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Building Science + Bullsh*t Seminar

Part six: Heating & Ventilation

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with Denise Martin & Peter Raimondo

Definition of terms – Recap

Ventilation	A system or means of providing fresh air
Ventilation ACH	Air exchange in reference to the ventilation volume of the occupied space, usually measured in m^3(fresh air) per hour per m^3 (total volume of occupied/ventilated space)
Infiltration	Unintentional or accidental introduction of outside air into a building, typically through cracks in the building envelope
Natural Infiltration ACH	Infiltration at natural pressure difference, a factor of building wind exposure, building air permeability @50Pa (Blowerdoor test) and small ventilation inefficiencies
Infiltration ACH (n50)	Result of a blower door test, Infiltration at artificial (reference) pressure difference of 50Pascals

Comfort & Health - IAQ

Individual perception of comfort is subjective and can't be uniformly applied, but it can be put into a range:

Room air temperature	Winter 20-23ºC, Summer up to 26ºC
Surface temperatures	18-19ºC, otherwise draft effects are perceived as uncomfortable
Relative humidity	40%-60%, ideal around 55%
Air velocity	0.12m/s winter, 0.19m/s summer, permanent air velocity over 0.2m/s is perceived as uncomfortable
Air quality (CO_2 levels, VOC's etc.)	NZS303, Table C1 (1990 may be a bit dated…)
Odours	Although not usually quantified, its being considered in Ventilation design (Unit measured in Dezipol [pollution])
Noise	35dB(A) (PassiveHouse) inside room noise for ventilation supply criteria, CIBSE guide A 30-36 dB(A) for background noise

Why Ventilate?
1. Humidity Control (breathing houses)

Base Ventilation to manage moisture generation within the building

	Ventilation ACH min
G4 (AS1)	0.35 (of the total ventilated area) for residential, no minimum in commercial required and not clear on whether it's moisture control specific
G4 (VM1)	0.4 (for bed and living) to control moisture, toilets >5 (!?!)
Passive House/PHPP (also used in H1 and Homestar) based on DIN 1946	0.3 specific minimum for moisture control

Why Ventilate?
2. Indoor Air Quality for occupants

Base ventilation to provide sufficient fresh air

	Supply air minimums for occupants
G4 (AS1)	7.5l/s (27m^3/h) per person (in residential), 8-18l/s (28.8m^3/h-64.8m^3/h) for commercial
G4 (VM1)	Room specific air supply per person, eg. 15l/s (54m^3/h) for bathroom and 60l/s (216m^3/h) for kitchen
Passive House, PHPP (also used in H1 and Homestar) based on DIN 1946	30 m^3/h for dwellings, 15-20m^3/h for schools, up to 60 m^3/h for sports halls

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Current Australian Guidelines				European Guidelines		NZS4303 (referenced in G4, AS1)	
Pollutant	Averaging time	Maximum air quality Value		www.umweltnet.at www.umweltbundesamt.de		Averaging Time Long term (short term)	Concentration ppm Long term (short term)
CO_2	8 hours	850 ppm		8 hrs	850ppm	continuous	1.8g/m3, 1000ppm (comfort levels) <3,500 acceptable exposure range....)
				Target < 1000ppm	Target < 800ppm		
				Target average p/1h < 1400	Target average p/h < 1000		
				Target average p/xh < 1900	Target average p/x*h < 1400		
CO	15 min	90 ppm (mg/m³)		15 min	100 mg/m³		
CO	1 hour	50 ppm (mg/m³)		1 hour	35 mg/m³	1 h (external reference)	(40,000 mg/m³ (35ppm))
CO	8 hours	25 ppm (mg/m³)		8 hours	10 mg/m³	8h (external reference)	(10,000 mg/m³ (9ppm))
CO	24 hours	10 ppm (mg/m³)		24 hours	7 mg/m³	1 h (external reference)	(40,000 mg/m³ (35ppm))
Formaldehyde CH_2O	30mins	0.1 mg/m³		30mins	0.1 mg/m³		0.4ppm
NO_2	1year	40 mg/m³	0.0197ppm	24 hour	250 mg/m³	1 year	100 mg/m³ (0.055ppm))
NO_2	1 hour	200 mg/m³	0.0987	1 hour	85 mg/m³		
O3	8 hour	100 mg/m³	0.0437ppm			1h (external reference)	(100 mg/m³ (0.05ppm))
PM2.5	1 year	10 mg/m³					
PM2.5	24 hour	25 mg/m³		24 hour	25 mg/m³		
PM10	1 year	20 mg/m³					
PM10	24 hour	50 mg/m³					
Total VOC	1 hour	500 mg/m³		Recommended guidelines VOC's			
				low	< 250 mg/m³		
				average	250 - 500 mg/m³		
				slightly elevated	500 – 1,000 mg/m³		
				elevated	1,000 – 3,000 mg/m³		
				Very elevated	> 3,000 mg/m³		
SO2						24 hours (external reference)	0.03 (0.14)ppm
$C_{10}H_6Cl_8$ Banned in the US in 1988...)							5 mg/m³, 0.0003ppm
Radon							100Bq/m

G4/VM1 – CIBSE Guide A (that's more like it)

Table 4.2 Approximate maximum sedentary CO_2 concentrations associated with CEN indoor air quality standards (BS EN 13779)[19]

Classification	Rise in indoor CO_2 concentration / ppm	Default value / ppm	Range in outdoor concentration / ppm	Total indoor value* / ppm
IDA1	<400	350	350–400	700–750
IDA2	400–600	500	350–400	850–900
IDA3	600–1000	800	350–400	1150–1200
IDA4	>1000	1200	350–400	1550–1600

* i.e. concentration rise plus outdoor value

Indoor Air Quality for occupants – compared metrics

Rotorua special mention hehe...

Ventilation Strategies

Natural ventilation
- Crack ventilation (infiltration)
- Window Ventilation
- Shaft ventilation

Mechanical ventilation
- Extract ventilation (extract is mechanical, supply is mix of infiltration, window ventilation)
- Supply Ventilation (supply is mechanical, extract is mix of infiltration, window ventilation)
- Balanced ventilation (both supply and extract is through ventilation ducts) with and without heat recovery

- Paired with the correct building permeability...

Table 1 – Best Practice Air Permeability Against Ventilation Strategy

Ventilation Strategy	Best Practice Air Permeability *(AP_{50})*
Background ventilation and/or intermittent extractors	3.0 – 5.0
Passive Stack	3.0 – 5.0
Continuous Mechanical Ventilation	2.0 – 4.0
Continuous Mechanical Ventilation with Heat Recovery	0.2 – 2.0
Other	Seek Specialist Advice

Natural ventilation

The effectiveness of these methods highly depends on the individual building - shape, orientation, exposure, occupant behavior

Window Ventilation

(don't need to explain, do we? Here's a picture)

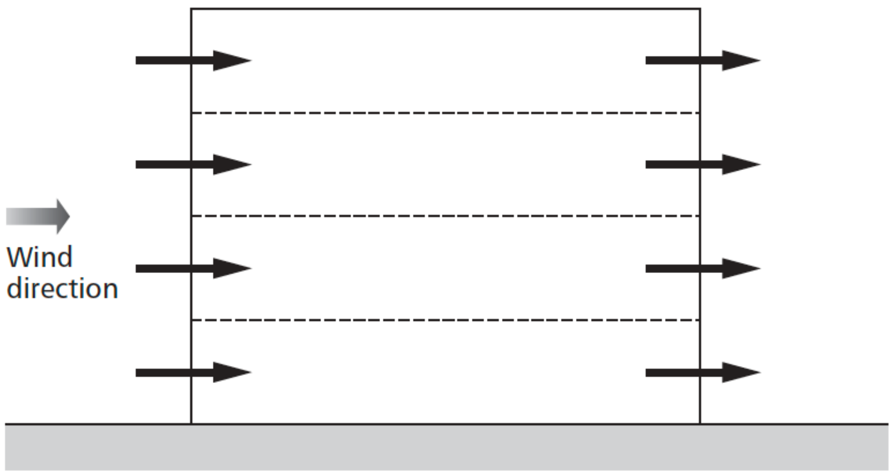

Figure 4.1 Wind driven airflow through a building

Stack Ventilation

(still somewhat ventilation through windows and infiltration through a central shaft in the

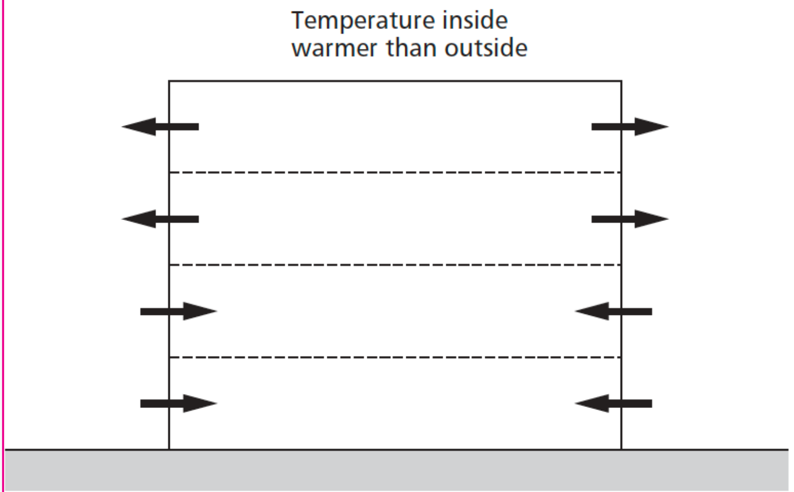

Figure 4.3 Temperature driven airflow (stack effect) through a building

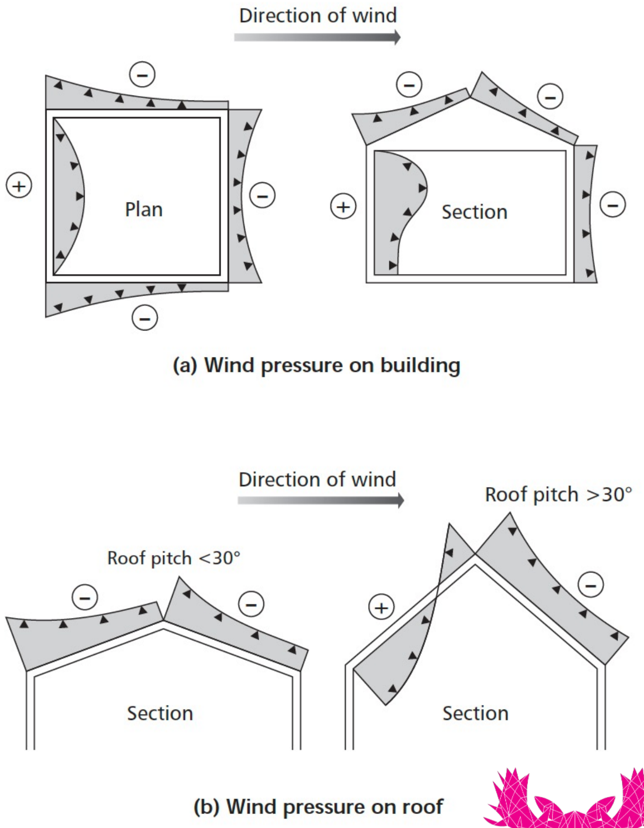

Figure 4.5 Wind pressure; (*a*) on building, (*b*) on roof

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Natural ventilation – trickle vents

Trickle ventilators

1.3.5 *Trickle ventilators* are devices that have an opening to the outside. *Trickle ventilators* shall:

a) have an opening of no less than 2000 mm^2 *equivalent aerodynamic area*, and

b) be located to minimise draughts, and 🤔

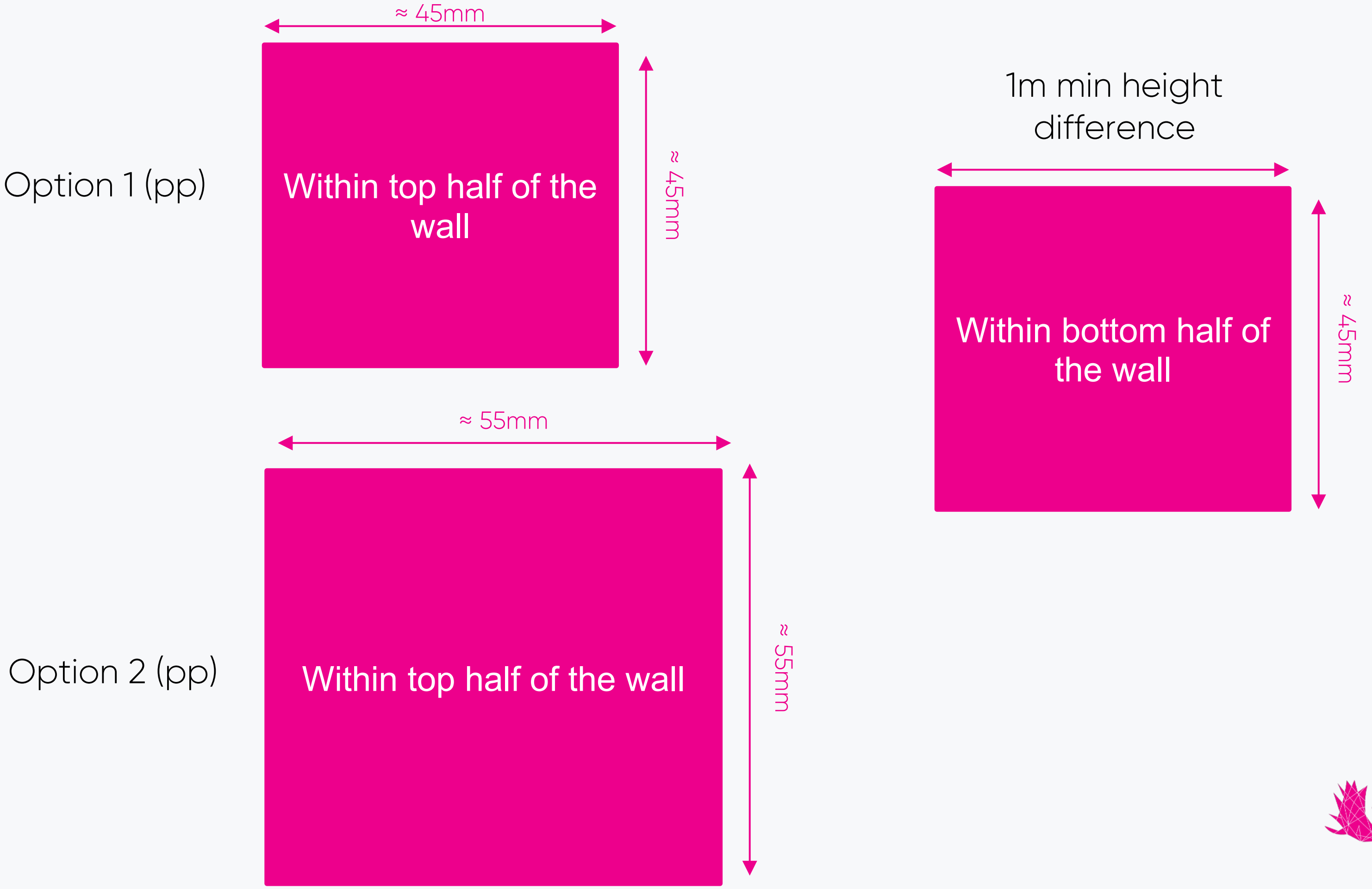
c) be secured to keep pests and insects out, and 🤔

d) have acoustic attenuation, if required by NZBC G6 Airborne and Impact Sound, and 🤔

e) be controllable and closable in all conditioned spaces, and 🤔

f) be installed in *household units*, providing they do not contain mechanical supply ventilation, and

g) have the *equivalent aerodynamic area*, based on the number of occupants, for the space as given in Tables 1 and 2, and



Natural ventilation – trickle vents (a thought experiment)

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

	Number of occupants				
Ventilator locations	**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

converting to possible air flow

Table 2 **(Potential air flow in m^3/h, based on 5m/s average wind speed like Auckland)**

Number of occupants	1	2	3	4	5
high and low level (option 1)	72m^3	144m^3	216m^3	288m^3	360m^3
high level (option 2)	54m^3	108m^3	162m^3	216m^3	270m^3

converting to corresponding floor area to meet 0.35ACH

Resulting max living area to achieve 0.35 ACH (assumed indoor ceiling height 2.5m)

high and low level (option 1)	10.08	20.16	30.24	40.32	50.4
high level (option 2)	7.56	15.12	22.68	30.24	37.8

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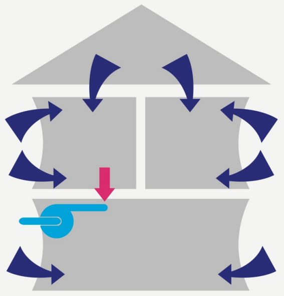
Types of mechanical ventilation – Extract (negative pressure)



Negative Pressure

It sounds negative, but it's the best type if you're on a budget or in an older house. This system consists of an extract fan (or multiple extract fans) installed in the bathroom(s), and kitchen.

What it does: The fan will constantly extract air from the house at a slow rate and then extract more moisture at high speed when the fan is turned "on" while cooking/showering.
How it controls moisture: it removes moist air from the source (bathroom, kitchen, and laundry) and exhausts it outside through a vent. By removing air from the house, it creates a negative pressure which pulls in air from outside through gaps in windows, doors, wall outlets, and any other small openings.
Pros: Removes moisture from the source. Fresh air is warmed (and therefore relative humidity is reduced) as it is drawn into the house. The cheapest effective option.
Cons: Make-up air comes from unknown sources (doors, windows, gaps), and may not be as clean as it could be. Can reverse the flow of exhaust gases in wood stoves or gas heaters, but this requires powerful exhaust fans and a very airtight envelope.

Price: $100-$300 depending on fan.

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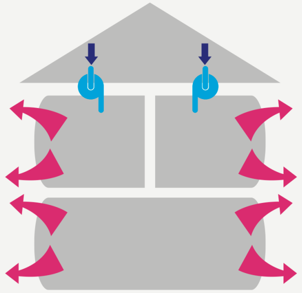
Types of mechanical ventilation – Supply (positive pressure)



Positive Pressure

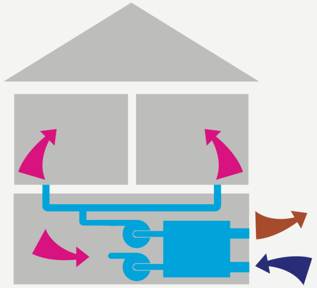
The name makes it sound good, but it's the riskiest type. Takes air from outside and forces it into the building. This is the typical cheapest system sold by HRV, DVS, Unovent, Smartvent, Reliance, Etc.

What it does: The fan(s) pull in air from the attic, filter it, and force it into the house when it is at the right temperature (i.e. 8-28 degrees)
How it alleges to control moisture: it forces attic air into the house in the hopes that the extra air (at whatever temperature and relative humidity) will dilute the moist interior air, and then pushes it outside through gaps in windows, doors, wall outlets, and any other small openings.
Pros: It is less expensive than a balanced system.
Cons: it is much more expensive than a negative system. It is based on hopes and dreams rather than scientific/engineering design. Forces moist air from a warmer area (inside) to a colder area (outside), which inherently carries the risk of condensation and moisture damage. Can work in a very air-leaky house if you're lucky, but can cause problems in a newer house. Branz appraisals for this system specifically state that they do not provide adequate ventilation. This strategy is not recommended.

Price: over $2500

https://dvs.co.nz/home-ventilation/

Types of mechanical ventilation – Balanced

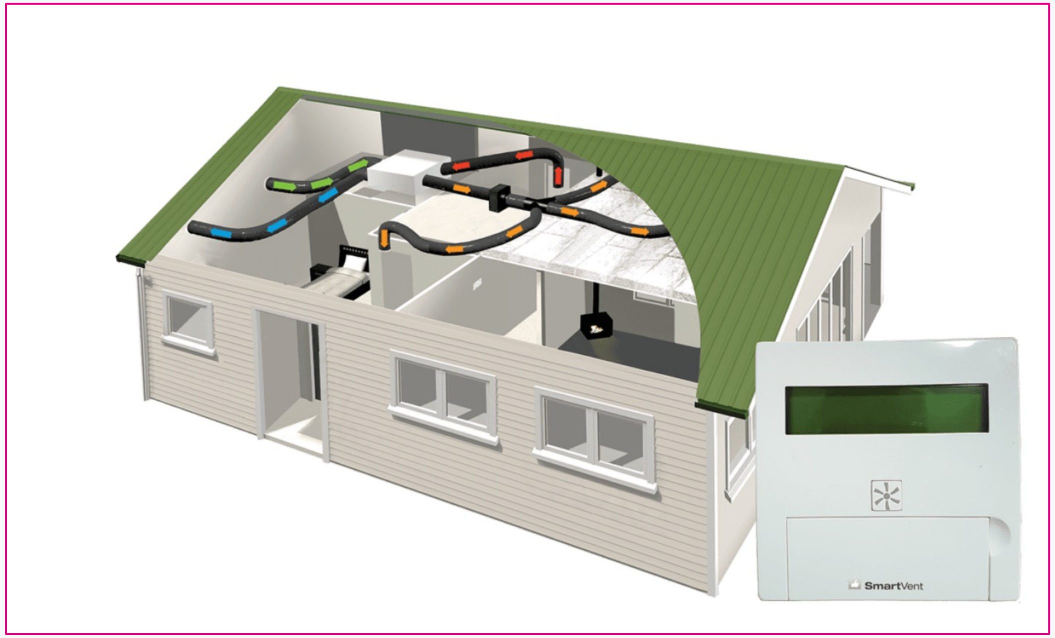


Balanced Pressure

This system is just right. It removes moist, stale air from your house, and replaces it with fresh air from outside. Usually it's also paired up with heat recovery, but it only reaches peak efficiency when the house is good and airtight. The system consists of multiple ducts throughout the house, half of which remove air from the house, and the other half of which feed fresh air back in. These ducts run next to each other through a heat exchanger so that the incoming air is being heated by the outgoing air.

What it does: The fan will constantly extract air from the house at a slow rate and replace it with fresh, outdoor air at the same rate.
How it controls moisture: it removes moist air from the source (bathroom, kitchen, and laundry) and exhausts it outside through a vent. The fresh air is brought in through a dedicated vent, heated (and dried) by the outgoing air, and then introduced to the interior to provide fresh, clean, warm air.
Pros: Removes moisture from the source. Fresh air is warmed (and therefore relative humidity is reduced) as it is drawn into the house. Fresh air comes from a known source and can be filtered on the way in, and when paired with an airtight house, this is the highest efficiency system.
Cons: Highest price, and only reaches design efficiency within an airtight building envelope.

Price: $2k - $10k depending on size of house and system



https://www.smartvent.co.nz/smartvent-balance/

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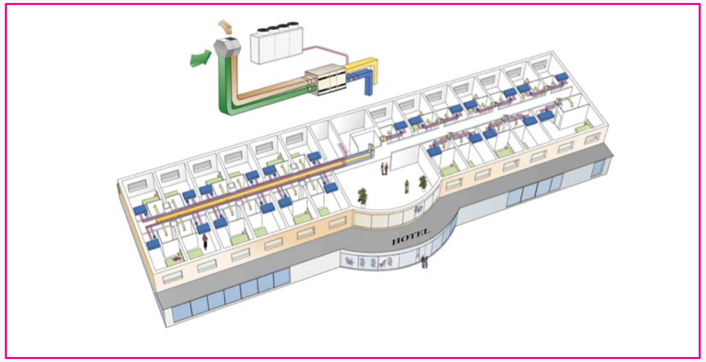
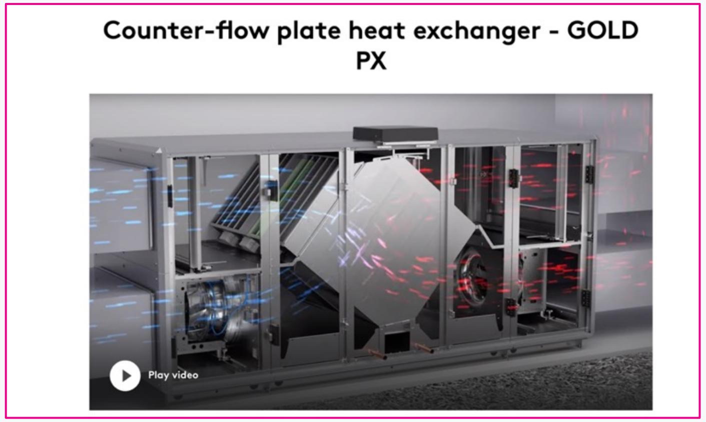
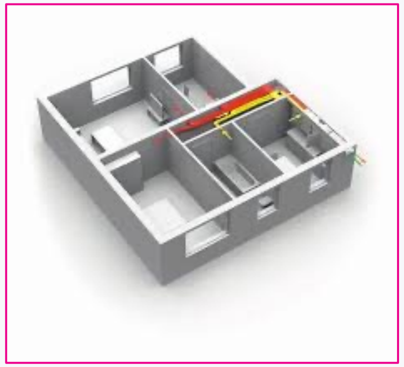
Types of mechanical ventilation – Balanced with Heat Recovery

Central building systems (commercial or large residential)

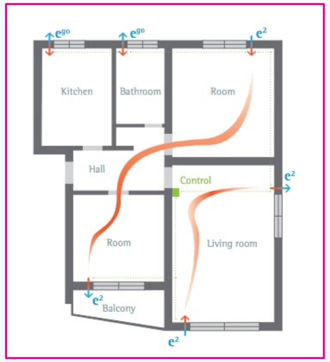


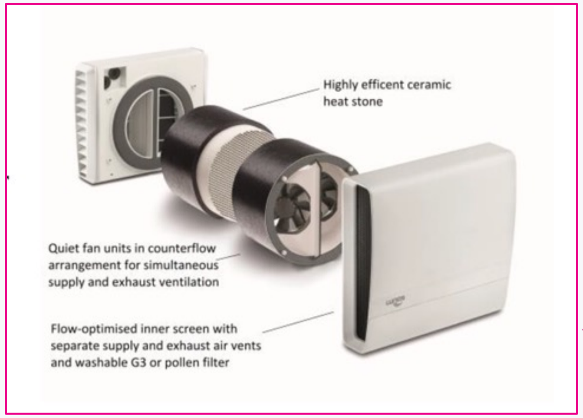


Central systems apartments, or residential



Through wall systems





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Ventilation Energy Efficiency

Ventilation Air change + infiltration air change + heat recovery efficiency (if any) + electric efficiency (fans)

min $0.35h^{-1}$ (G4)
base ventilation

≈ 30-35%! kWh per year
See our airtightness presentation)

system efficiency (Heat recovery core)
and installation, everything else is just heating

Electrical use to run fans 24/7
1kWh should give you enough electricity to move $2000m^3$

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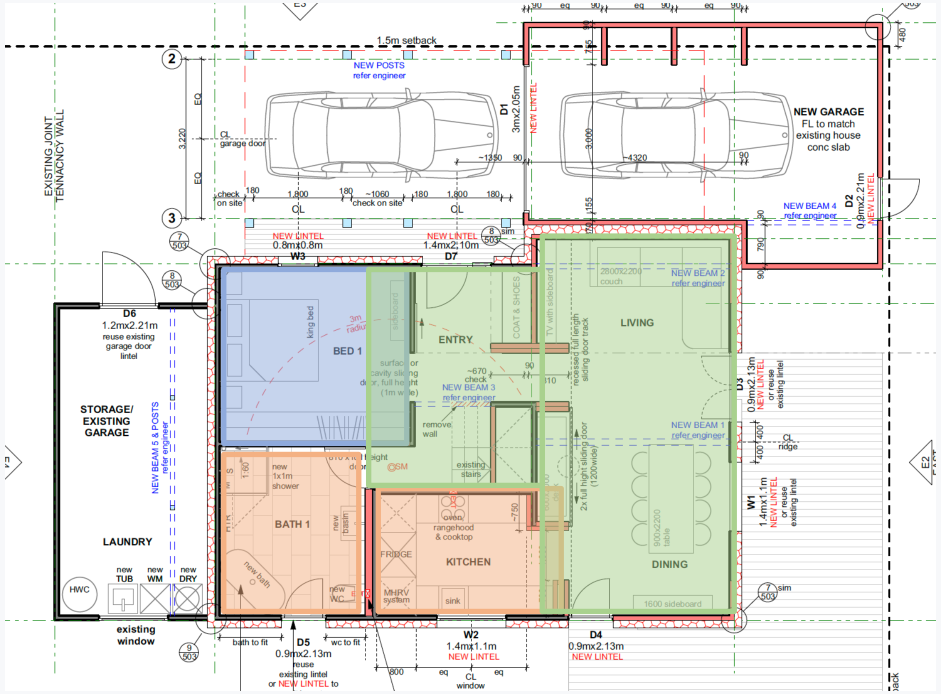
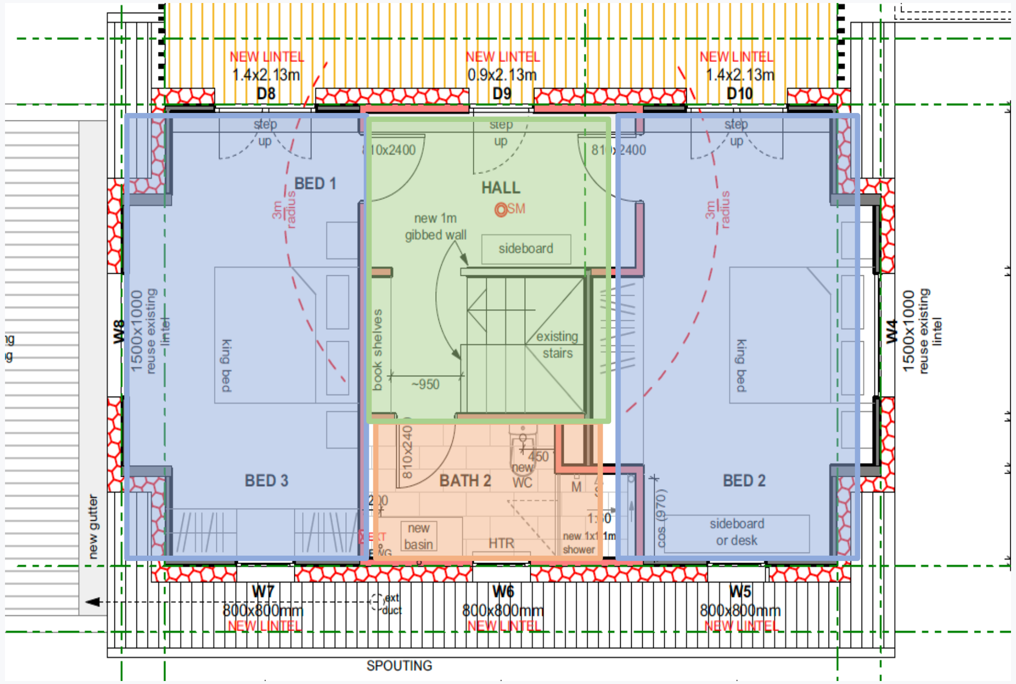
How to design balanced ventilation – Basics





$$115.2m^3/((24m^2+45.1m^2+53.8m^2)*2.5m) = 115.2m^3/307.25m3 = 0.375\ ACH$$

Bathroom 1	10.1m²	36 m³/h (10l/s continuous)	Bedroom 1	13.5m²	2 pers	2 x 27 m³/h (7.5l/s continuous)	Entrance, stairs, Living	41.2m²
Bathroom 2	5.7m²	36 m³/h (10l/s continuous)	Bedroom 2	15.8m²	1 pers	2 x 27 m³/h (7.5l/s continuous)	Landing, Hall	12.6m²
Kitchen	8.2m²	43.2 m³/h (12l/s continuous)	Bedroom 3	15.8m²	1 pers	2 x 27 m³/h (7.5l/s continuous)	Transfer areas	53.8m²
Extract total	24m²	115.2 m³/h (32l/s continuous)	Total Supply	45.1m²	4 pers	108 m³/h (30l/s continuous)		

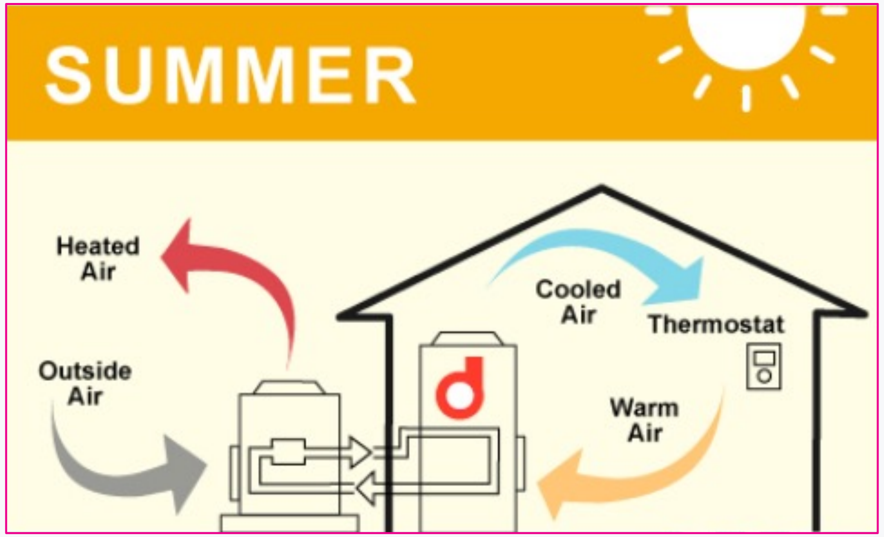
Heating systems – Heat Pumps

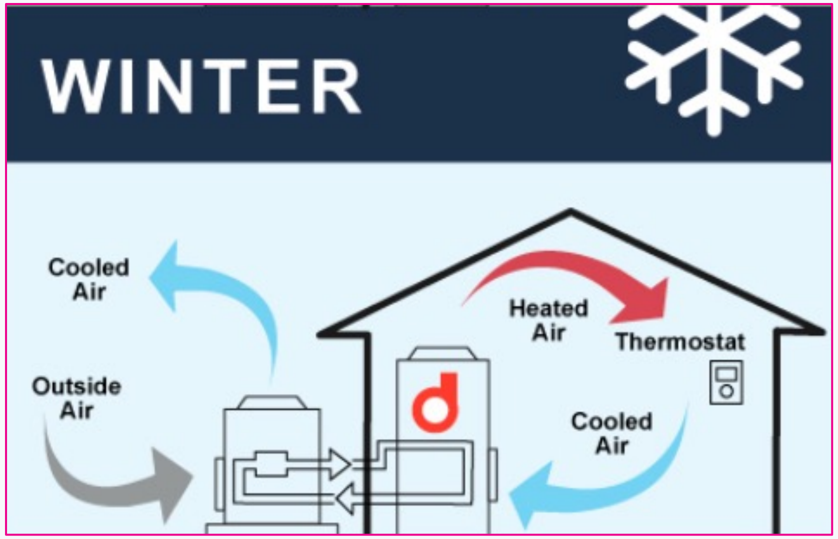
Heat pumps are not ventilation systems!

The air source heat pump **absorbs heat from the outside air into a liquid refrigerant at a low temperature**. Using electricity, the pump compresses the liquid to increase its temperature. It then condenses back into a liquid to release its stored heat.

There is no exchange of air!

PROS	CONS
Electric efficiency	Air velocity
Heating and cooling in one	Overly dry air in winter
	Noise





Source; https://www.aaaheatingandcoolinginc.com/heat-pumps-how-they-operate-for-heating-cooling/

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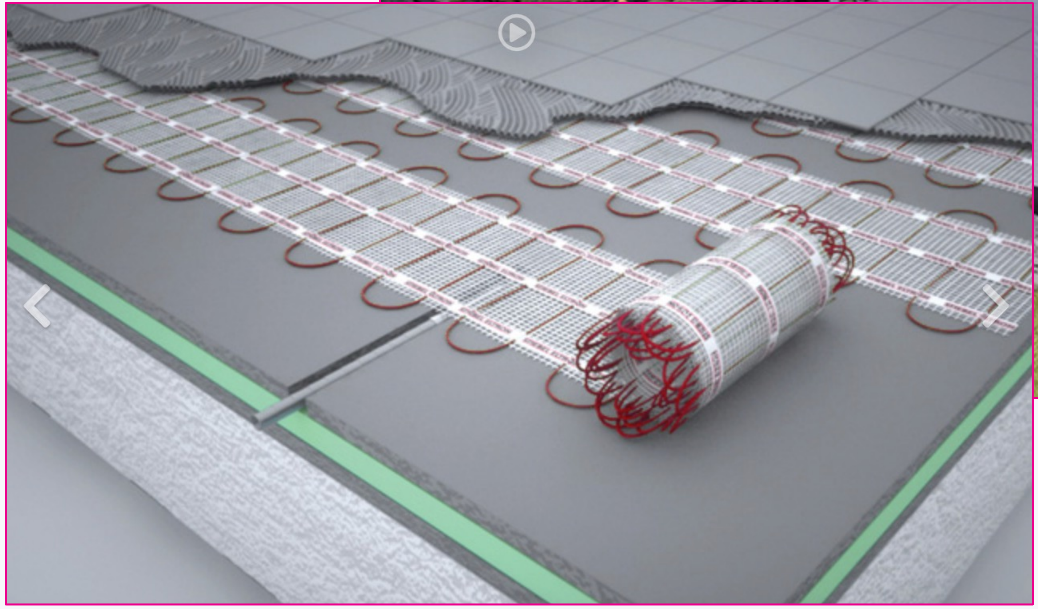
Heating Systems – Hot water heat pumps with radiators, or underfloor loops

PROS	CONS
Electric efficiency	Storage tank required
Heating and cooling in one	
Radiant heat	



https://www.stiebel-eltron.co.nz/

Heating Systems – electric

PROS	CONS
Easy install everywhere	Electric efficiency
Radiant heat	

https://lhz.co.nz

Heating Systems – Fire, Log burners

PROS	CONS
Radiant heat	Emissions are high
	Problematic with airtight design
	Draughts

https://www.kent.co.nz/wood-fires

Heating Systems – Gas

PROS	CONS
	Puts live and health at risk

https://1news.co.nz

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Questions

- External Insulation, Dew Point/Interstitial moisture, Airtightness
- Model method for architects
- Alterations - modelling not an option

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Q&A

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More information?

@pink.moose

Oculus Architectural Engineering Ltd

www.oculusltd.co.nz (H1 page, Q&A, Resources, Podcast)

Building Science + Bullsh*t – Thurs 29th September – H1 Changes Part Seven: Thermal Bridges