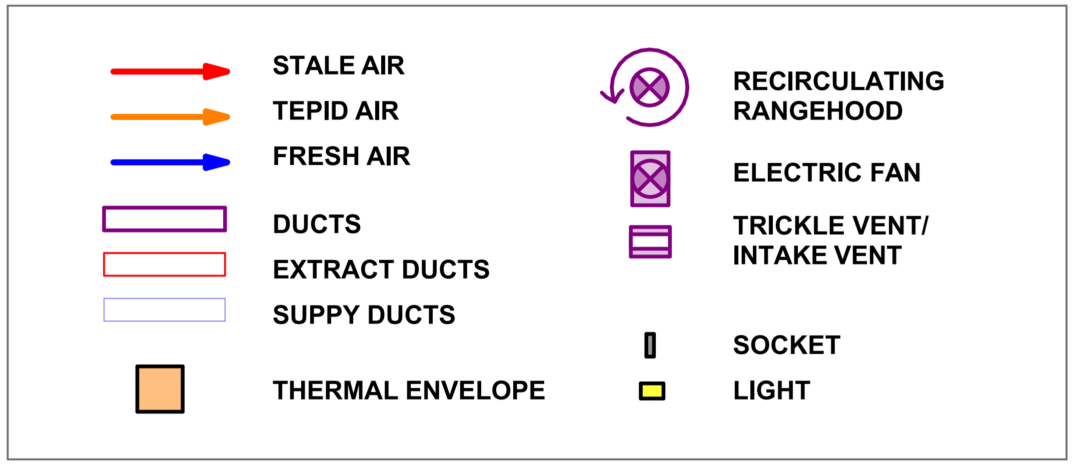
Positive Presssure

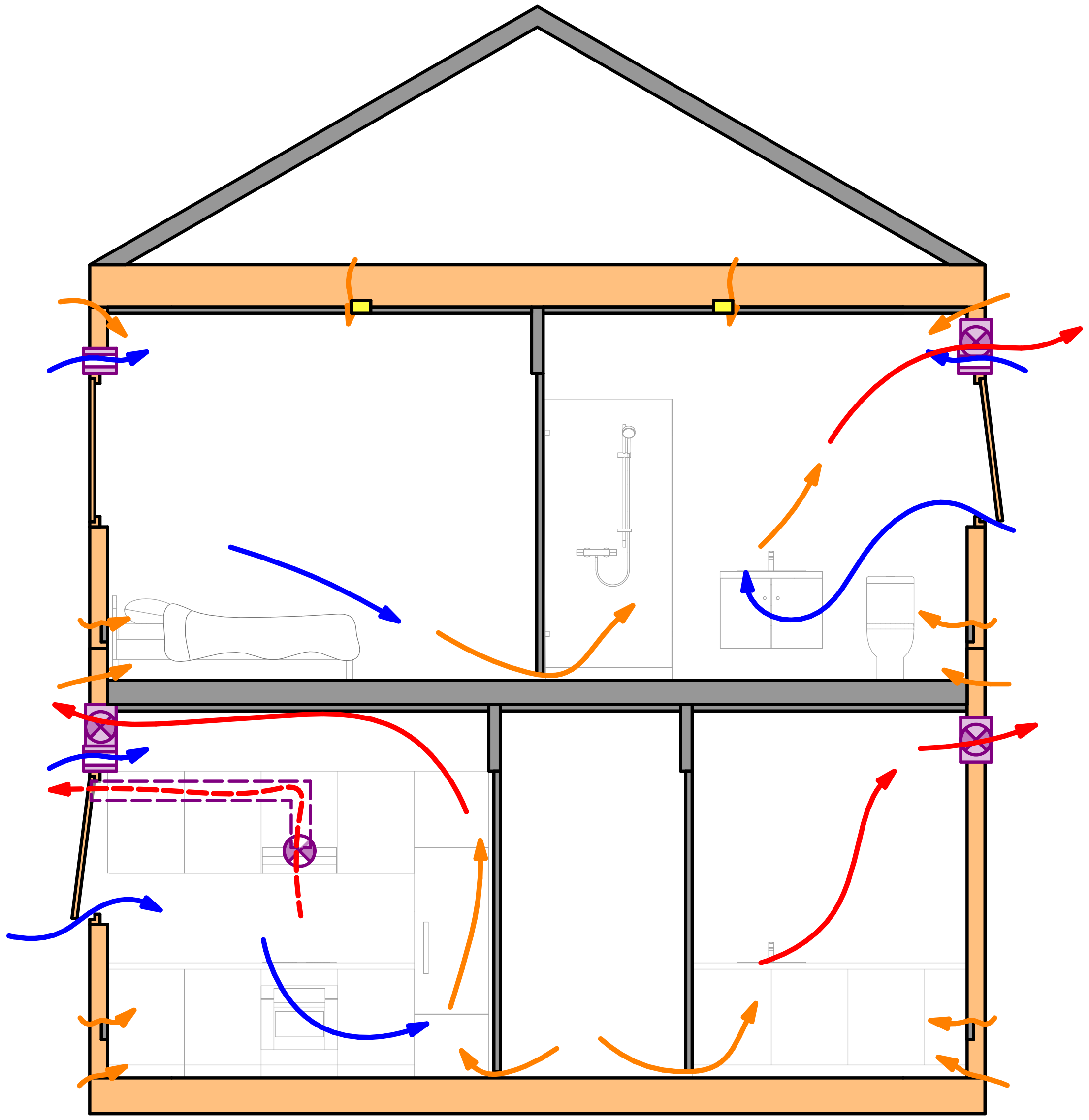
Negative pressure

Negative pressure systems are the opposite, using fans to remove the air within the building and depressurize it, pulling make up air into the building through trickle vents and open windows, but also any gaps in the building fabric if the supply vents aren't suitably sized, or open. Examples are bathroom fans and kitchen extracts ducted to the exterior.

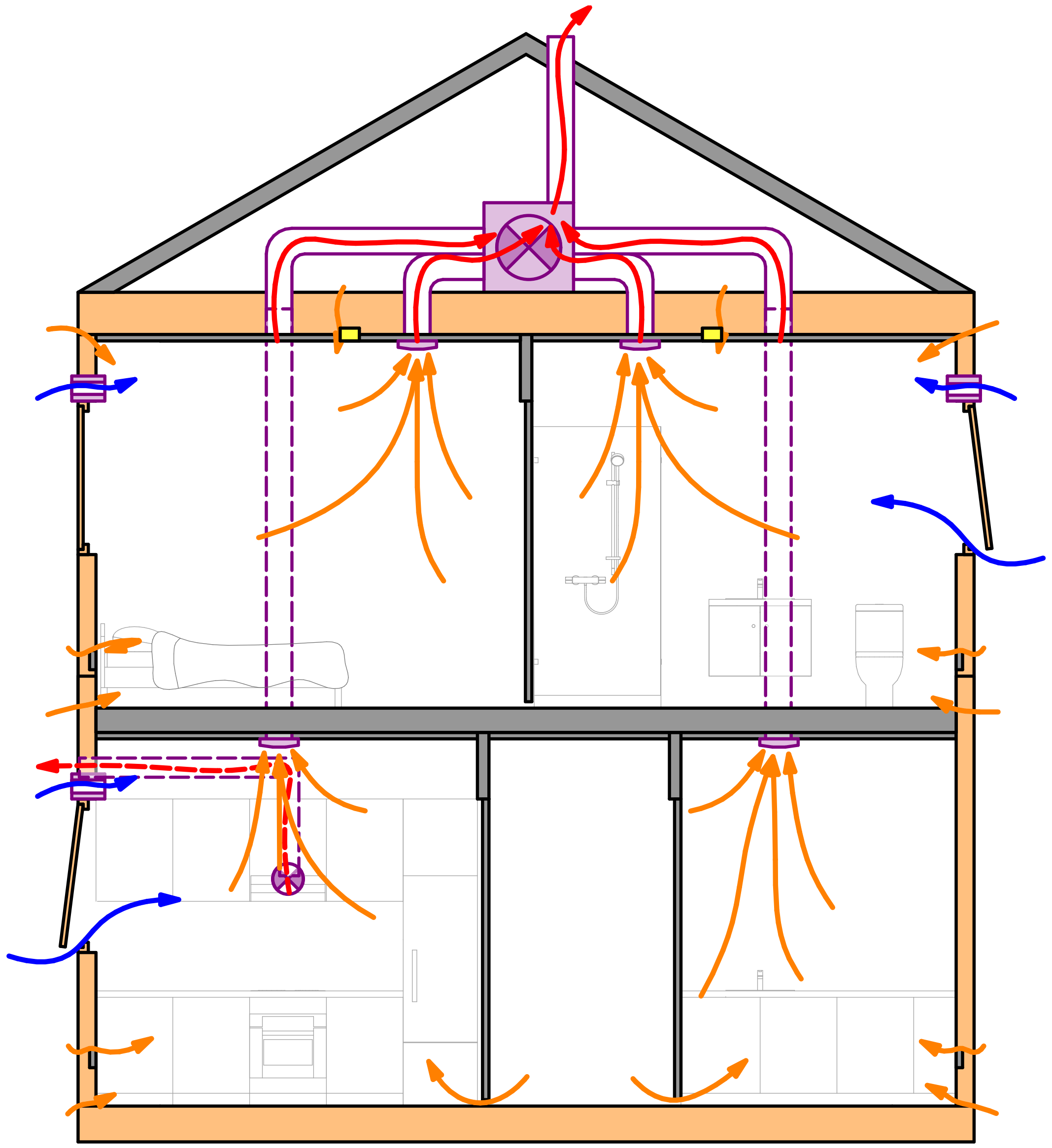
This is less risky than positive pressure systems and it will help to remove moisture and VOCs. But design needs to ensure that all areas of the house benefit with careful positioning of the fans and vents. Include sufficient 'make up' air to replace the air extracted from the building. This should not rely on openable windows, so trickle vents in the joinery, or specific in-wall vents should be included.

Negative pressure systems can be ducted or decentralised. The important point is that the fan needs to be sized to work continuously and at reduced noise levels. Intermittent fans do not meet the Homestar ventilation standard, and can create mould issues from moisture not being extracted sufficiently through ducts to the outside.





Negative Pressure - Decentralised

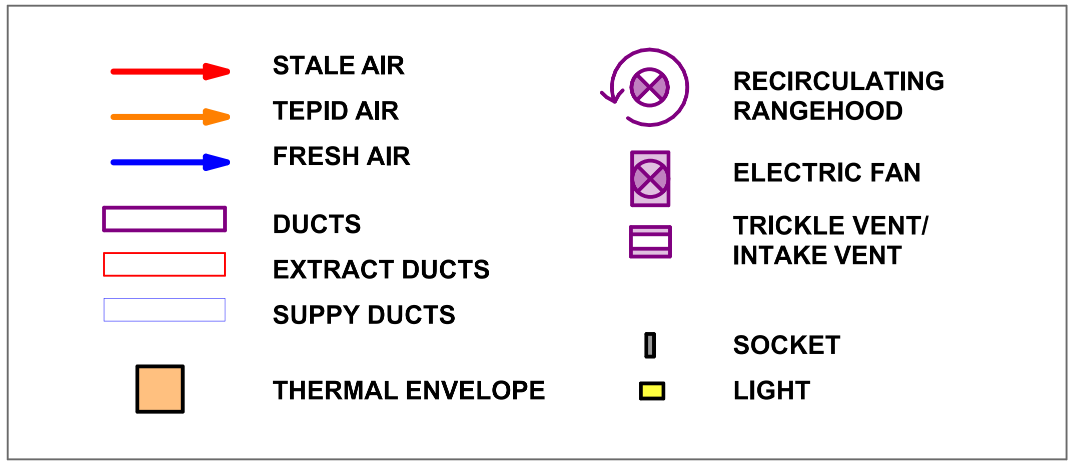


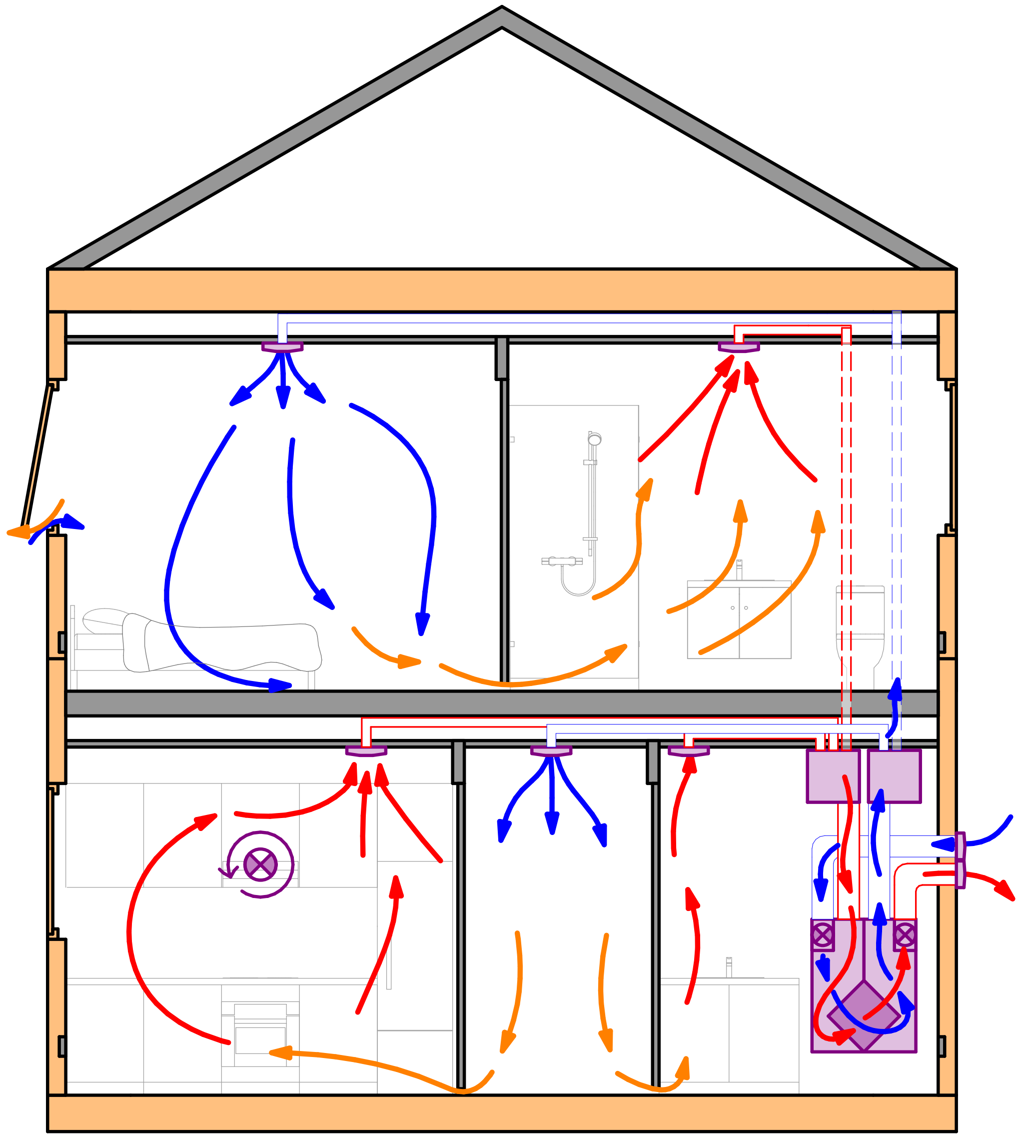
Negative Pressure - Centralised

Balanced pressure

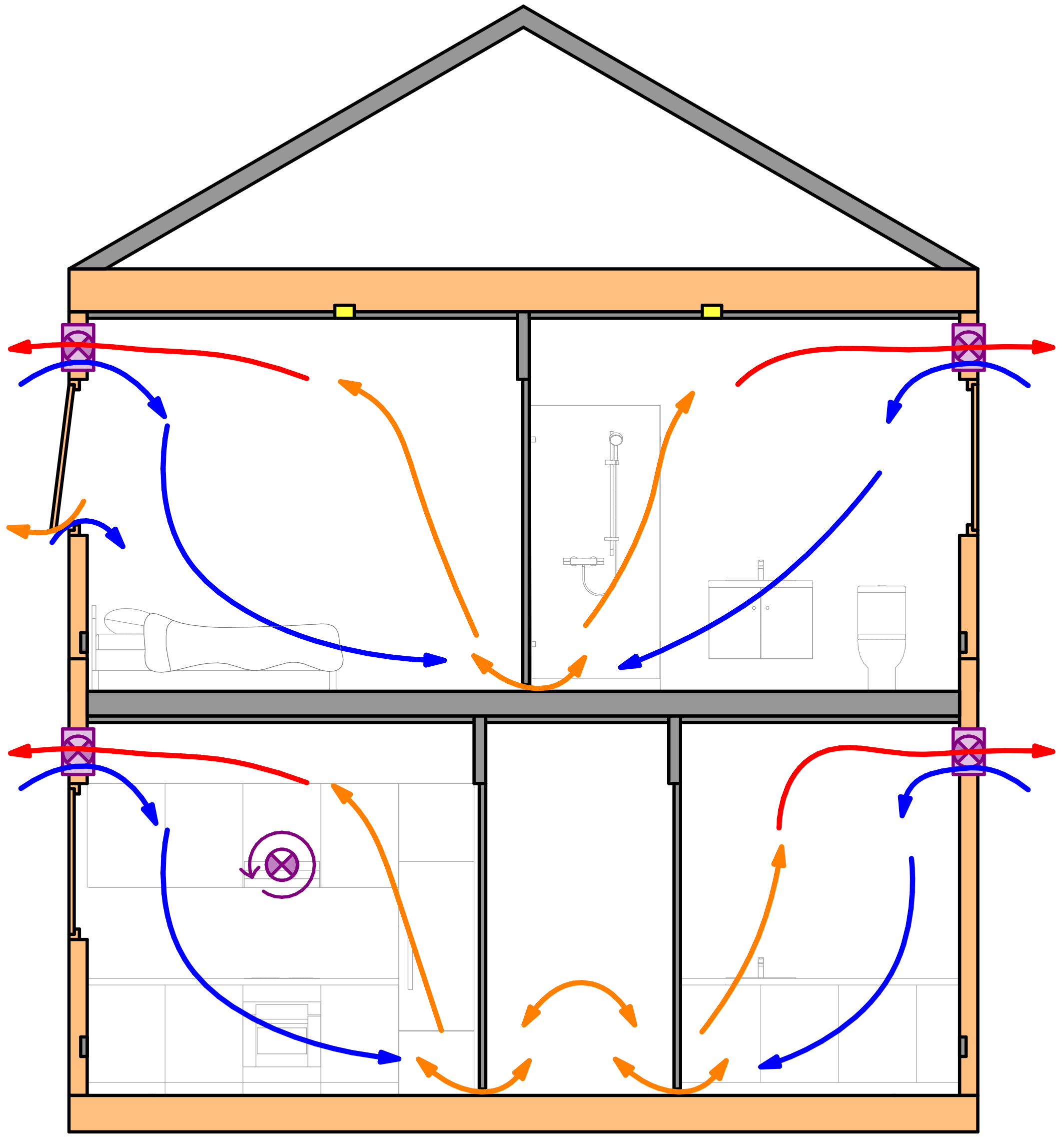
A balanced pressure ventilation system uses two fans to bring in the same amount of air as it removes. This ensures there is no additional pressure on the building envelope. Balaned pressure systems are the recommended solution for new homes. They can come with heat exchangers that recover waste outgoing heat and preheat the incoming fresh air (in winter - and the opposite in summer).

The following recommendations are largely to do with optimising the performance of negative and balanced ventilation systems in order to meet Homestar criteria.





Balanced Pressure + Heat Recovery - Centralised



Balanced Pressure + Heat Recovery - Decentralised

Ventilation system design considerations

Ventilation system design is not as straightforward as adding in a few fans - each system will need its own design considerations. For most,the following advice will apply, but if you're unsure it's recommended to engage an HVAC designer.

Occupancy and flow rates

The number of people in the building dictates the amount of ventilation required, as stated in NZS 4303.1990, which says:

- Either a minimum 0.35 air changes per hour for the whole building
- Or 7.5 litres per second per person
- Whichever is greater.

If the occupancy of a building is likely to be higher, then a higher rate can be used - e.g. 0.8 air changes per hour, however **the higher the flow rate, the higher the rate of heat loss** - a balance must be found.

To comply with the New Zealand Building Code, G4/AS1 1.1.2 states:

> *Ventilation of spaces within buildings must be provided by natural ventilation, mechanical ventilation, or a combination of mechanical and natural ventilation*

Section 1.5 covers the requirements and flow rates of mechanical ventilation, which is the section relevant to the design of ventilation systems required by Homestar, as natural ventilation is not relied on.

Fan size and air flow

Door undercuts, air grilles or acoustic door head details will be required for both systems, to allow air to flow between rooms. These are also a requirement of G4/AS1.

Negative pressure systems

- Are the vents suitably sized to provide sufficient make up air?
- Is the fan sized suitably to provide sufficient extract volume? Advice should be sought from fan suppliers to ensure fan pressures are adequate for the system design.
- Has the flow rate been based on the products, or the system as a whole? Duct lengths and bends can impact the overall performance.
- Consider each room and the airflow pathway - is there a continuous route from a make up air intake vent or trickle vent, to an extract fan through all spaces?
- Will the noise of the fan be mitigated, or will it transfer down ducts?

Balanced pressure systems

- Is the unit sized correctly for the air volume of the house & the occupancy levels?
- Have you included noise attenuators?

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.
Kitchens[b]	100 cfm (50 L/s) intermittent or 25 cfm (12 L/s) continuous or openable windows	Installed mechanical exhaust capacity.[c] Climatic conditions may affect choice of the ventilation system.
Baths, Toilets[b]	50 cfm (25 L/s) intermittent or 20 cfm (10 L/s) continuous or openable windows	Installed mechanical exhaust capacity.[c]
Garages: Separate for each dwelling unit	100 cfm (50 L/s) per car	Normally satisfied by infiltration or natural ventilation
Common for several units	1.5 cfm/ft^2 (7.5 L/s·m^2)	See "Enclosed parking garages," Table 2.1

[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.

Table from NZS 4303.1990

Table 2: Total required equivalent aerodynamic area per space (mm²)
Paragraph 1.3.5

Ventilator locations	Number of occupants 1	2	3	4	5
High and low level	4000	8000	12,000	16,000	20,000
High level only	3000	6000	9000	12,000	15,000

Table from G4/AS1

Location

Negative pressure systems

- Keeping extract fans up high will will remove hot air where it is likely to form
- Keeping trickle vents and passive intake vents up high will reduce the potential for user interference, encourage better mixing and result in less complaints from users about drafts.

Balanced pressure systems

- Keep the intake and extract ducts between the unit and the exterior envelope as short as possible to mitigate heat loss through the duct and reduce potential for condensate to form on the outside of ducting
- Keep the unit as central as possible in the building to enable the ducts to be similar lengths, but also close to an external wall.

Allow space

With decentralised ventilation systems, you only have some extra penetrations in your walls or ceilings. However, with MVHR these fans also contain a heat recovery core which adds width to the unit. For this reason you may need to allow for internal boxing or cabinetry, or an external cowl.

For ducted or centralised ventilation systems there will be potentially a large number of ducts to allow space for. Negative pressure systems potentially have ducts from 150mm to over 200mm which can fit in the roof void. However, risers and bulkheads will be required for multi-storey buildings.

Balanced pressure systems usually have ducts between 75-90mm. These can potentially fit within standard wall framing, but must be inside the thermal envelope, so dropped ceilings and wall services cavities will be required. The number of ducts can build up too, so don't underestimate the amount of space needed!

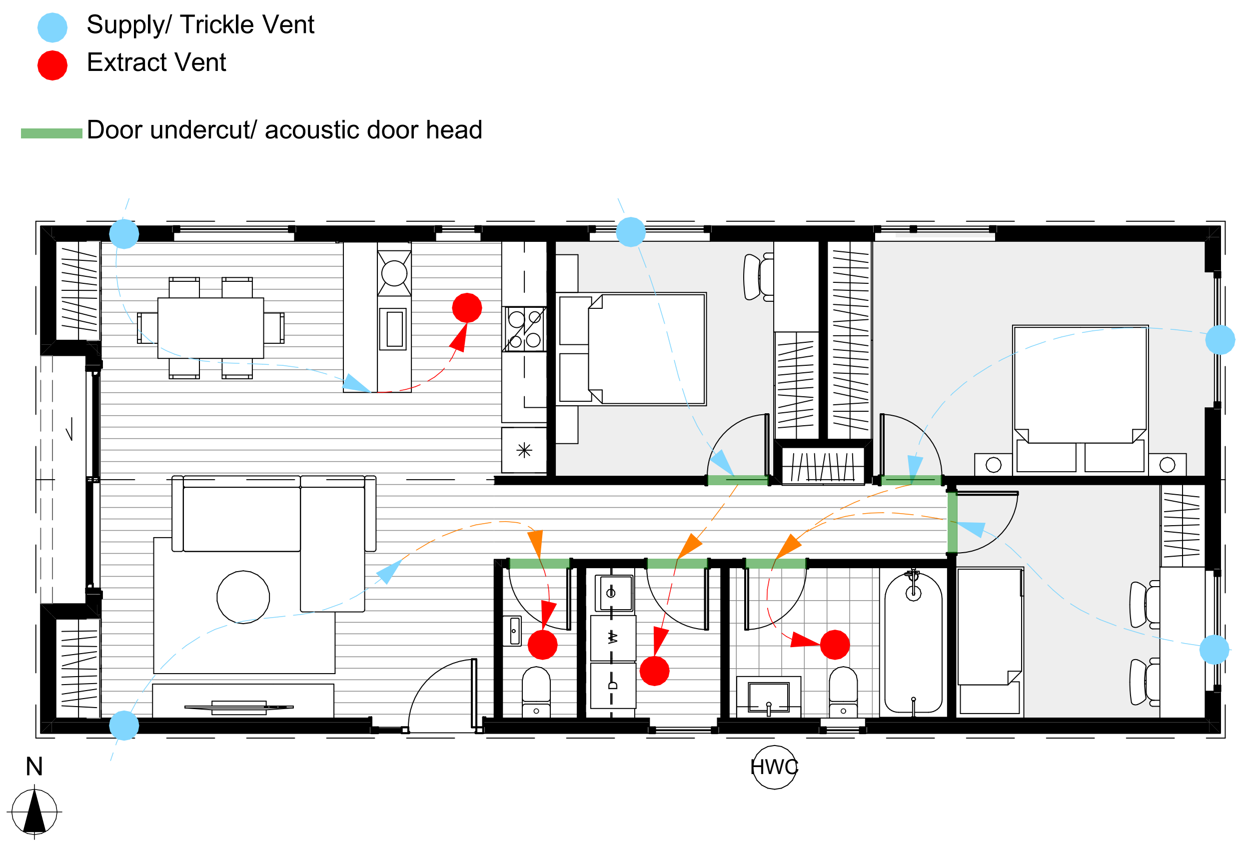
Balanced pressure systems also require noise attenuators, which prevent fan noise from the unit travelling down the ducts, but also reduces 'cross talk' where sound from each room can be transferred to another down the ducts. These usually also form the manifold, where the single large duct from the unit splits into multiple smaller supply ducts, and can be 600x500x150mm, 1200x500x150mm or larger, depending on the system and unit requirements.

Duct runs

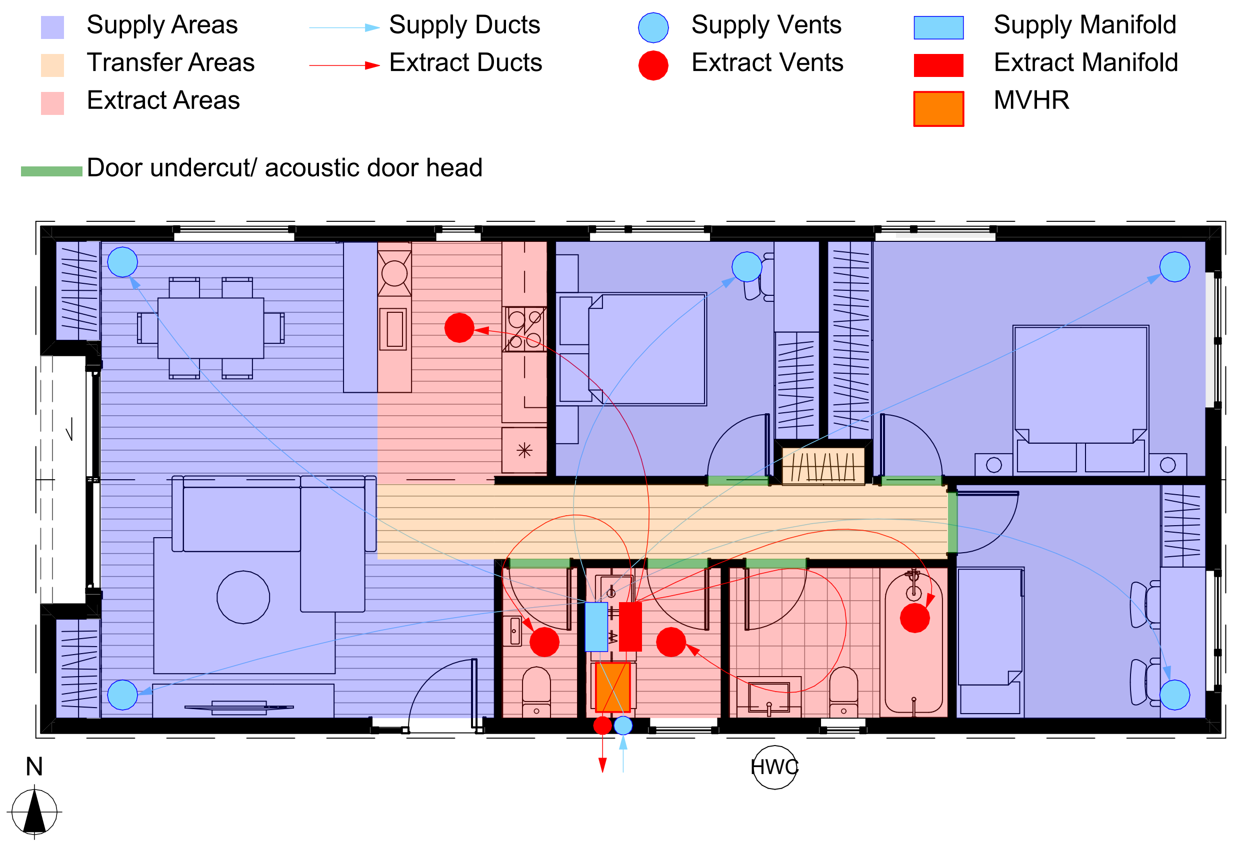
The straighter and shorter the ducts, the less surface resistance there is on the air, and the less the pressure will drop, so you will get higher performance.

- Keep ducts as straight as you can
- Keep any bends as gradual as you can
- Keep ducts as short as you can - but less than 5m may result in additional noise transfer in balanced systems
- A caveat to this is to keep ducts similar lengths - if there is a big difference between the longest and shortest ducts, there may be a big pressure difference.

Example negative pressure and balanced pressure system layouts for Case Study 1 and 2



Negative Pressure Ventilation Plan



Balanced Pressure Ventilation Plan

Commissioning

A system is only as good as its installation quality, and you can only assess this by commissioning the system.

This involves measuring the flow rates of the supply and extract air at the vents to ensure they meet the required volumes. Air flow monitors are placed over the various intake and extract vents and their flow rate measured, and any required tweaks undertaken.

Maintenance

All ventilation systems will require maintenance - checking ducts, cleaning, replacing filters, etc. So care must always be taken to ensure all elements of the system are readily accessible.

Product and system availability

There are a range of products and suppliers for both negative pressure and balanced pressure systems in New Zealand. Ask the following questions when specifying them.

- Is the efficiency quoted for the components on their own, or in a system as installed?
- Will the fan speeds be sufficient in the installed system?

An example of a passive intake vent with a replaceable filter, for use with a negative pressure ventilation system instead of, or as well as, trickle vents.

Kitchen extract hood

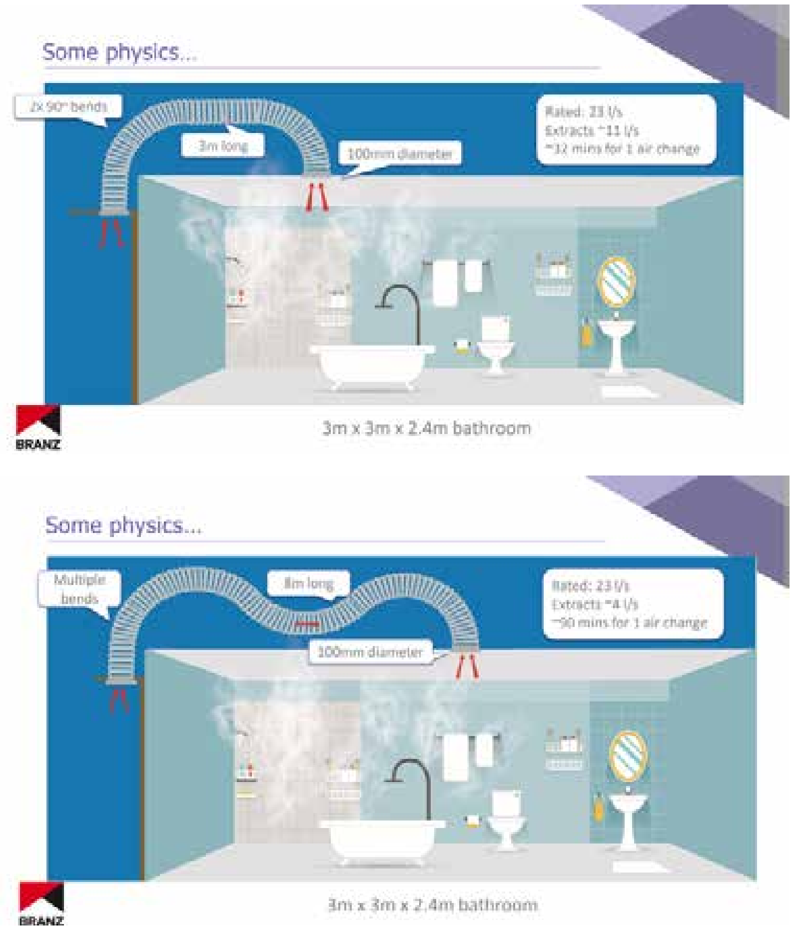
This is a separate entity to whole house ventilation. This is due to the hood operating at much higher flow rates than required for ventilation, as it needs to remove moisture, smells and cooking oils as soon as it can. This can be dealt with in two ways:

An extract hood ducted to the exterior

- This is fine in negative pressure systems, as make up air can be drawn in through the trickle vents and passive intake vents.
- In balanced pressure systems, make up air must be provided either by opening a window every time you turn the hood on, or by including an additional intake vent to provide make up air, with airtight dampeners.

A recirculating extract hood

- This removes the oils and smells (but not moisture) at source and recirculates the air back into the building. This is an easier approach for balanced ventilation systems as you do not need to provide make up air. However, as with all rangehoods, filters need to be cleaned regularly. Moisture from cooking, washing up and kettles still needs to be dealt with effectively, which will influence the design of the system and in particular location of extracts in the kitchen.



The importance of straight duct runs!

70mm flexible ducts for a balanced mechanical ventilation system - mid-install

A worked ventilation example

In this example we will use case study 01 and design a ventilation system for it.

What system?

We are aiming for 7 Homestar so can utilise a continuous negative pressure system. To minimise the amount of penetrations in the envelope, and the amount of fans required, we will use a centralised system with a single fan, ducts to the wet extract areas, and passive intake vents for the make up air.

Where?

As it's a negative pressure system, the ducts and the fan unit can be outside the thermal envelope, perhaps in the loft space. It will need to be accessible for maintenance and inspection so a full sized, insulated and airtight loft access hatch should be included in the project. The ducts will be around 150mm in diameter.

The passive intake vents will go in the bedrooms and living spaces, positioned furthest away from the interior doors to minimise any dead spots where the fresh air won't get to. If they're higher up on the wall, it's less likely the users will experience draughts.

Work out the extract flow rates

We need to work out the interior air volume of the building. This can be done by multiplying the floor area by the stud height, or can be worked out in 3D BIM for more complex buildings. The air volume for this building is 252.28m^3, so to achieve 0.35 air changes per hour the flow rate needs to be at least 88.3m^3/hour, which is 24.5l/second.

We also need to assess how many people will be using the building. As this is a 3 bedroom home, we will assume four people will be living there. According to the NZS 4303.1990 the supply rates need to be:

- 7.5l/second per person is required from living spaces, so 30l/second for four people

The minimum continuous extract demand is:

- 12l/second for the kitchen plus 10l/second each for the bathroom, laundry and WC.

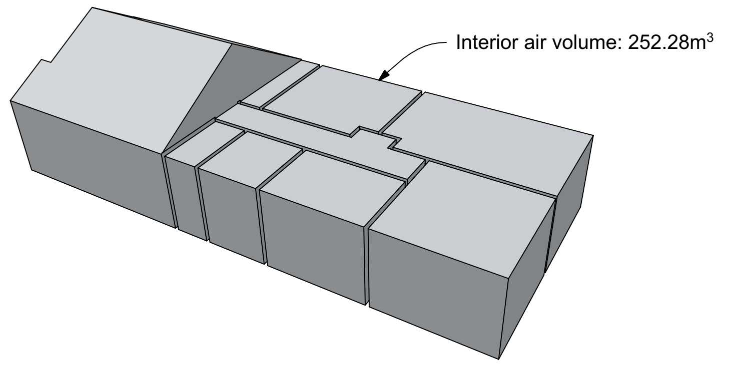
This totals 42l/second extract rate, which is 151.2m^3/hour. As this is greater than the 0.35ach and 30l/second rates, this is the flow rate we must design for, and the minimum flow rate the selected extract fan must achieve.

Work out the supply volume

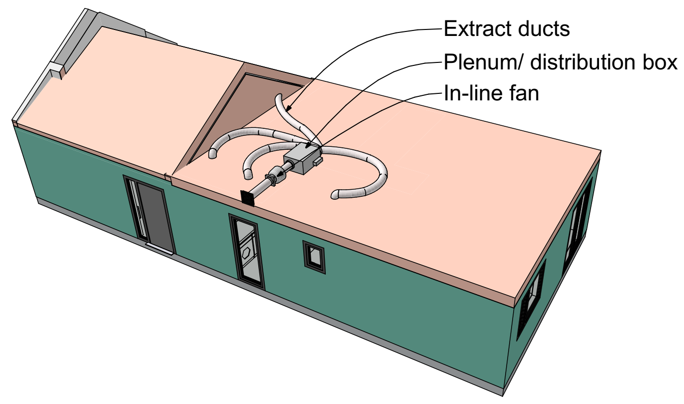
Now we know the extract volume and rates, we need to ensure there is sufficient provision for make up air, to ensure there is no pressure on the building envelope.

G4/AS1 paragraph 1.3.5 and table 2 state the minimum supply area size for supply vents based on occupancy. For 4 occupants and high level vents, 12,000mm² (0.012m²) must be provided:

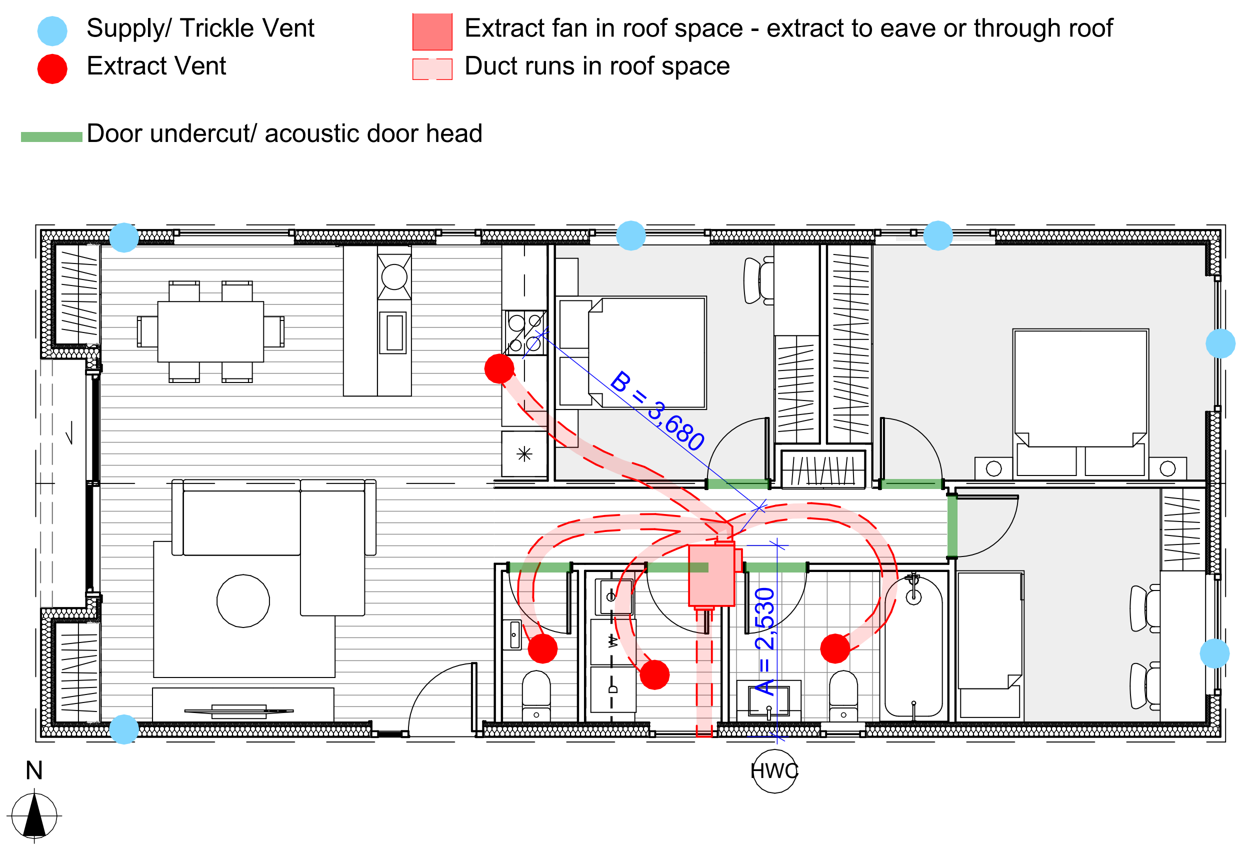
- A typical passive vent available in NZ provides 3,000mm² equivalent aerodynamic area, so four would suffice.



Interior air volume



Ventilation system



Worked ventilation plan

- G4/AS1 requires trickle vents to have a minimum of 2,000mm² equivalent aerodynamic area, and a 10x300mm trickle vent would provide 3,000mm².

    4 x trickle vents = 12,000mm² (10mm x 300mm each)
    9 x trickle vents = 27,000mm² (10mm x 300mm each)

- A combination of in-wall passive vents and trickle vents could be specified.

A minimum of 10mm door undercuts, acoustic door heads or vent grills between all rooms must also be included.

Duct runs and pressure drop

As the air flows through the ducts, the friction causes the pressure to drop. To ensure the fan extract rate is achieved, the ducts will need to be as straight as possible, and around equal lengths to prevent too much pressure drop. For this case study, this is quite easy to achieve as we have a roof void to run the ducts in. Hwever, we still need to account for the pressure drop to size the fan.

,
To calculate the pressure drop:

01 Work out the length of the duct from the exterior grill to the plenum box (A) and the length of the longest duct (B) and add them together

02 Use a duct pressure drop calculator (available online) and input the air volume, duct diameter, duct length (A+B) duct type, and any grilles or bends to calculate the pressure drop

03 Plot the calculated pressure drop against the fan performance curve sourced from the supplier, to show you what volume flow the fan will need to provide.

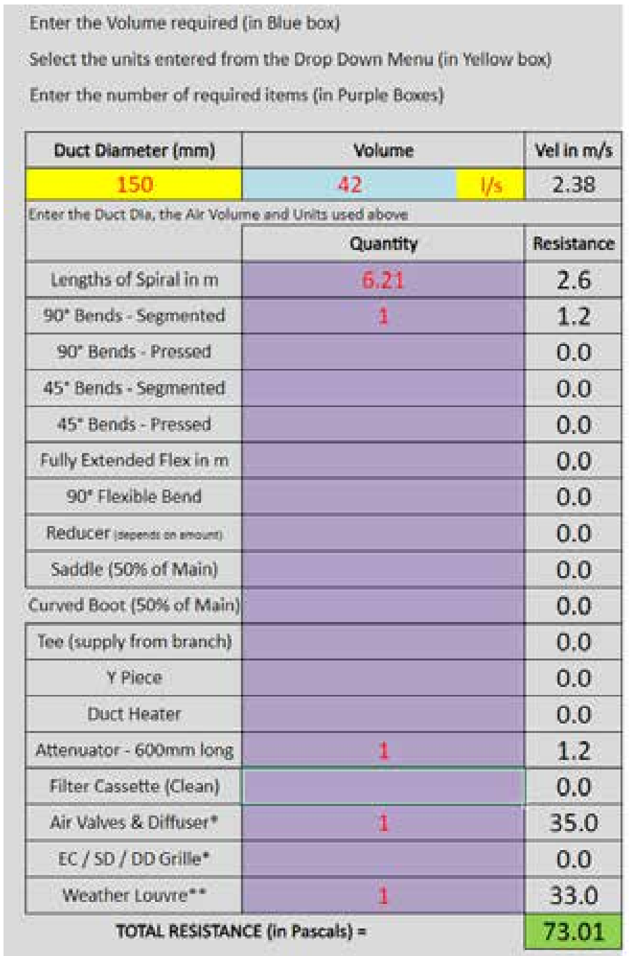
04 Select a fan that is speed controllable to enable the correct speed to be selected, to provide the required flow rate..

Some suppliers have fan selectors on their websites to help.

As built performance

A final step would be to commission the system. While this isn't yet a requirement for 7 Homestar projects it is strongly recommended, to assess whether the system is performing as designed.

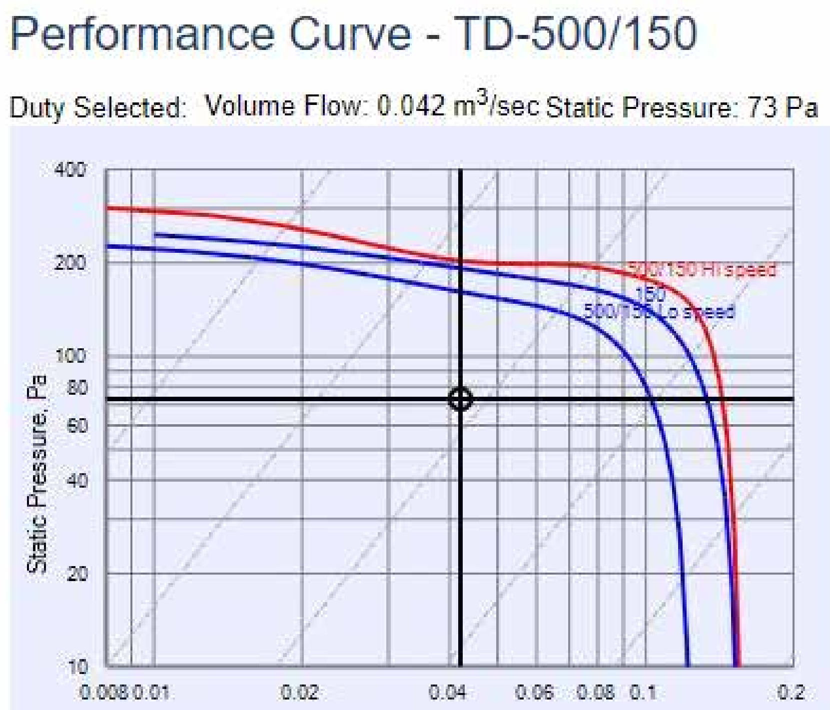
These principles should provide a starting point, to enable designers to specify simple systems, and incorporate best practice design elements when specifying residential ventilation systems. For more complex systems it is recommended to engage a ventilation supplier or mechanical engineer, at an early stage in the design process.



Enter the Volume required (in Blue box)
Select the units entered from the Drop Down Menu (in Yellow box)
Enter the number of required items (in Purple Boxes)

Duct Diameter (mm)	Volume		Vel in m/s
150	42	l/s	2.38
Enter the Duct Dia, the Air Volume and Units used above			
	Quantity		Resistance
Lengths of Spiral in m	6.21		2.6
90° Bends - Segmented	1		1.2
90° Bends - Pressed			0.0
45° Bends - Segmented			0.0
45° Bends - Pressed			0.0
Fully Extended Flex in m			0.0
90° Flexible Bend			0.0
Reducer (depends on amount)			0.0
Saddle (50% of Main)			0.0
Curved Boot (50% of Main)			0.0
Tee (supply from branch)			0.0
Y Piece			0.0
Duct Heater			0.0
Attenuator - 600mm long	1		1.2
Filter Cassette (Clean)			0.0
Air Valves & Diffuser*	1		35.0
EC / SD / DD Grille*			0.0
Weather Louvre**	1		33.0
TOTAL RESISTANCE (in Pascals) =			73.01

An example system pressure drop calculator



A fan performance curve - plot the calculated pressure drop against the volume flow rate to allow you to select a suitable fan.

Glossary

Air and vapour control layer (AVCL)	This is a layer designed to control the air and vapour flow through a building assembly. Examples include specialist membranes and taped plywood or oriented strand board (OSB).
Air changes	The number of times that the total air volume in a home is completely removed and replaced with outdoor air, usually expressed per hour.
Airtightness	An assessment of the amount of unintended air leaks in the building envelope. Homestar uses the envelope area (Air permeability qE50 from ISO9972) as a reference for airtightness: m3 of air loss per m2 of envelope per hour @ 50pa pressure.
Annual electricity demand	'Delivered' energy includes everything associated with operational energy - excludes plug loads/appliances. It takes into account efficiency of any systems (e.g. demand might be 30 kWh/m²/yr, but using a heat pump with COP=3 means delivered energy is only 10 kWh/m²/yr).
Annual space heating demand/ heat demand	The amount of energy required to keep the building interior at a specified temperature.
Balanced ventilation	A balanced pressure ventilation system uses two fans to bring in the same amount of air as it removes. This ensures there is no pressure on the building envelope so no air is pushed or pulled through the building fabric.
Building performance	In the context of this guide this refers to the overall energy efficiency, user comfort and long-term durability of a building.
Climate zone	Designation of areas within New Zealand that share similar climatic characteristics.
CLT	Cross laminated timber - a form of mass timber construction.
Cold roof	Conventional New Zealand roof build-up where the structure of the roof (e.g. the rafters) is outside the thermal envelope.
Conditioned floor area (CFA)	Space within the thermal envelope of the dwelling that could maintain a temperature band of between 20-25°C for 365 days of the year. Refer to the Homestar Technical Manual for more details.
Continuous extract ventilation	Whole-dwelling ventilation system that extracts air continuously at a low rate.
Decentralised ventilation	A ventilation system that uses several fans in different locations to deliver and remove air in a building.
Ducted ventilation	A ventilation system that uses ducts to deliver and remove air in a building, with a single central fan unit.
ECCHO	The Homestar® energy analysis tool, ECCHO (Energy and Carbon Calculator for Homes), is a web app that allows users to calculate the heating and cooling demand, energy consumption, overheating risk, and carbon emissions of a home.
Embodied carbon	Embodied carbon is the carbon dioxide (CO_2) emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure.
Energy balance	The assessment of the amount of energy lost through the thermal envelope vs the amount of energy gained, with the difference made up by heating or cooling to maintain a balance.
Energy/ thermal modelling	Energy modelling of buildings is a process that uses computer software to simulate how a building will consume energy based on its design, materials, and systems.
EPD	Environmental Product Declaration, used to determine the environmental footprint of a product following life cycle assessment, verified independently.
Form factor	The ratio of total external surface area of the thermal envelope (including the floor slab area) to the conditioned floor area. Typically, a large building will have a lower form factor than a smaller one. A simpler shape will also have a lower form factor than a more complex shape. The lower the number, the less insulation needed in the same climate (everything else being equal).
Frequency of overheating	The amount of time in a year the interior spends at 25ºC or above. Note this can assume night and window ventilation, so if the building is modelled with more ventilation than used in practice it may overheat more than predicted.
fRsi	Temperature factor. Value between 0 and 1 that expresses how cold the inside surface of a junction is likely to get. The lower the number the higher the risk of mould. Numerically this is the difference between the interior surface temperature and the exterior air temperature, divided by the average temperature difference between interior and exterior.
g-value	Fraction of solar heat energy that enters a building compared to that which hits the outside of the glazing unit. Roughly equivalent to Solar Heat Gain Coefficient (SHGC) which is sometimes published instead for glazing units.
Heat loss area	The exterior area of the building that is between interior heated space and the exterior air, through which heat is lost - generally the walls, floor, roof and windows of a building. If a building is joined to another building, the adjoining area is not a heat loss area as it is attached to another heated space.
HECC	The Homestar Embodied Carbon Calculator developed by BRANZ for NZGBC, an easy to use tool for estimating the embodied carbon content of a typical home.
HPCDH	The High Performance Construction Details Handbook, a document that covers a wide range of typical thermal bridges, assemblies and build-ups used in New Zealand, produced by Passive House Institute New Zealand, BRANZ and Jason Quinn.
HVAC	Heating, ventilation, and air conditioning systems.
Hygrothermal modelling	Hygrothermal modelling uses a computer program to model the long-term effects of heat and moisture within and through parts of a building and assesses interstitial condensation risks.
Internal heat gain	The heating in a building from its occupants and the use of appliances within the thermal envelope.
kgCO²-e/m²	Kilgograms of carbon dioxide equivalent per square metre (of the home). A measurement of embodied carbon.
kWh	Kilowatt hour, a unit of energy. A 2kW portable heater on for one hour would use 2kWh (2000Wh) of energy. 1kWh = 3.6MJ (megajoules). A 1m² window in direct sunlight allows approximately 1kW of energy into the home.
kWh/m²/year (sometimes abbreviated to kWh/m²)	Kilowatt hours per m² per year. Measures the space heating demand compared with the usable or conditioned floor area (CFA in Homestar® v5, measured externally of the insulation; ICA or internal conditioned area in v4.1, measured internally of the insulation).

Life cycle assessment	Life cycle assessment (LCA) calculates the environmental footprint of a product or service over its lifecycle. LCA tools include HECC (for embodied energy only - see above), the BRANZ LCAquick tool and ETOOL LCD.
Low-e coatings	Low emissivity coating, most commonly on glass surfaces between double or triple pane windows. Low emissivity coatings reduce heat transfer by lowering the level of infrared radiation transmission. They achieve this by reflecting IR radiation and work best if there is both a physical gap and the coating is not covered with dirt or condensation (which is why they are commonly used in the sealed environment between glass panes). There are many types of low-e coatings and the thermal performance can vary significantly between them.
Mandatory minimum	Each Homestar® star band has a set of mandatory minimums that must be met. These dictate the performance levels we are aiming to achieve in each climate zone with each typology.
Mechanical ventilation with heat recovery (MVHR)	Also known as heat (or in some applications, energy) recovery ventilation or comfort ventilation. A whole-house ventilation system that exchanges heat between the exhaust air and the supply air. Fresh air is typically delivered to living areas (e.g. living room and bedrooms) and extracted from kitchens and bathrooms. MVHR units do not necessarily supply additional heat into the supplied air. However, a supply duct radiator, heat pump or electric coil can be used to add heat or coolth to the new air before or after it leaves the MVHR unit.
Negative pressure ventilation	A mechanical ventilation system that uses fans to remove the air within the building and de-pressurize it, pulling make up air into the building through trickle vents and open windows.
Positive pressure ventilation	A mechanical ventilation system that uses fans to push air into the building, pressurizing it. The air is then forced out of the building through any gap it can find. Positive pressure systems are not acceptable at any Homestar level.
psi value	Measure of heat loss ('thermal bridging') within a junction of two thermal elements, measured in W/mK. Represents the rate at which heat passes through a junction per metre per Kelvin temperature difference [W/m/K]: for example, the junction between two walls forming an external corner. The length of the junction (ie height of the corner) is multiplied by the psi value to calculate the heat loss coefficient for that corner.
R-value (m2K/W)	Thermal resistance rating used to determine a material or assembly's ability to resist heat flow.
S/V	Surface to volume ratio - an assessment of the compactness of the building form.
Service cavity	A service cavity is a secondary cavity (that may or may not be insulated) usually to the inside of the structural elements and the AVCL (air and vapour control layer). It contains the wiring, plumbing etc to keep penetrations of the AVCL to a minimum. The service cavity is usually but not necessarily insulated. Commonly, the AVCL is tested for air leakage before insulating the service cavity or installing the interior finish.
Shading factor	A measure of how much solar heat gain enters through a window compared to an unshaded window.
Structural Insulated Panel (SIP)	A panellised off-site construction building system. The panels consist of an insulating foam core sandwiched between two structural facings, typically oriented strand board (OSB). The panels are cut to size in the factory and are delivered to site.
Thermal bridge	A location in the thermal envelope where the uniform thermal resistance is changed by higher conductivity materials or geometry change.
Thermal conductivity	A material's ability to transmit heat is measured by the thermal conductivity (or lambda value). Unlike R-value, the thermal conductivity of a material remains the same irrespective of the thickness of the material.
Thermal envelope	The surfaces that enclose the building's conditioned spaces, which may or may not include garages. This includes the floor area to the exterior. For tools such as ECCHO and PHPP, external dimensions are used. This means from the bottom of the insulation below the concrete slab to the top of the insulation in the ceiling.
Thermal mass	The ability of a body of material to absorb, store and subsequently release heat (due to its specific heat capacity and its mass).
Transmission heat loss	The loss of heat energy via the building components of the house.
Upfront carbon	The carbon emitted in the production phase of products and materials, from mining and processing of natural resources, transport to processing sites, and the manufacturing phases, before any construction begins.
U-value (W/m^2K)	Thermal conductance, the inverse of thermal resistance (R-value). Describes the heat flow per m^2 of an assembly per degree Kelvin.
Ug-value	U-value at the centre of a pane of glass. Note that this is not the U-value of an entire window (Uw) which must be calculated to include the balances of losses through the glass and frame.
VLT	Visible light transmission. VLT is expressed as the percentage of light allowed through the glass.
Waffle pod	A structural slab system that is made up of concrete ribs with plastic or polystyrene pods between, and a concrete slab on top.
Warm roof	A roof build up where the insulation is on the exterior of the structure.
WRB	Water resistive barrier. This is typically the flexible wall underlay but this can be the top layer of a rigid air barrier product used under the ventilated rain-screen cladding. Used to designate the control layer in the building assembly that is intended to stop rainwater entry.