Designing Healthy Homes

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Changing Expectations

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Changing Expectations

Changing built fabric
Improved thermal comfort
Improved occupant health??

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Human needs

Temperature

- Step 1 > 13^0 deg C (Human health and dewpoint)
- Step 2 > 15^0 deg C (human health)
- Step 3 > 20^0 deg C (min typical thermal comfort)
- Step 4 21^0 deg C (Typical thermal comfort)
- Step 5 $<25^0$ deg C (thermal comfort)
- Step 6 $<28^0$ deg C (Human health)

Relative humidity

- > 35% Health and comfort
- >45 & < 55 HVAC – comfort and productivity
- <70% health and comfort
- Note – mould growth

Air Quality

- Min ventilation rate 0.35 l / s / m2 / person

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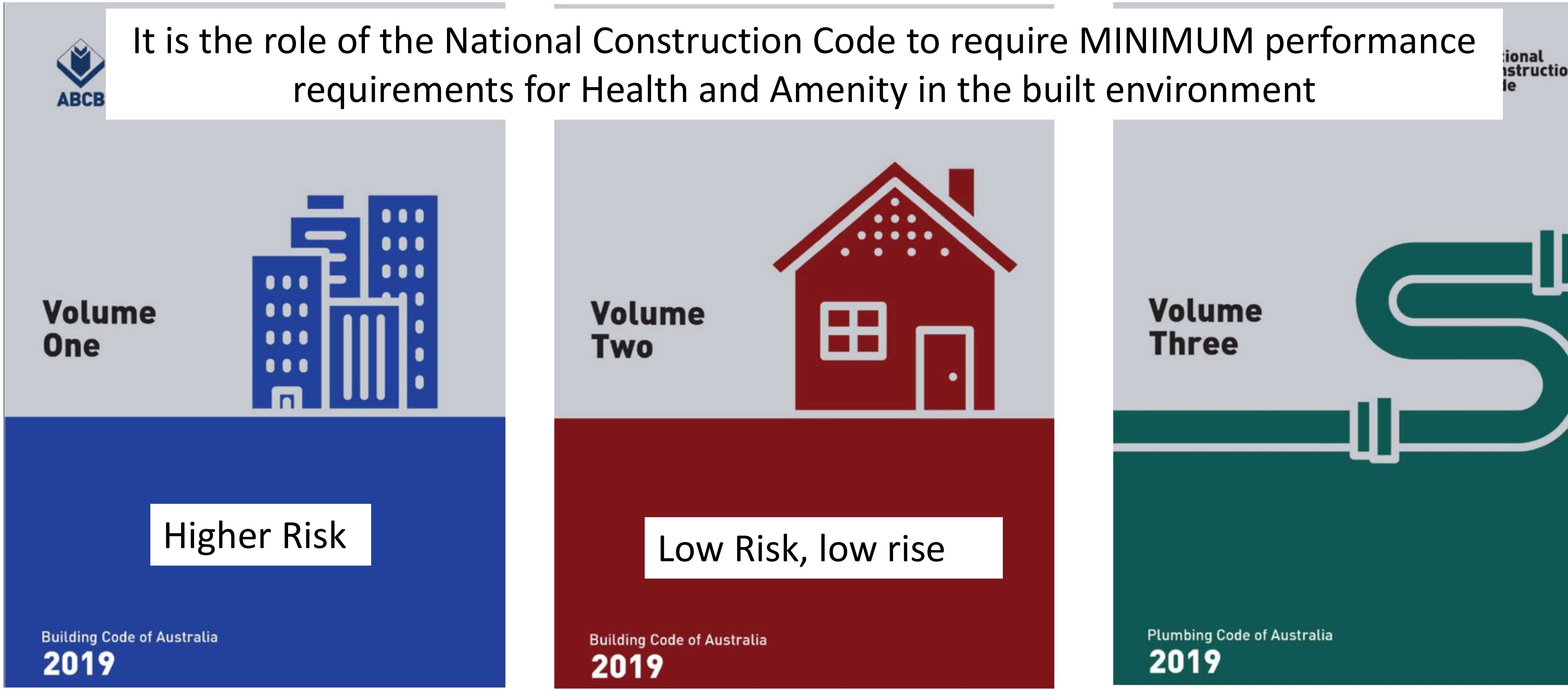
The Australian building regulations

It is the role of the National Construction Code to require MINIMUM performance requirements for Health and Amenity in the built environment



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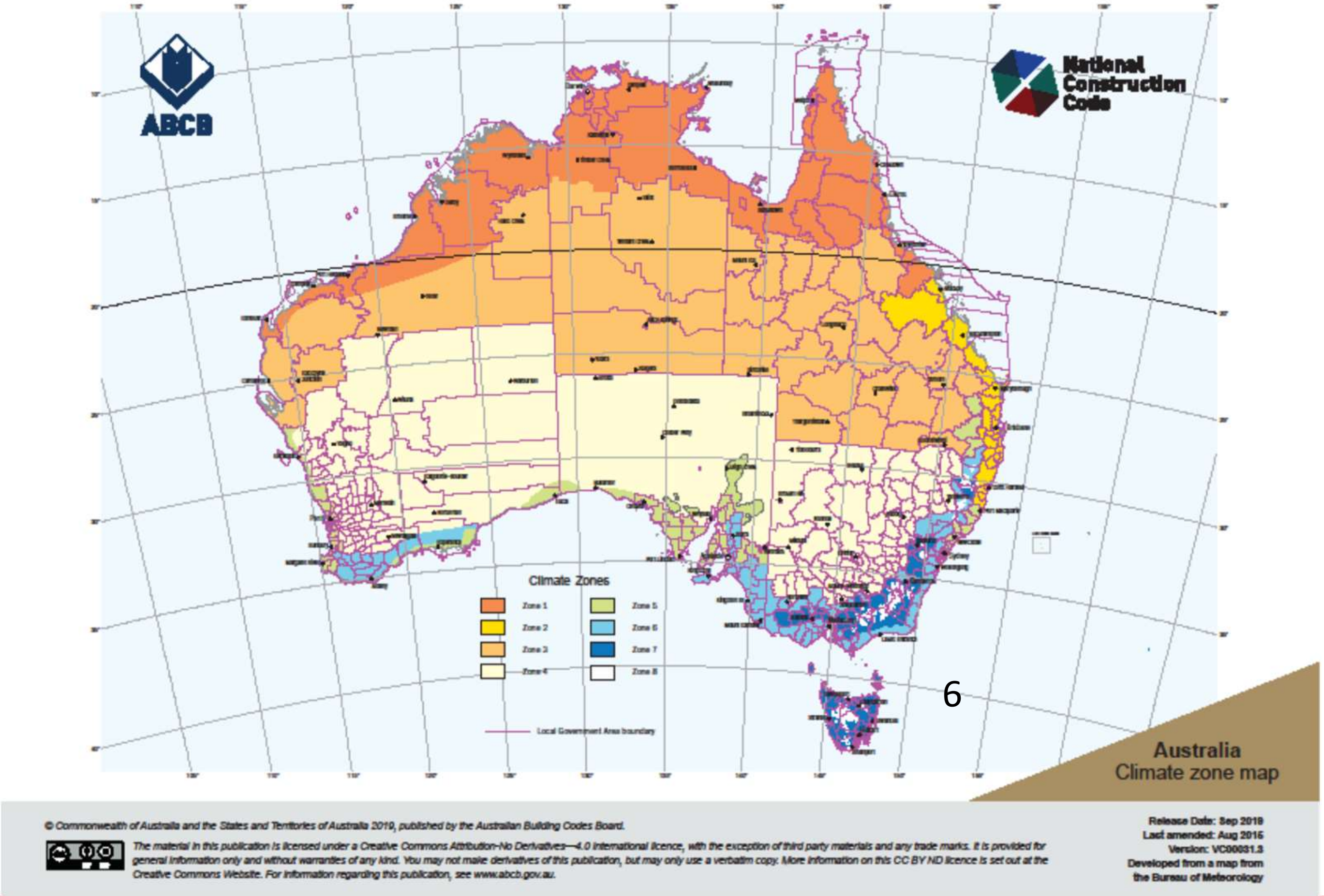
Australia’s building regulation climates



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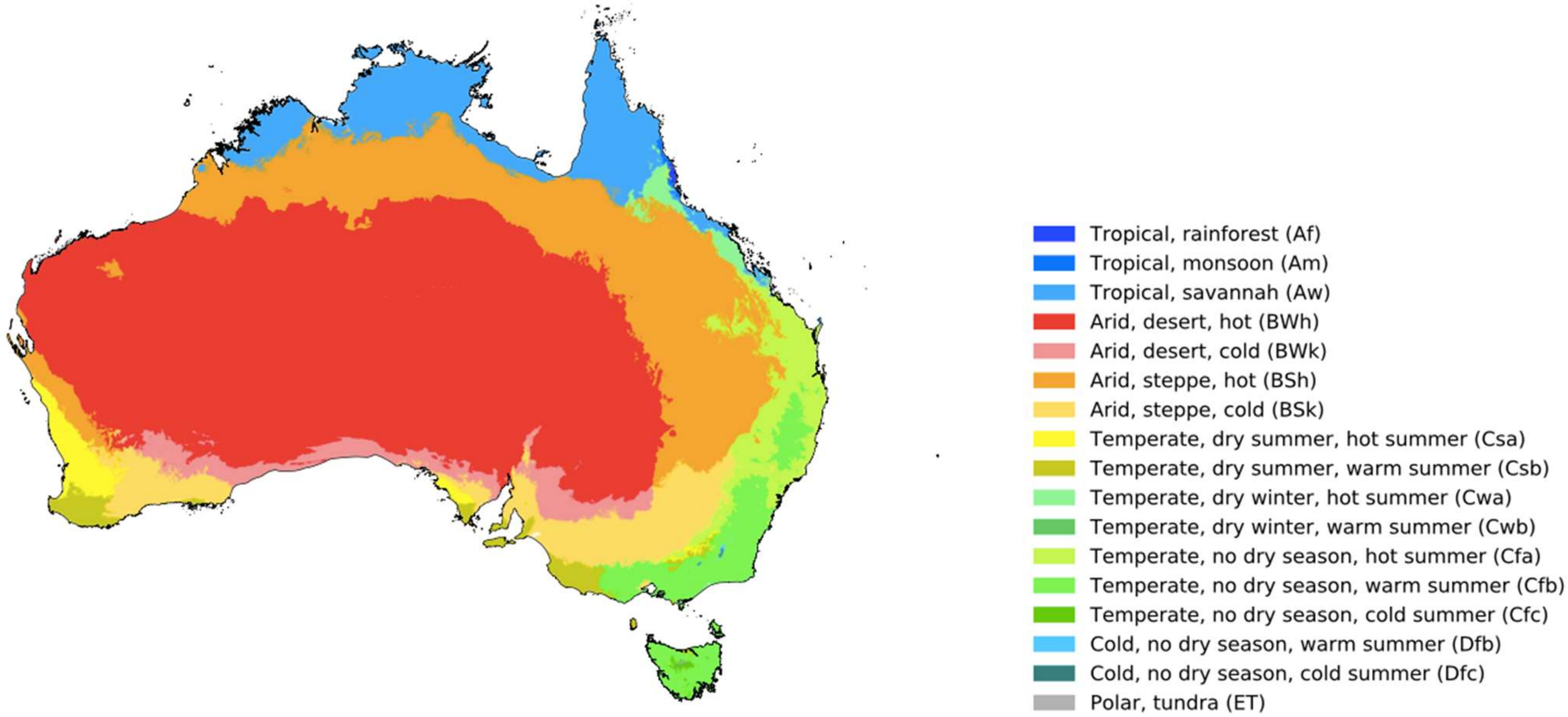
Australia’s Hot-humid to Cool-temperate climates



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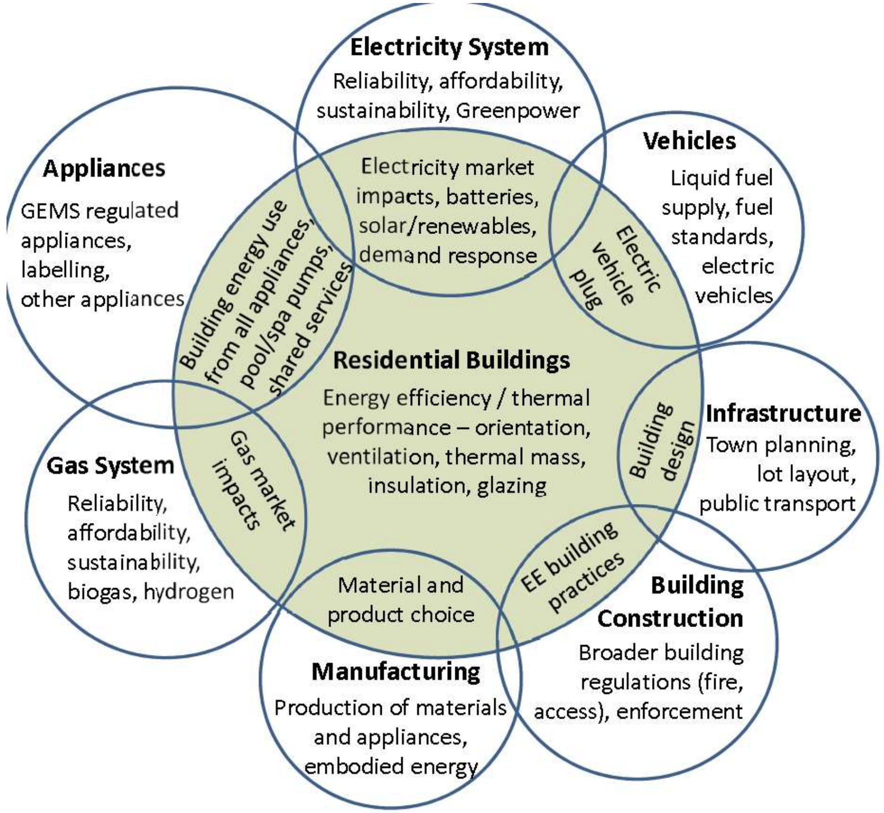
NatHERS & healthy housing

- Sadly NatHERS, is not the answer
- The NatHERS remit is about the reduction of greenhouse gas emissions that may be caused by house operation.



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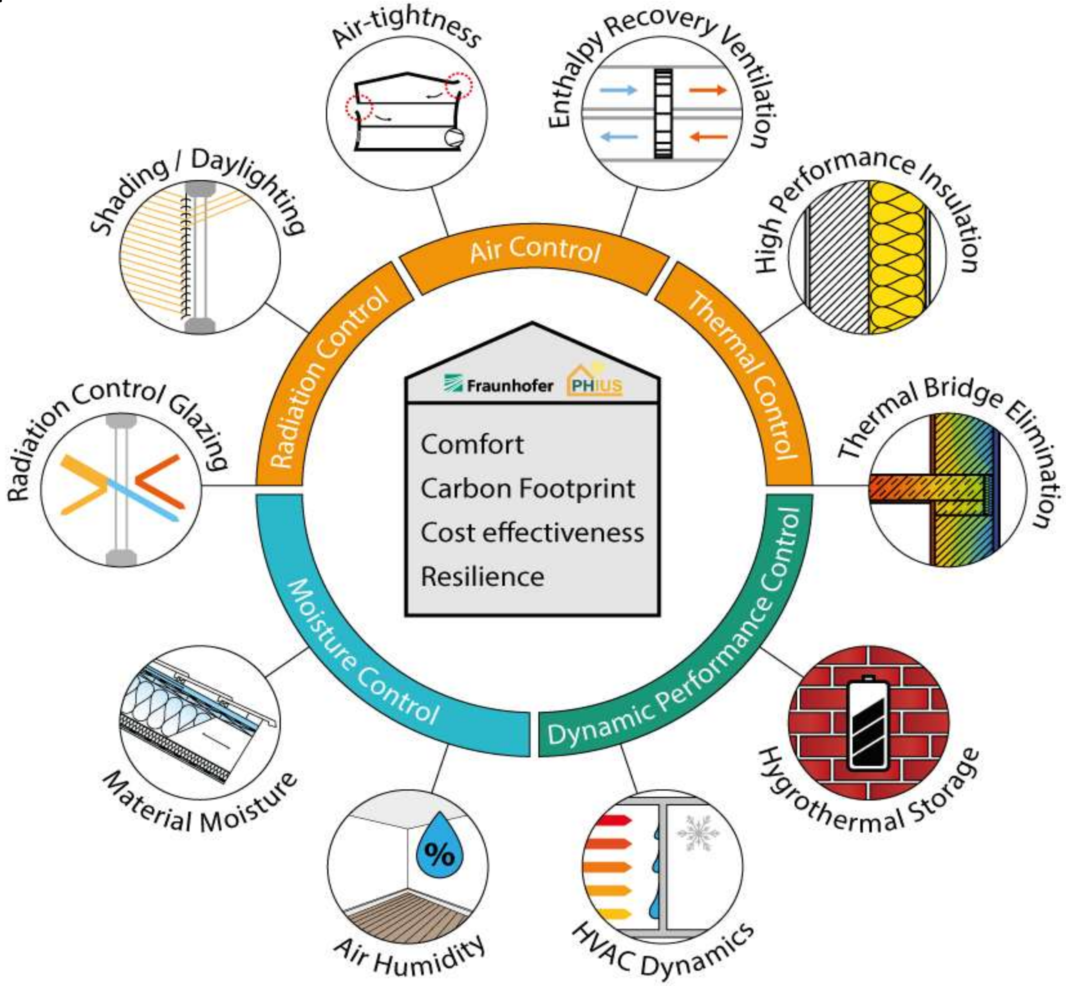
Recalibrating priorities



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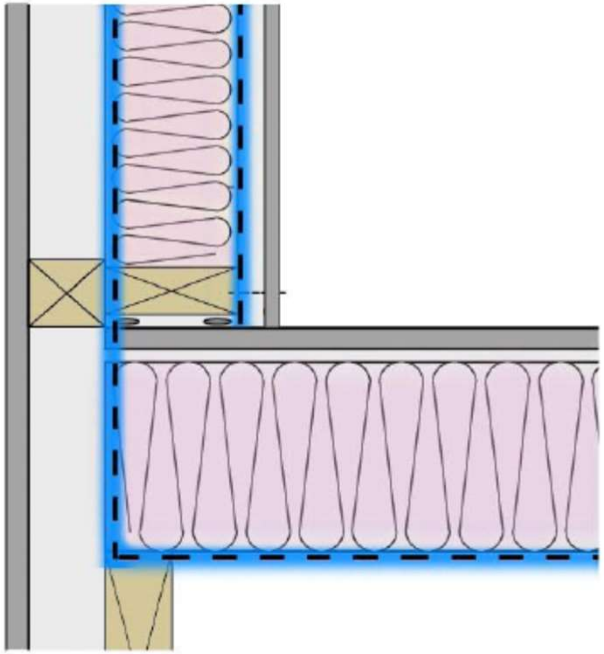
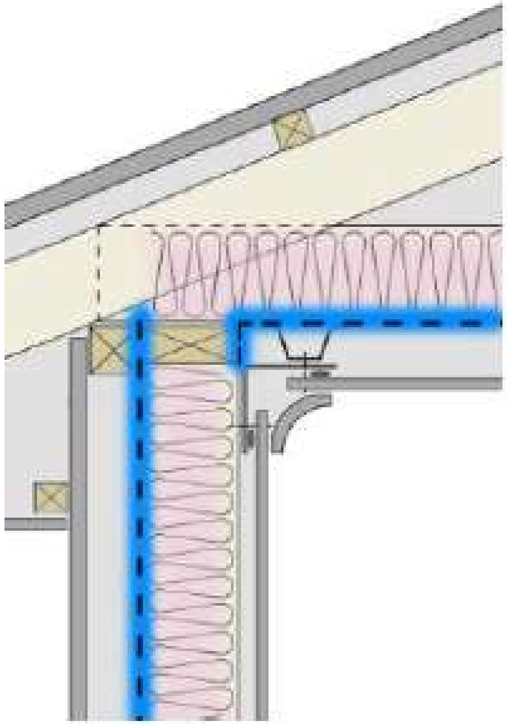
Air Control (air-tightness & ventilation)

Air Control Layers





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Air Control Layers

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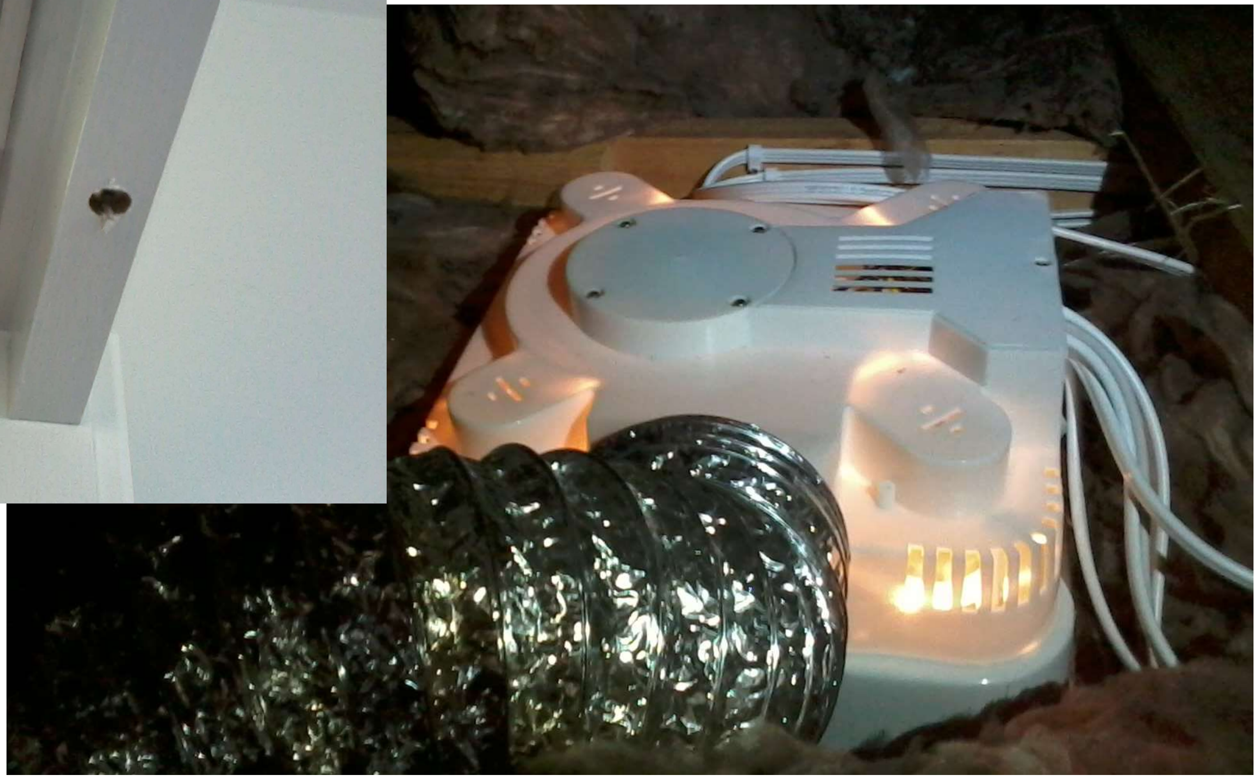
Un-intended Mass Air and Water Vapour Transport



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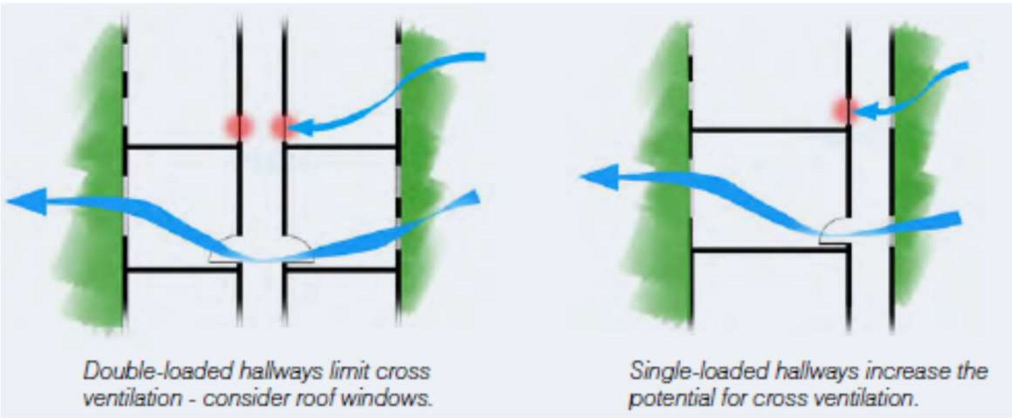
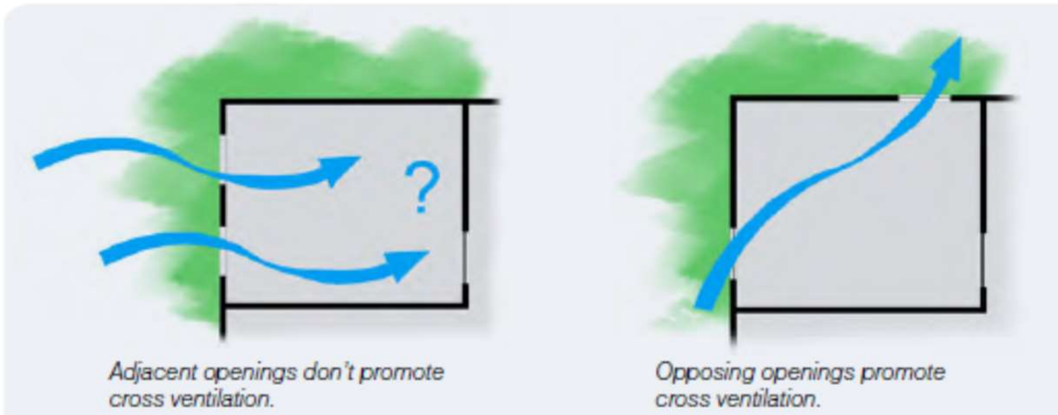
Methods to manage interior generated water vapour

Passive vapour control systems

- House ventilations (doors, windows)





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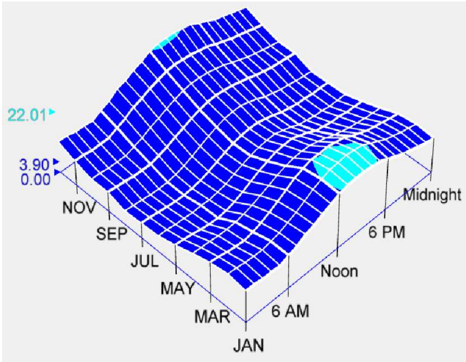
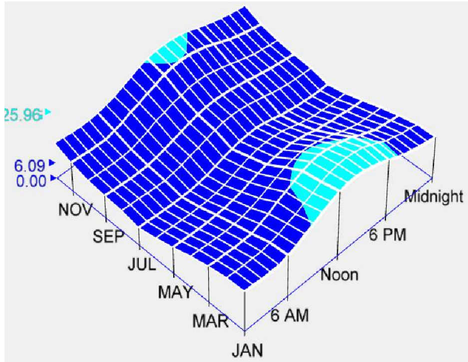
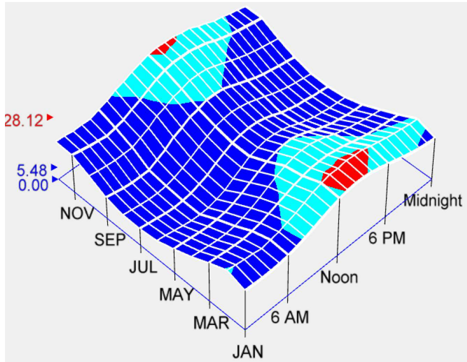
When is Water Vapour Trying to Escape (ext env <18degC)



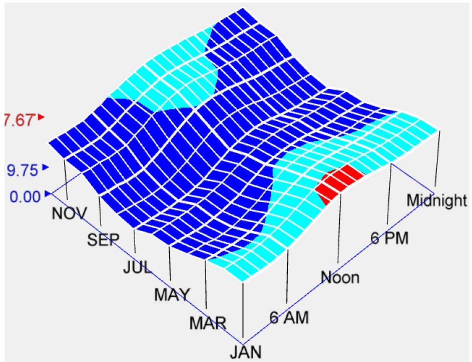
Launceston CZ-7 – 91%



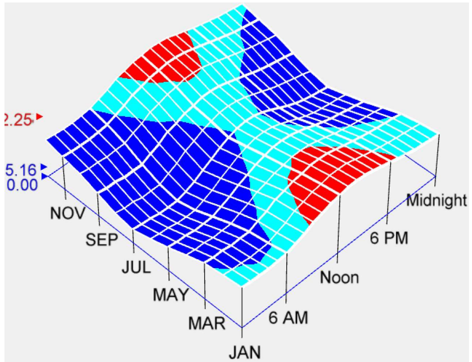
Melbourne CZ6 - 88%



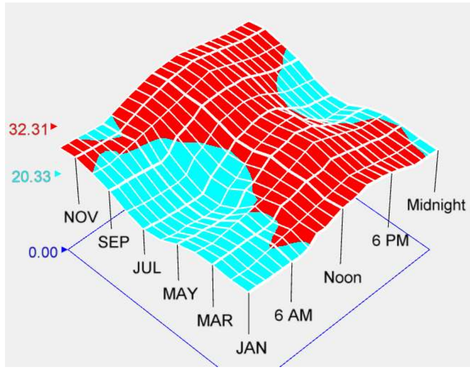
Richmond CZ6 - 72%



Sydney – 65%



Amberly CZ2 - 50%



Darwin CZ1 – 58% Hot

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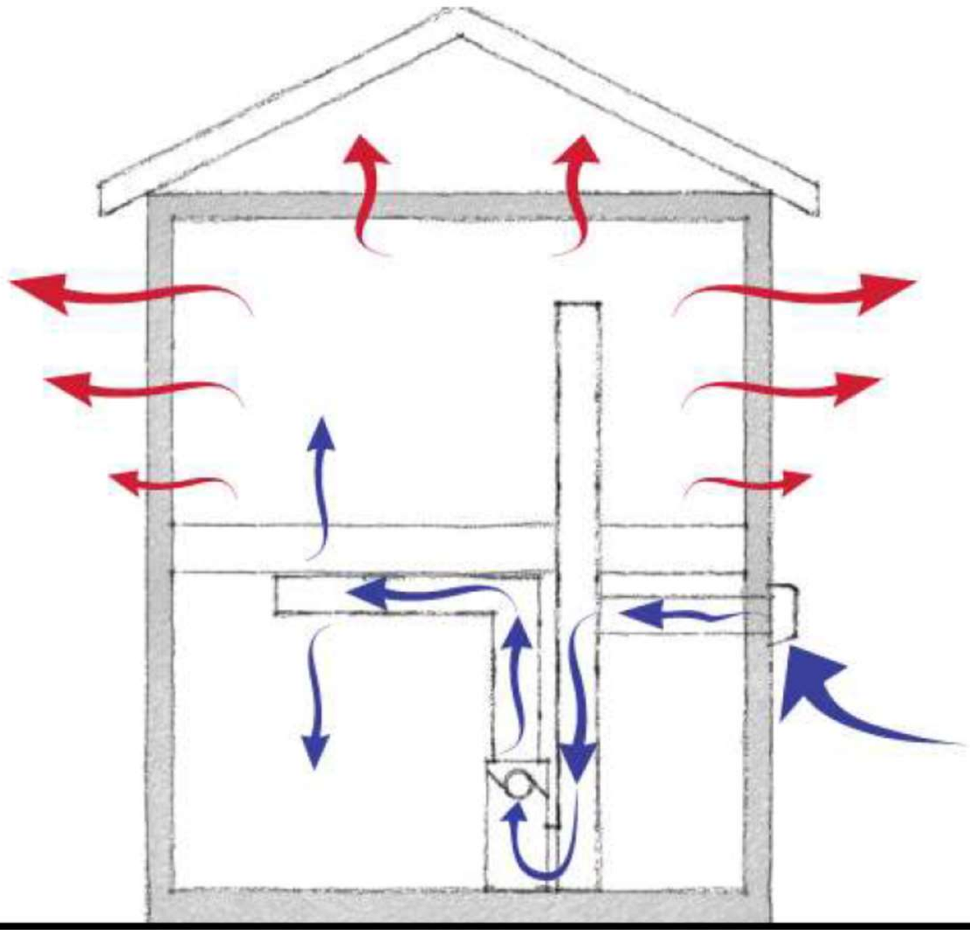
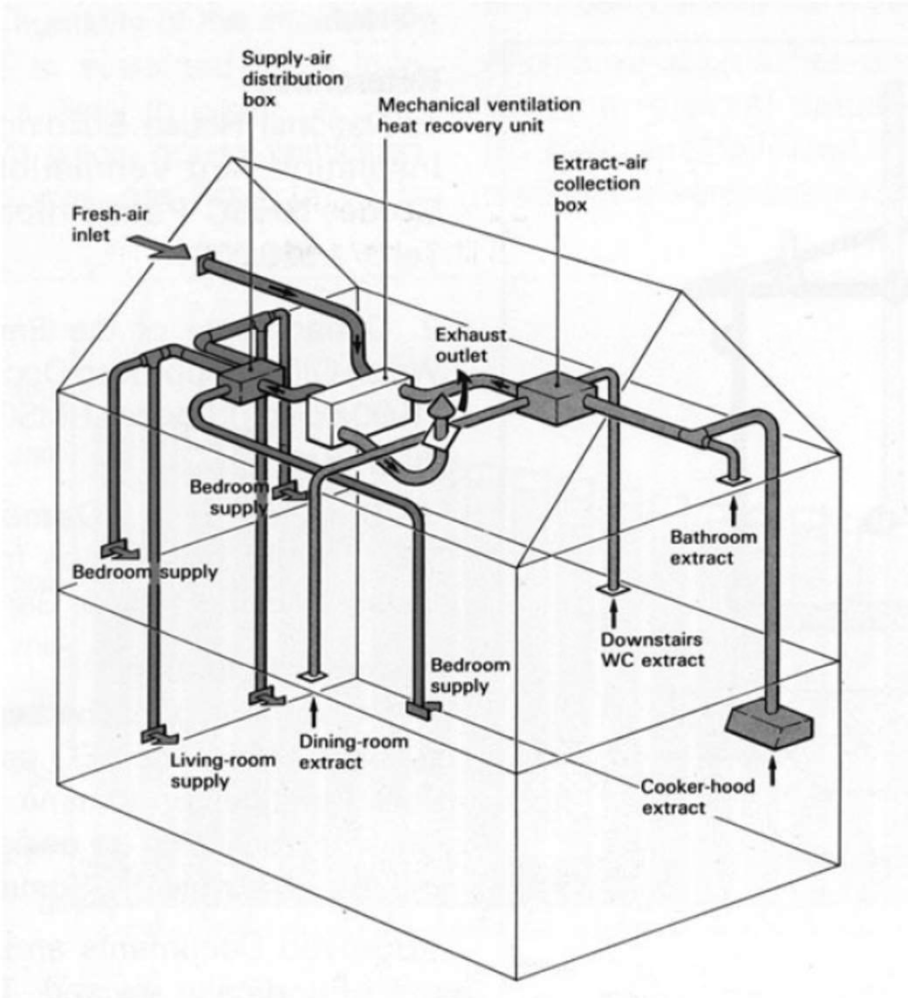
• Exhaust only

• Supply only



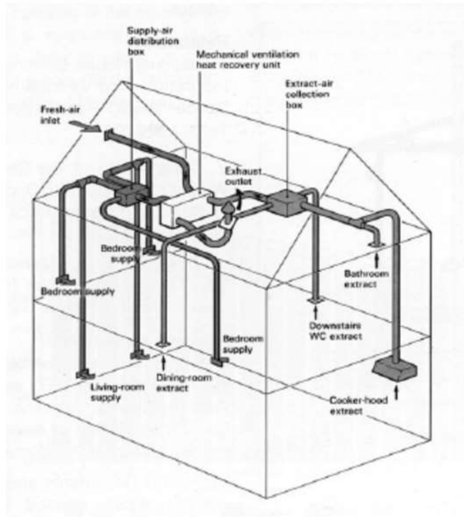
- Balanced

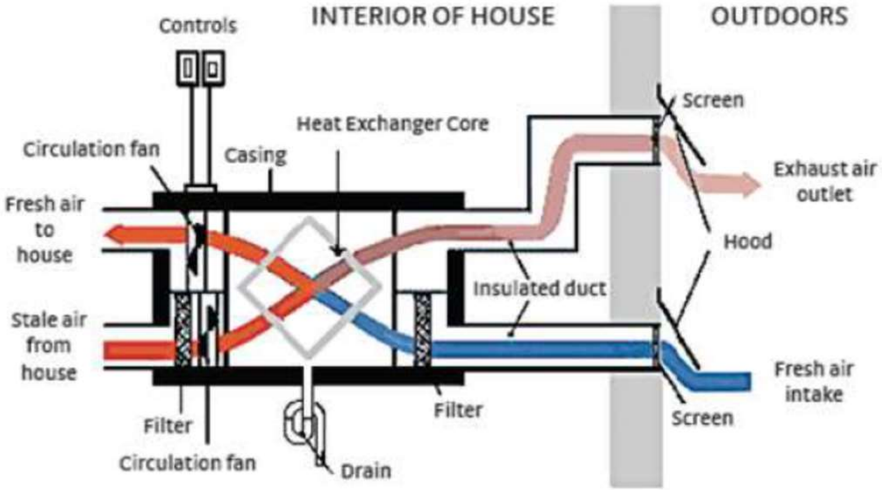


Supply-air distribution box
Mechanical ventilation heat recovery unit
Extract-air collection box
Fresh-air inlet
Exhaust outlet
Bedroom supply
Bedroom supply
Bathroom extract
Downstairs WC extract
Bedroom supply
Dining-room extract
Living-room supply
Cooker-hood extract

Enthalpy recovery is a ventilation system that:

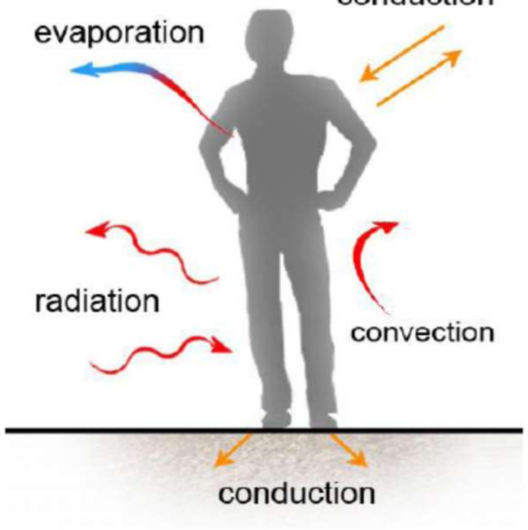
- Uses the warm outgoing exhaust air to pre-heat incoming air, during times of indoor heating, and/or
- Uses the cool outgoing exhaust air to pre-cool incoming air, during times of indoor cooling

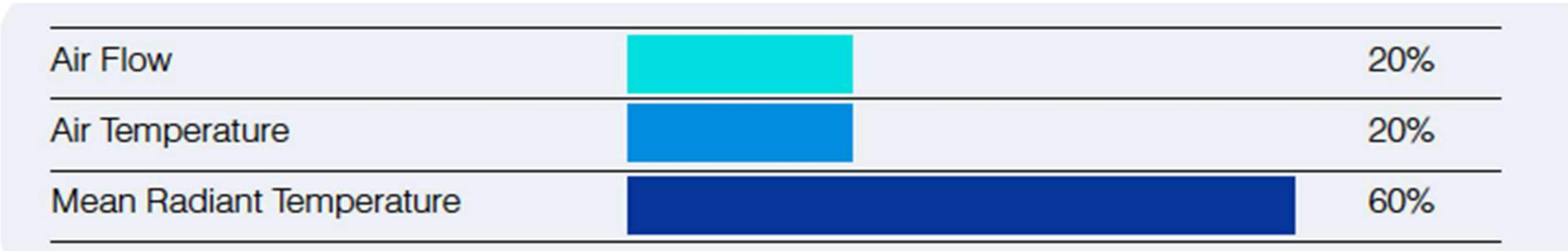




Thermal control

Thermal Comfort





Thermal Control

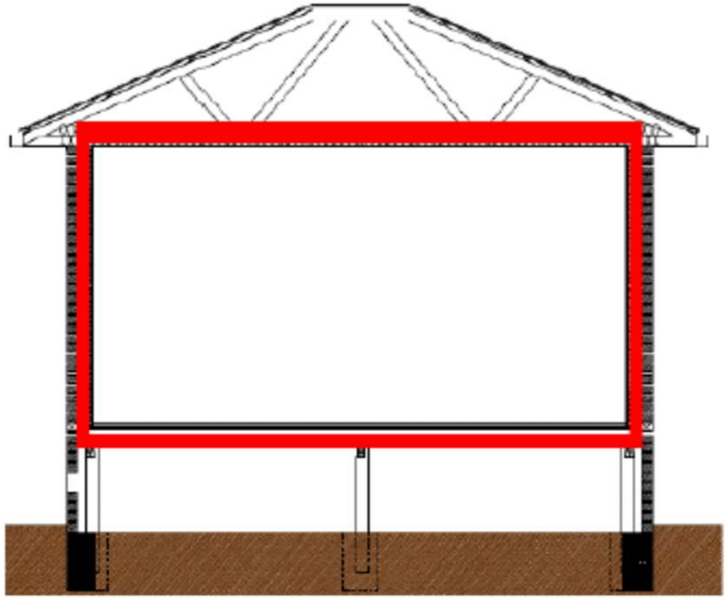


Figure 10 – Insulation continuity

http://www.aliexpress.com/compare/compare-quick-brown-fox.html

http://www.dhgate.com/womens-down-coats-zipper-collar-feather-down/p-ff80808139bf02410139ed6b248f40e5.html

Thermal Control

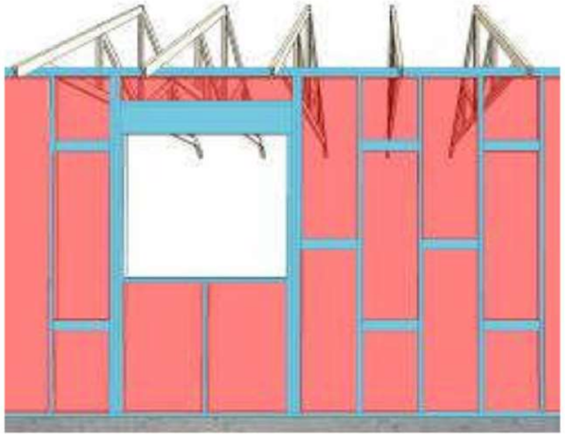


Figure 82 – Example of Unaligned Wall and Roof Structure Requiring a Double Top Plate

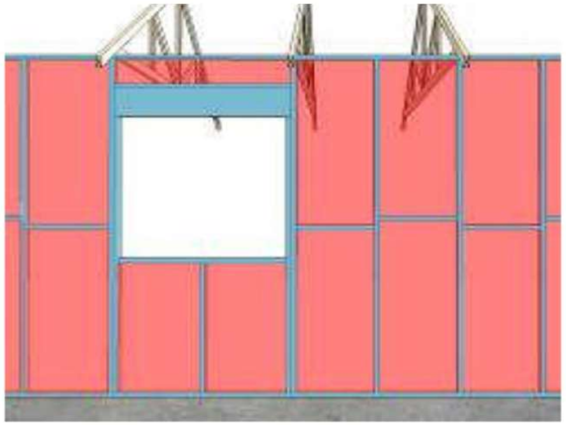


Figure 83 – Example of Aligned Wall and Roof Structure Requiring a Single Top Plate

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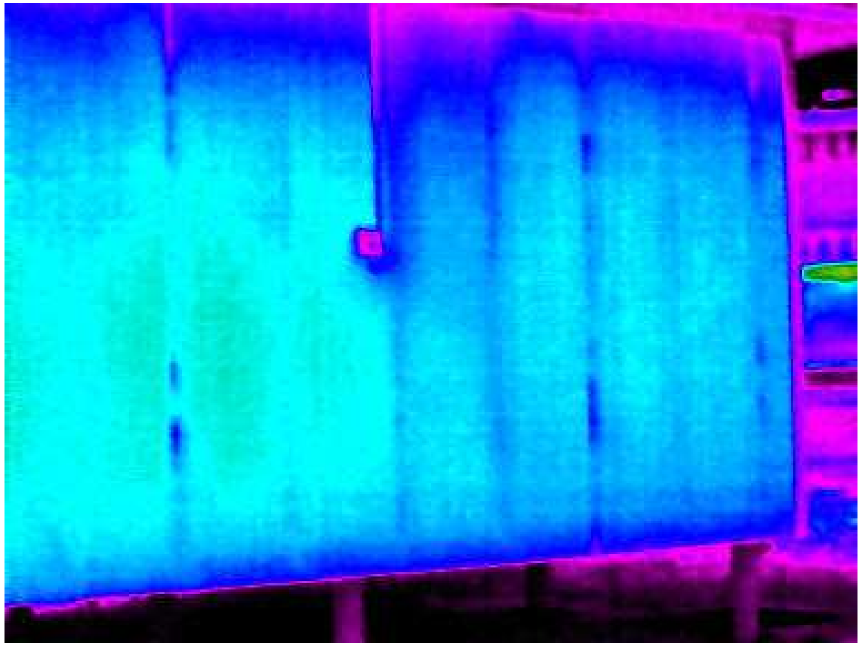
Thermal Control Layer– Thermal Bridging

In this old house, the exterior cladding is HOT

In this new building, the exterior cladding is COLD



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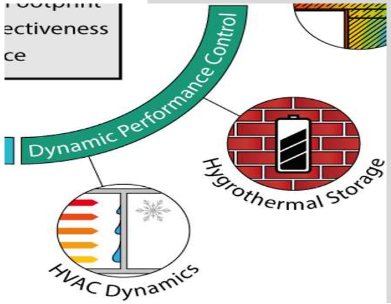
Dynamic performance control (vapour)

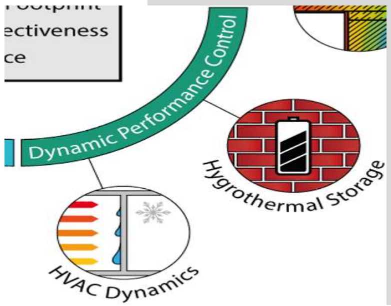
Dynamic daylight performance control



If we consider daylight control:

- The values for daylight transmittance are static,
- Whilst the exterior conditions (amount of cloud cover and cloud density) are dynamic, and
- We use variable wattage lamps with Lux sensors to manage interior lighting

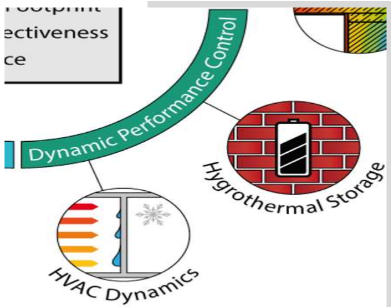
Dynamic noise performance control



If we consider noise control:

- The values for noise transmission are static, and
- We design based on a worse case scenario

- The values for noise quality are dynamic, and
- Basic calculation methods explore a single value, or
- We use dynamic software tools like Dr Rob Bullen's 'Soundscape' to explore how various sounds are experienced in a space.



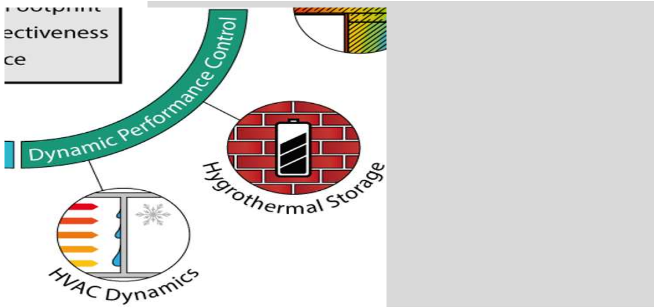
Dynamic radiation performance control

If we consider radiation control:

- The values for radiation calculations are static, and
- We design based on static value (NCC)

- But as per the radiation lecture, the direct and diffuse radiation is continually changing (is dynamic).
- Better dynamic simulation tools use hourly Global, Direct and Diffuse solar radiation inputs to inform the affect of radiation on building performance.

Dynamic air-tightness performance control

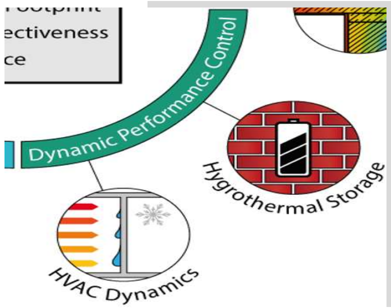


If we consider air control / airtightness:

- The values for air control and air tightness are generally a static value (i.e., 10@n50 ACR).
- But tracer gas research highlighted the need to observe environmental data (temperature, relative humidity, barometric pressure, wind speed and wind direction) to inform the calculations regarding Air Changes per Hour (ACH), and
- The blower door test method measures the relative leaky-ness of a building at different pressure differentials up to a 50Pa difference.

- But how do we include these variable inputs with a building simulation?

Dynamic ventilation performance control



If we consider air control/ ventilation:

- The values for air control and ventilation are generally a static value.

But

- The temperature of the outdoor air is always changing,
- The relative humidity of the outdoor air is always changing,
- The wind speed is always changing, and
- The wind direction is always changing.

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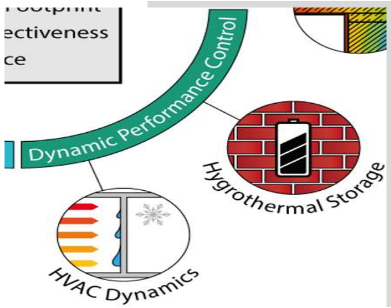
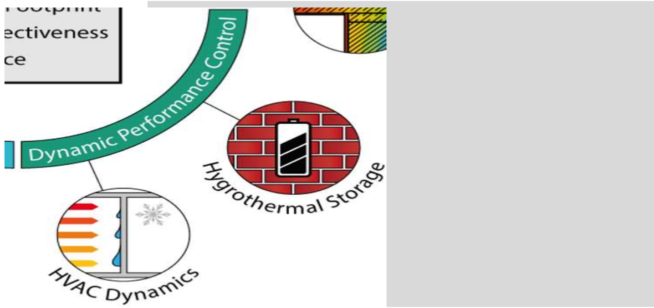
Dynamic ventilation performance control



This is further complicated by new and more efficient technologies

- Historically HVAC systems had a single and often constant rate of air flow that could be measured and adjusted.
- But newer systems have variable ventilation rates, requiring the more precise quantification of air flows.
- Furthermore, these are significantly affected by the dynamic operation of the building.
- It is easier to control dynamic air flows if an over-pressure of air is used.
- But for this to work, the moisture balance of the building materials must be known and managed.
- This becomes even more complex when retrofitting of low grade facades is considered.

Dynamic thermal performance control



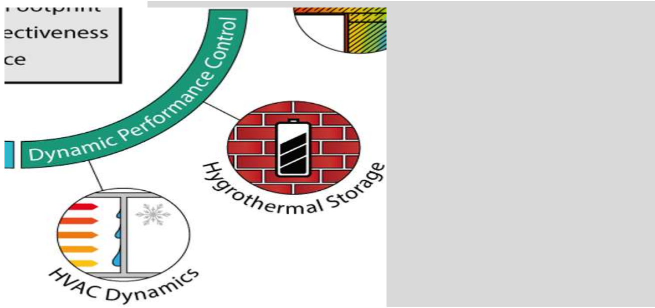
If we consider thermal control:

- The values for the external climatic conditions historically only considered a single average air temperature
- The conductivity values for materials only considered a single value based on a test result for a single temperature and relative humidity.

But

- The temperature of the outdoor and indoor air is always changing,
- The relative humidity of the outdoor air and indoor air always changing, and
- How do we account for thermal capacitance

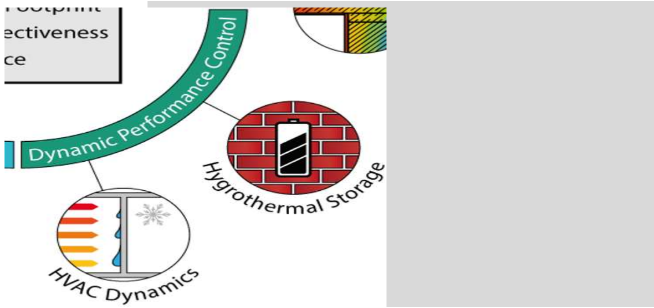
Dynamic hygrothermal performance control



If we consider the Hygrothermal calculation in lecture 8a:

- The temperature and relative humidity values for the external climatic were static.
- The temperature and relative humidity conditions for the interior environment were static.
- The conductivity values for the materials, regardless of temperature and moisture content, were static.
- The water vapour resistivity values for each material, regardless of temperature and relative humidity, were static.
- There was no consideration about the water vapour and moisture adsorptions affect on thermal mass.
- There was no consideration of moisture accumulation, wetting, drying or mould growth risks.

Dynamic thermal comfort control



If we consider thermal comfort:

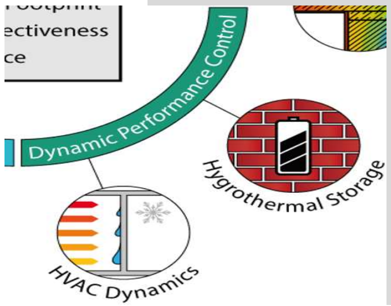
Our simplistic calculation methods need for us to specify a single interior temperature.

But

The ASHRAE and other standards show that our thermal comfort changes subject to:

- Our physical activity
- The seasons
- Our contact with the outdoors
- Our clothing
- The relative humidity, and
- The interior air speed.

Dynamic HVAC performance control



The HVAC system may be needed for:

- Ventilation of air-tight buildings
  - air quality
  - cooling, subject to external air temperature
  - heating, subject to external air temperature
- Heating to ensure temperatures always meet health requirements (>15^{0}C)
- Heating to ensure thermal comfort bandwidths and/or worker productivity relative to function and activity (i.e., sedentary office worker >20^{0}C)
- Cooling to ensure temperatures always meet health requirements (<28^{0}C)
- Cooling to ensure thermal comfort bandwidths and/or worker productivity relative to function and activity (i.e., sedentary office worker <25^{0}C)
- Relative humidity control

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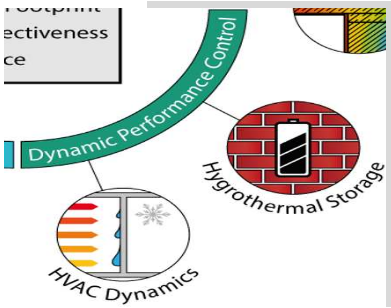
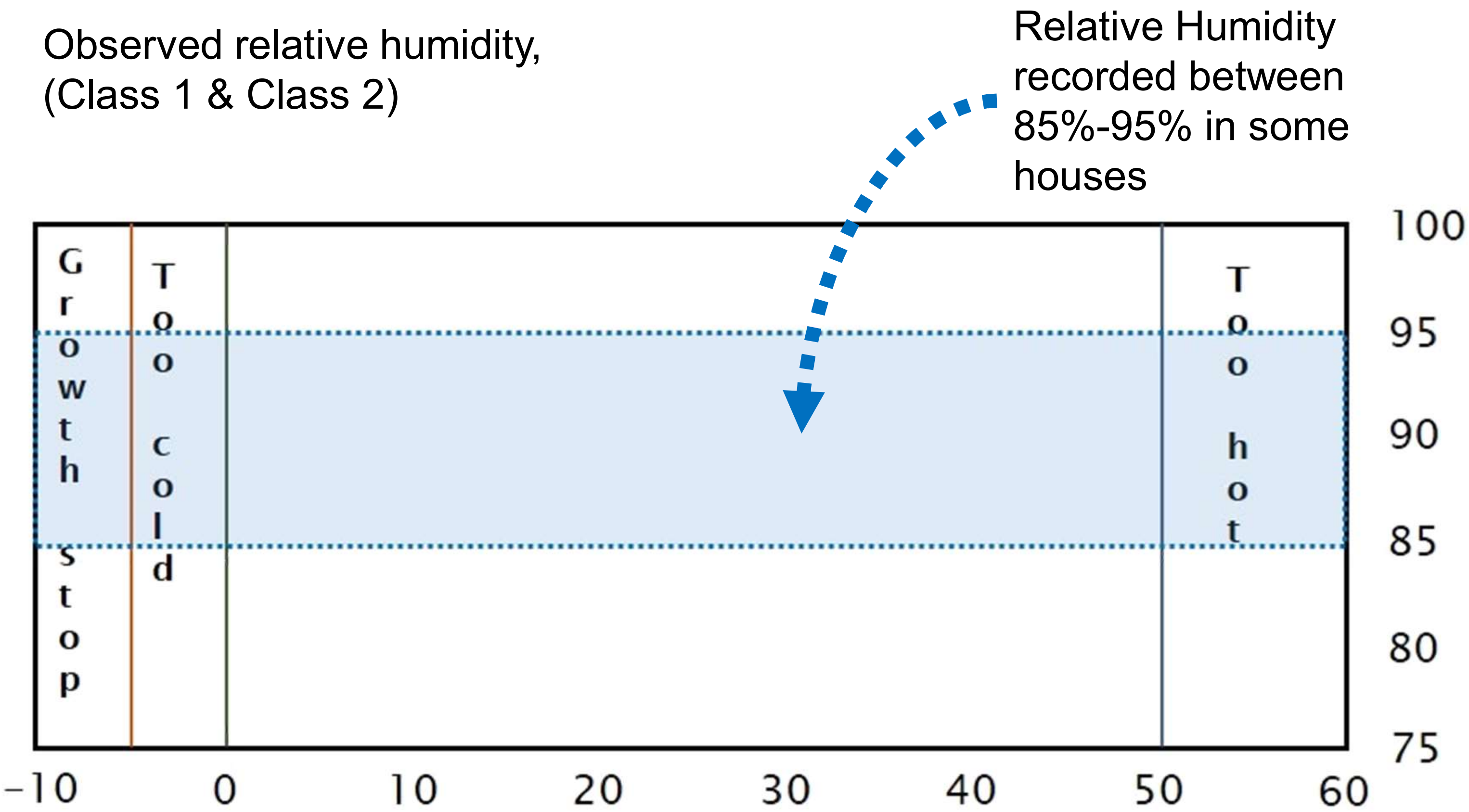
Dynamic humidity control

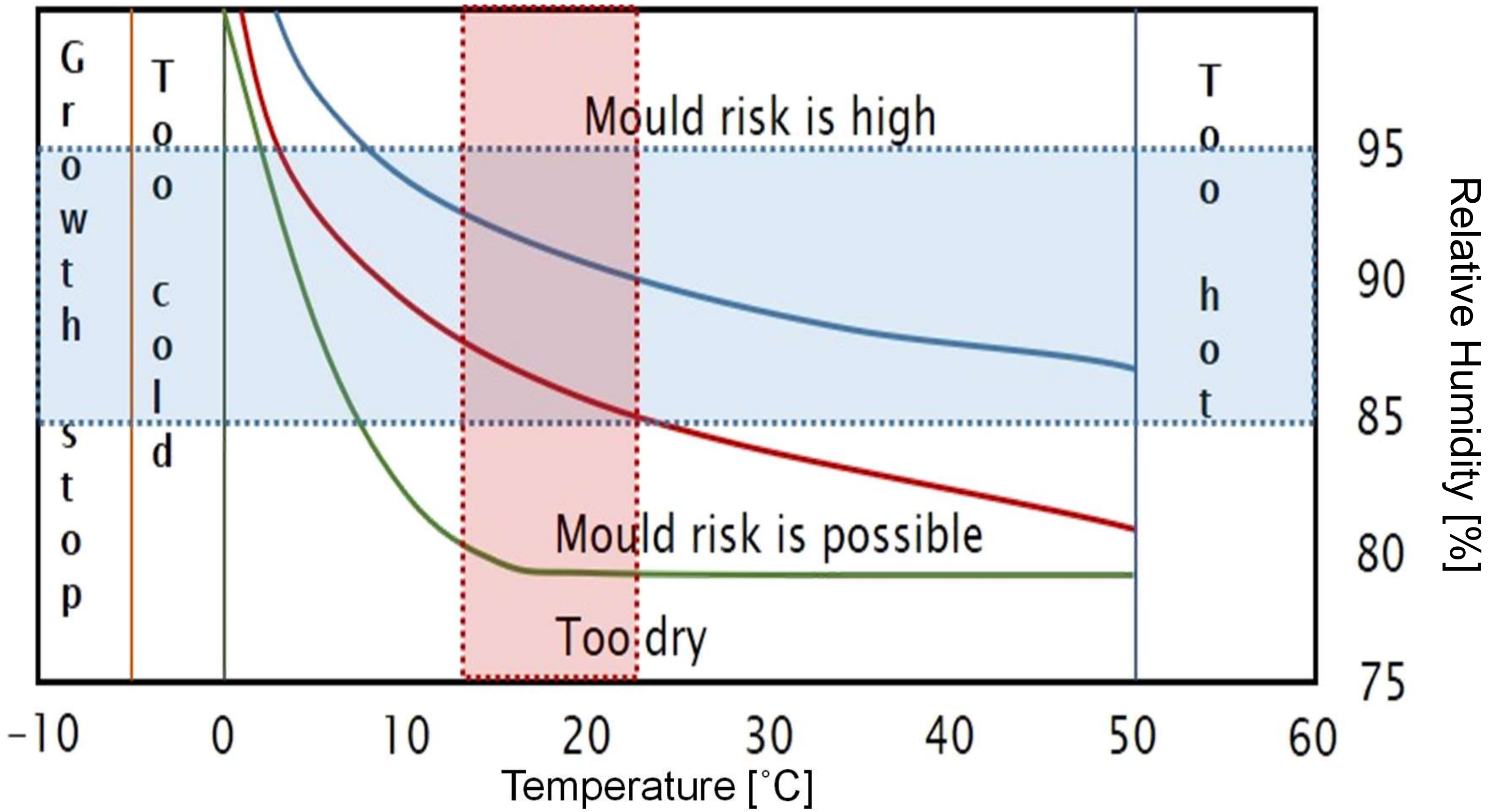


- The relative humidity and its control is an increasingly complex component of the design and construction of buildings.
- Water vapour exists in the air we breath and in most construction materials
- As the air heats up, it absorbs moisture from all materials in the building.
- As the air cools down, materials adsorb the water vapour until either materials become saturated or dew-point temperature is reached.
- Within a building, the amount of water vapour within the air, and water vapour sources, play a pivotal role in the heating, cooling, dehumidification and ventilation energy a building may need.
- Simple or complex static calculations will not provide enough guidance.
- But we have mould growth when the RH is above 75% (recent UK research suggests 60%). What is the RH in Australian buildings?

An Energy Efficient and Healthy Home



An Energy Efficient and Healthy Home??



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Is new housing a health hazard? Nath, Dewsbury, Orr, 2018

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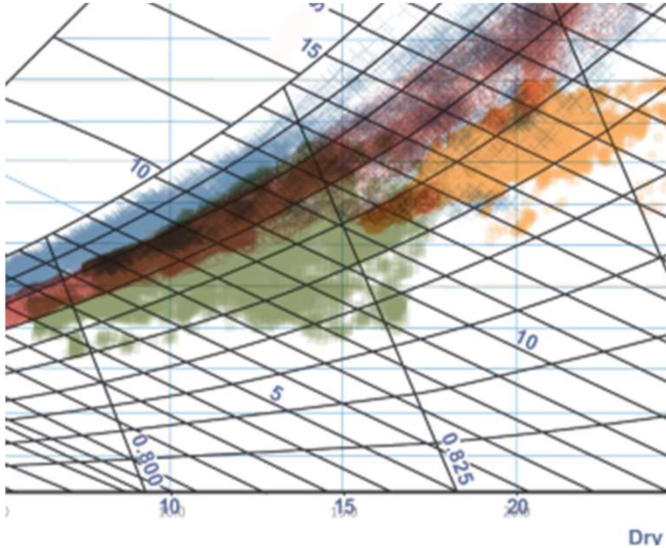
Condensation



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Mould

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Consumer peril

Mould in public housing: Trevallyn family seeks action claiming repeated calls for support go unanswered

Adam Holmes

David and Taylor Kearnes inspect tl
Tasmania house in Trevallyn, which rea

Mould woes add strain for Melbourne re during coronavirus stage 4 lockdown

By Nicole Asher
Posted Sun 30 Aug 2020 at 6:57am, updated Sun 30 Aug 2020 at 8:28am

The hidden signs of mould in your home, and how to protect your house over winter

Kaitlin Peek and Jenny Ky • *The Daily Edition*
Published: 21/05/2020 • Updated: Thursday, 21 May 2020 3:48 pm AEST

Canberra mum 'hospitalised 160 times' due to mould-infested public housing home

By Emily McPherson • Senior Journalist | 12:53pm Aug 1, 2018

Home / Sydney / Inhabitants live in horror due to the spread of mold in Sydney's social residential areas

Sydney

Inhabitants live in horror due to the spread of mold in Sydney's social residential areas

tomwood • February 22, 2021

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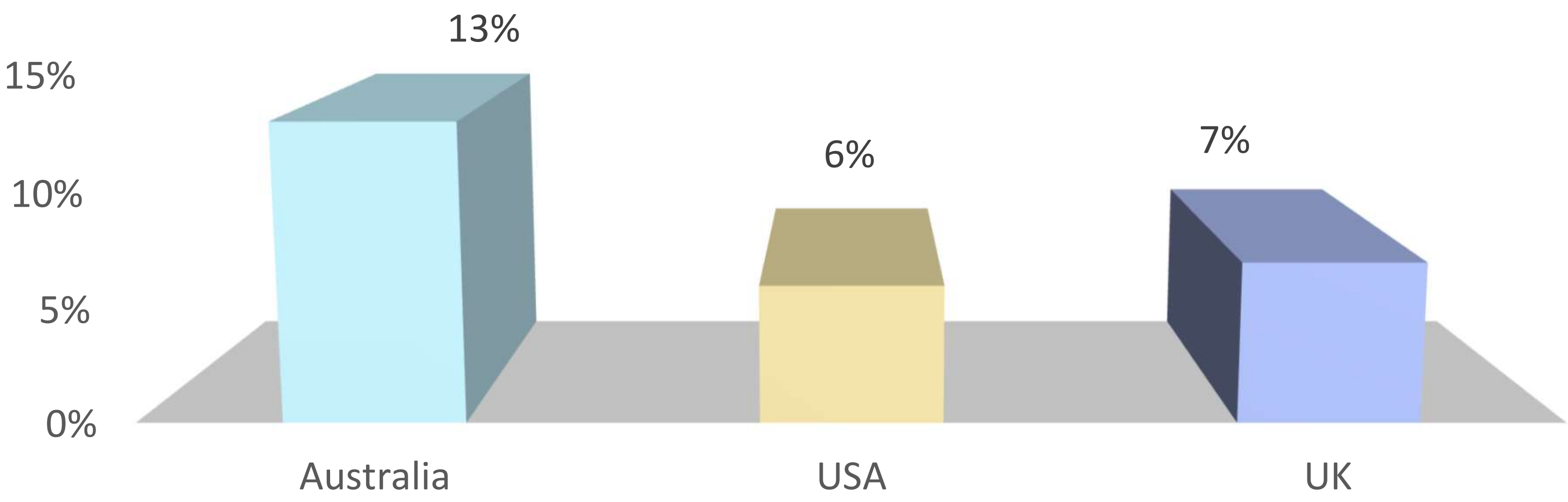
The human health cost

- The 2009 WHO report stated that residential dampness is associated with a 50% increase in Asthma.
- Australia has double the OECD average for Asthma
- In 2019, Australia was the only developed nation with NO comprehensive regulations on condensation and mould in buildings.



Is new housing a health hazard? Nath, Dewsbury, Orr,. 2018

Moisture and condensation

- Sources of moisture
- Water vapour in our homes and workplaces
- When water vapour is not managed properly
- Methods to manage interior generated water vapour
- Methods to manage exterior generated water vapour
- Regulatory support
- Professional risk

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Creating Water vapour in our homes

In 1 month

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Water vapour in our workplaces

- Classroom

– 28 Children @ 80-90 grams per hour

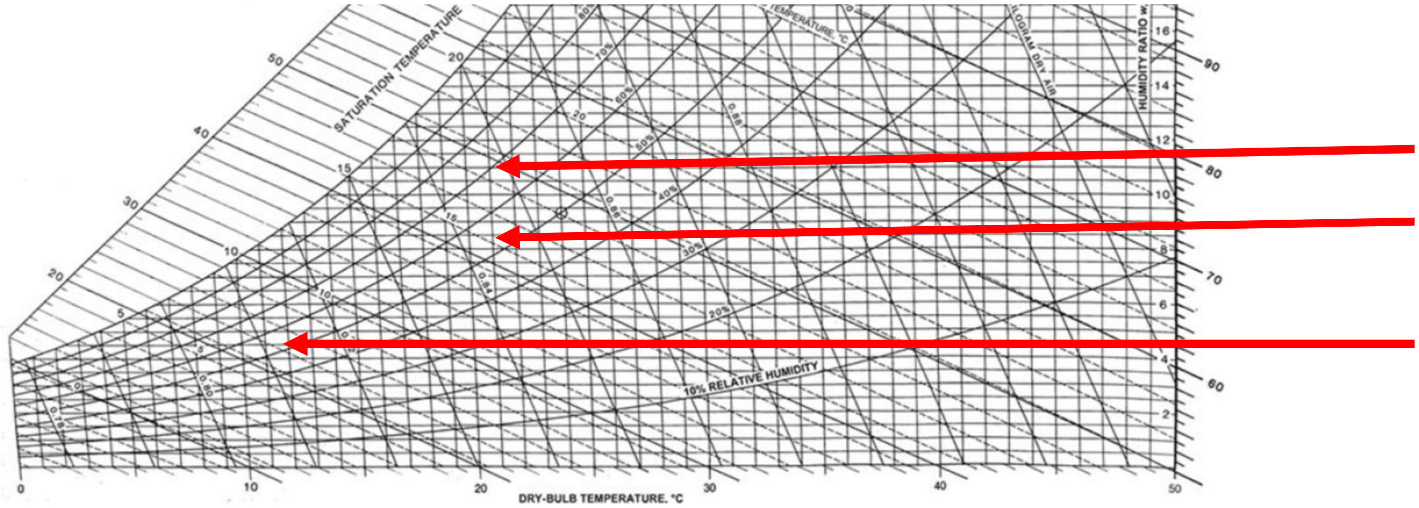
- Office

– 1 person per 10-15 m2, creating 70-90 grams per hour

How much water vapour can the air hold

Humidity ratio of moist air

- grams of water /kg of dry air



21 Deg C, 70% RH = 11 grams/kg

21 Deg C, 55% RH = 9 grams/kg

12 Deg C, 55% RH = 5 grams/kg

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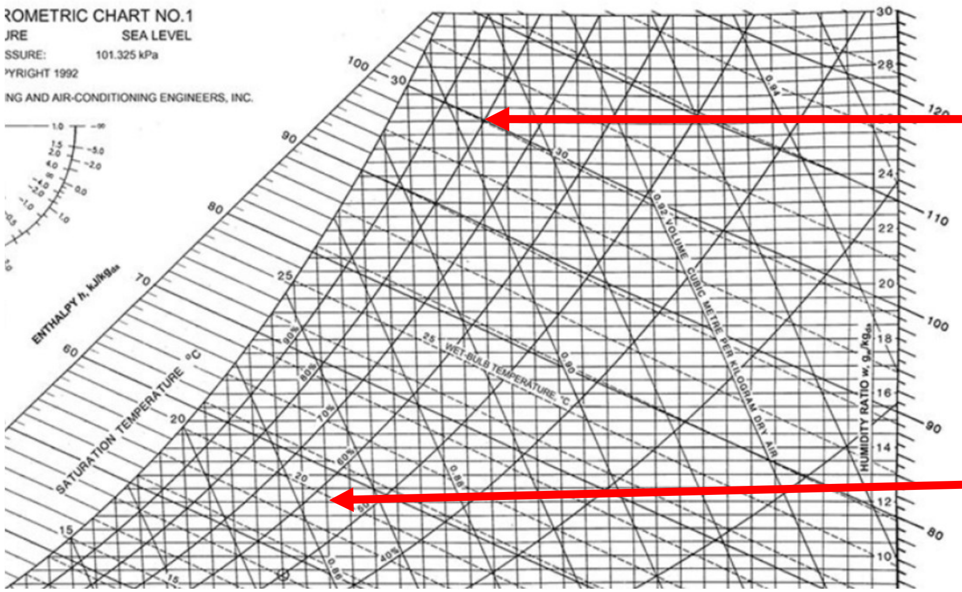
How much water vapour can the air hold

Humidity ratio of moist air

- grams of water /kg of dry air



33 Deg C, 80% RH = 26 grams/kg

26 Deg C, 55% RH = 12 grams/kg

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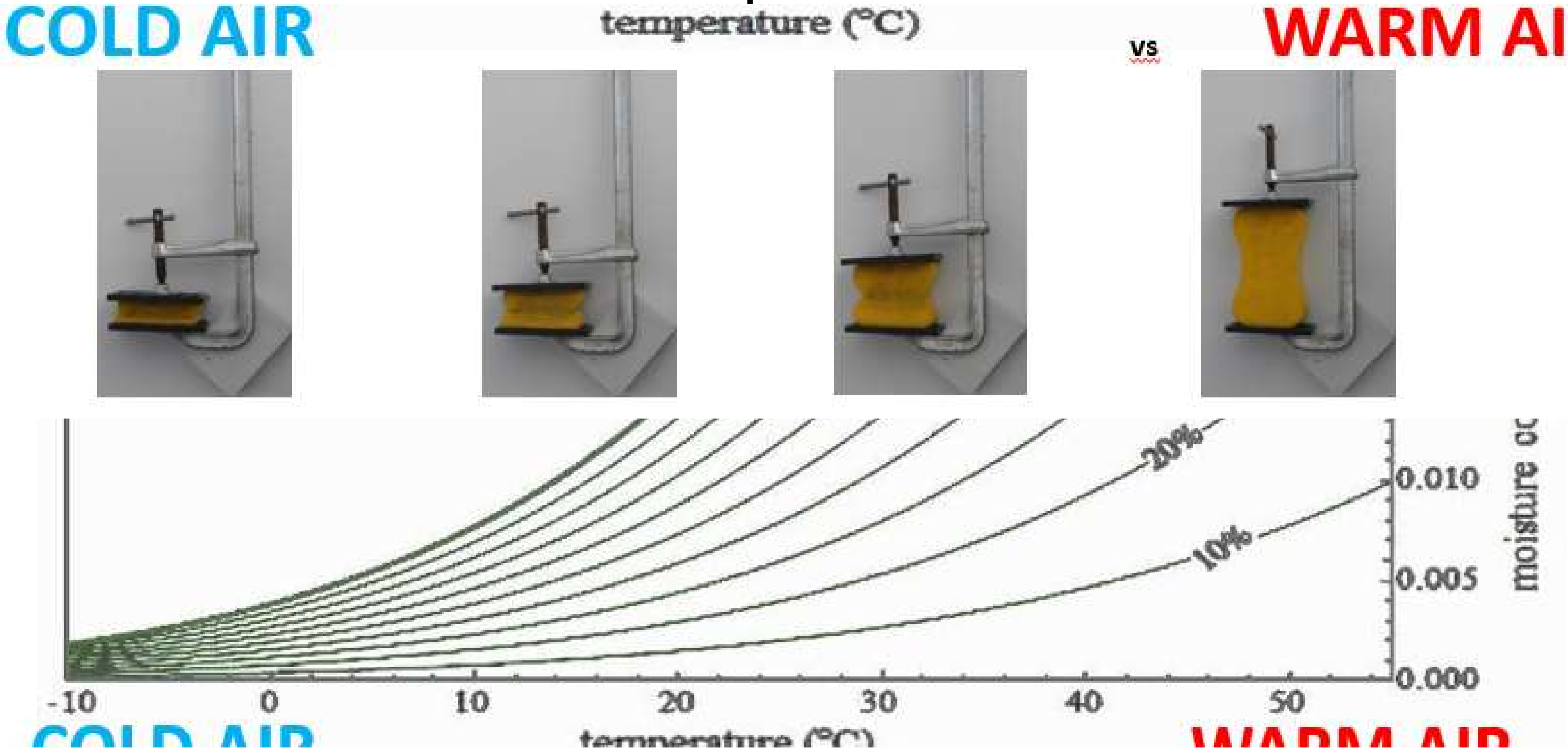
How much water vapour can the air hold



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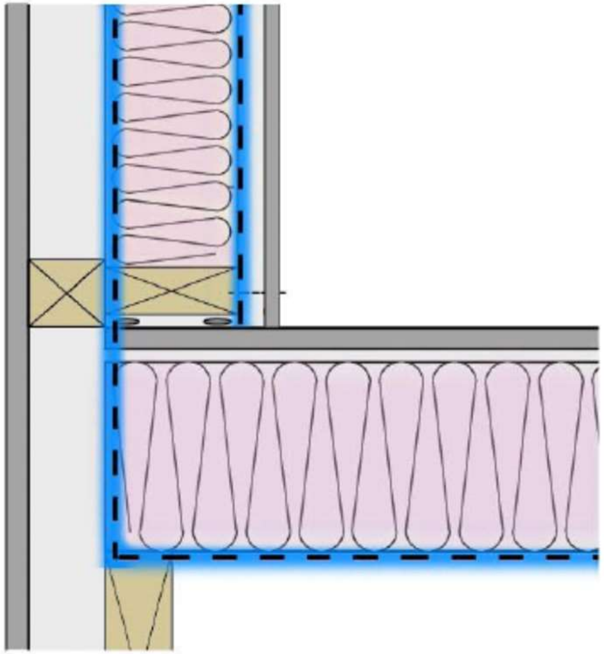
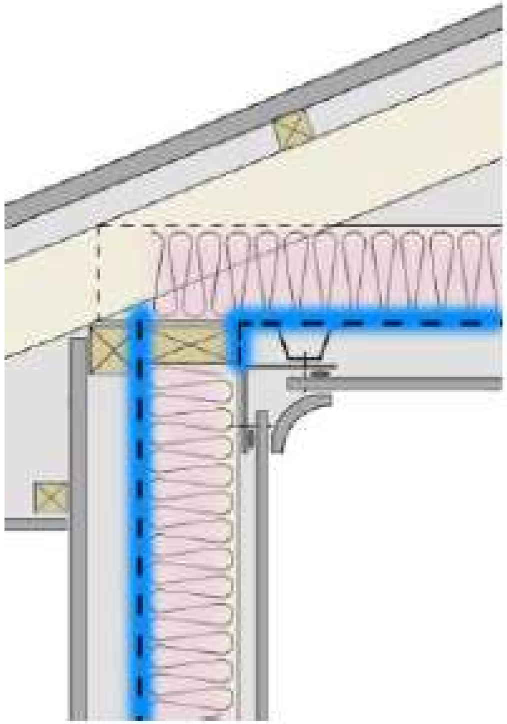
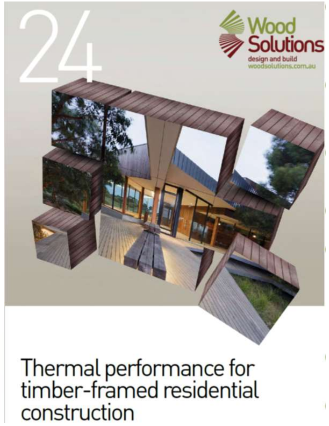
Vapour Control Layers







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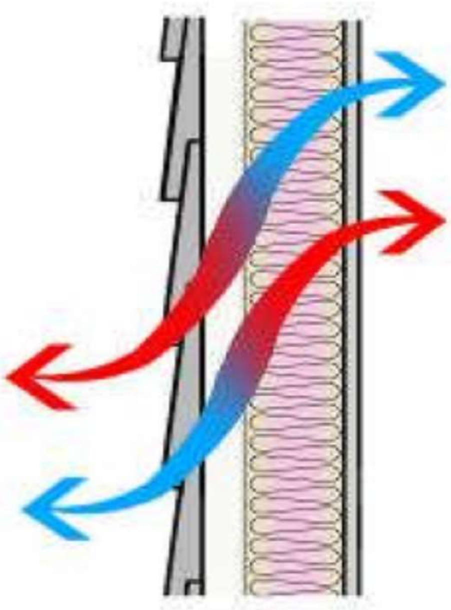
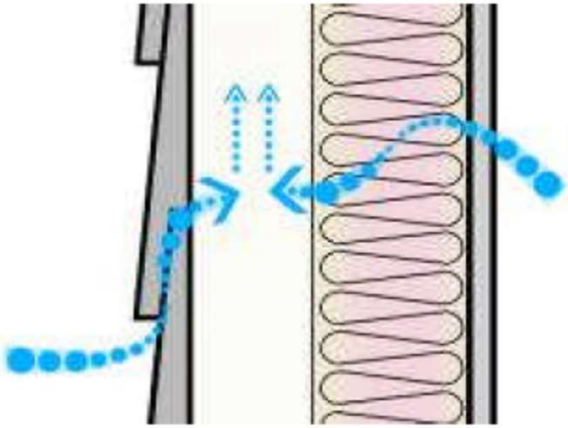
Water Vapour – Managing Vapour Pressure





Vapour Control Layers

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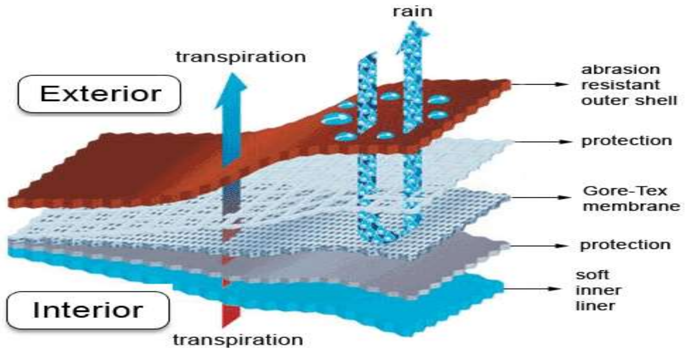
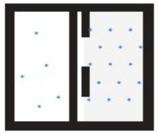
Water Vapour Diffusion

Water Vapour Permeable, and
Water Vapour Impermeable Materials

Vapour impermeable	*Vapour semi-impermeable*	*Vapour semi-permeable*	*Vapour permeable*
Polyethylene, *Vinyl,* *Glass,* *Aluminium foil,* *sheet metal,* *Foil faced insulation*	*Oil based paints* *Some vinyl wall coverings* *Extruded polystyrene* *Paper faced bulk insulation*	*Wood,* *Plywood,* *Particleboard,* *Expanded polystyrene,* *Most plastic paints*	*Unpainted paper-faced plasterboard,* *Unpainted plaster* *Bulk insulation* *(rock-wool, glass-wool and polyster)* *Cellulose insulation* *Timber* *Clay bricks* *Concrete blocks*





Vapour Control - Permeability

Water Control

Gore-tex

Thermal Control

http://www.freshnessmag.com/2009/10/02/adidas-origi ıeighborhood-zivil-courage-diaplex-check-shirt/

http://www.getprice.com.au/Henri-Lloyd-GORE-TEX-Ocean-Explorer-Jacket-Women-Gpnc_668--71896123.htm

http://www.getprice.com.au/Gordini-Elevation-II-Gore-Tex-R-Gloves-Waterproof-Insulated-For-Women-Gpnc_446--90756828.htm

http://www.mcas.com.au/motorcycle-clothing-road-textile-pants/dainese-lontan-gore--tex-pants

http://www.koolstuff.com.au/products/bates-delta-9-gore-tex-black-waterproof-zip-sided-tactical-law-enforcement-army-military-boots.html

Vapour control - permeability

TABLE 4

VAPOUR CONTROL MEMBRANE (VCM) CLASSIFICATION

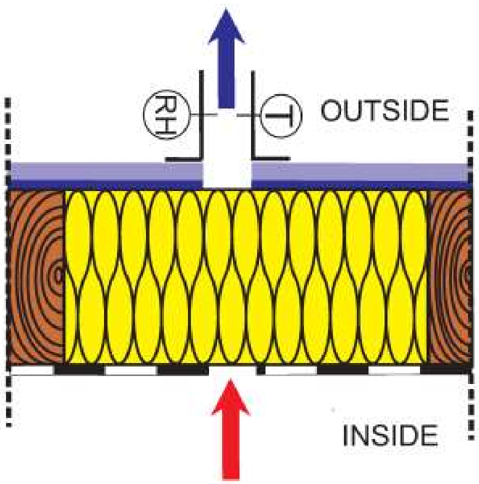
		Vapour permeance (see Note) µg/N.s	
Class	**VCM category**	**Min. (≥)**	**Max. (<)**
Class 1	Vapour barrier	0.0000	0.0022
Class 2		0.0022	0.1429
Class 3	Vapour permeable	0.1429	1.1403
Class 4		1.1403	No max.
	ASTM-E96 Method B Wet Cup—23°C 50%RH		

NOTE: Vapour permeance is the inverse of vapour resistance. It shall be calculated as follows:

Vapour permeance µg/N.s = 1/ (Vapour resistance MN.s/g)

How Much Water Vapour Diffusion?

One 5 mm hole in the middle of the warm side, air extraction at the bottom of cold side (5 Pa)



Kunzel, H, (2019) Fraunhofer IBP

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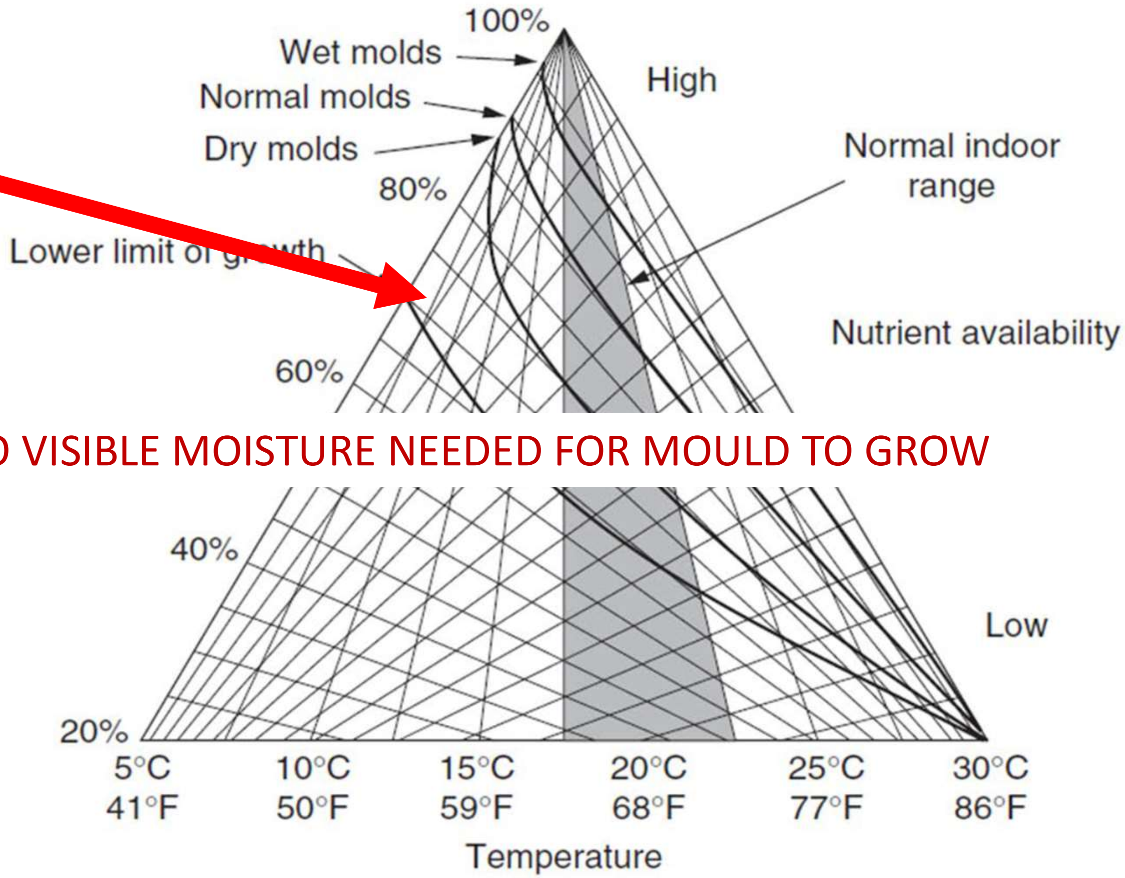
TEMPERATURE, RELATIVE HUMIDITY & MOULD GROWTH

75% RH
@18 deg C



NO VISIBLE MOISTURE NEEDED FOR MOULD TO GROW

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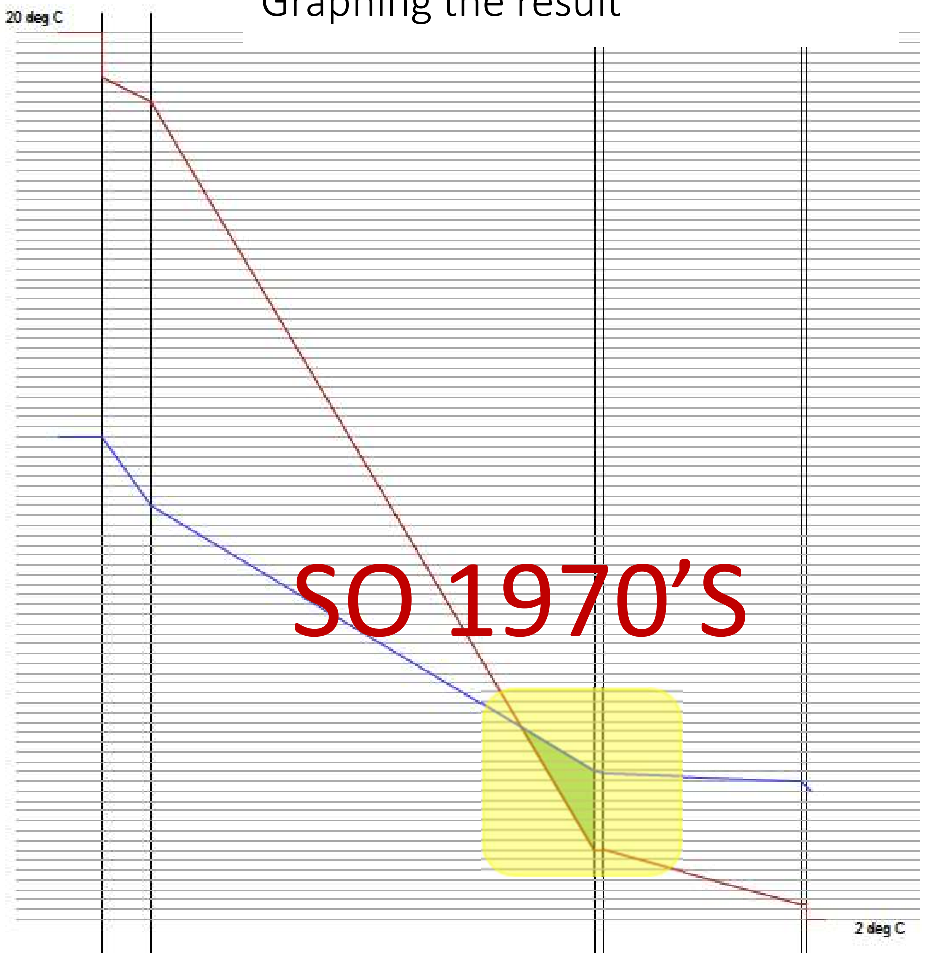
Moisture control

Condensation Risk Calculation



Heat/Energy/Temperature

Dew Point Temperature

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Non-transient simulations

WALL 2

10mm Plasterboard/90mm R2.0 Insulation/*Variable Vapour Membrane*/*Variable Vented Airspace Cavity*/19mm Weatherboard

TASMANIA - COASTAL
CONDITIONED INTERIOR - CLIMATE ZONE 67

WALL 2.1
10mm Plasterboard/90mm R2.0 Insulation/*Vapour Impermable Membrane*/*No Cavity*/19mm Weatherboard
- R Value (out) = 2.42 m²K/W
- Thickness = 119 mm

WALL 2.2
10mm Plasterboard/90mm R2.0 Insulation/*Vapour Permable Membrane*/*No Cavity*/19mm Weatherboard
- R Value (out) = 2.42 m²K/W
- Thickness = 119 mm

WALL 2.3
10mm Plasterboard/90mm R2.0 Insulation/*Vapour Impermable Membrane*/*25mm Cavity*/19mm Weatherboard
- R Value (out) = 3.27 m²K/W
- Thickness = 144 mm

WALL 2.4
10mm Plasterboard/90mm R2.0 Insulation/*Vapour Permable Membrane*/*25mm Cavity*/19mm Weatherboard
- R Value (out) = 3.27 m²K/W
- Thickness = 144 mm

Australian NatHERS Dew Point Analysis

Annual Moisture Accumulation 0 kg/m²

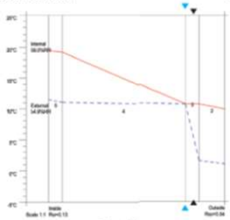

Fig. 17

Condensation @ Layer: Insulation
Peak Buildup: 0.37927 kg/m²

Annual Moisture Accumulation 0 kg/m²

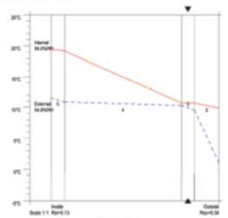

Fig. 18

Condensation @ Layer: N/A
Peak Buildup: 0 kg/m²

Annual Moisture Accumulation 0 kg/m²

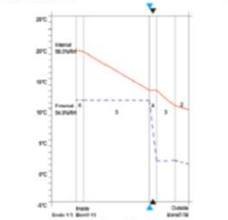

Fig. 19

Condensation @ Layer: Insulation
Peak Buildup: 0.69253 kg/m²

Annual Moisture Accumulation 0 kg/m²

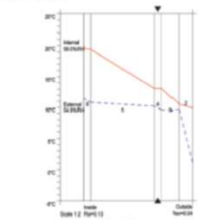

Fig. 20

Condensation @ Layer: N/A
Peak Buildup: 0 kg/m²

International ISO NatHERS Dew Point Analysis

Annual Moisture Accumulation 0 kg/m²

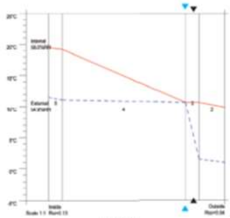

Fig. 21

Condensation @ Layer: Insulation
Peak Buildup: 0.37927 kg/m²

Annual Moisture Accumulation 0 kg/m²

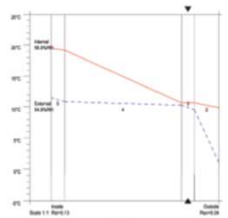

Fig. 22

Condensation @ Layer: N/A
Peak Buildup: 0 kg/m²

Annual Moisture Accumulation 0 kg/m²

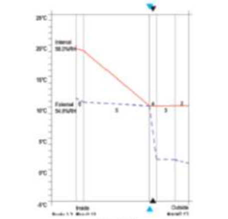

Fig. 23

Condensation @ Layer: Insulation
Peak Buildup: 0.69253 kg/m²

Annual Moisture Accumulation 0 kg/m²

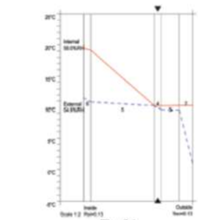

Fig. 24

Condensation @ Layer: N/A
Peak Buildup: 0 kg/m²

Buildup kg/m² Buildup kg/m²

COMMENTARY

Cavity ventilation affects air temperature at vapour barrier

The closed air cavity acts as an insulator in the Australian simulations. The simulated air temperature in the wall does not fall to outside air temperatures until the cladding.

The vented air cavity is more realistic in the International ISO simulations. The temperature in the air cavity is closer to the outside air temperature.

Fig. 19 shows a temperature of approx. 13° C at the vapour barrier vs the more realistic value of approx. 11° C in Fig. 23, where it meets the dewpoint and condenses at the insulation layer.

Permeabiity of vapour barrier

LEGEND
- Vapour Barrier
- Condensation Point
- Air Temperature
- Dew Point Temperature

7

Airspace Cavity/19mm Weatherboard

TASMANIA - ALPINE
CONDITIONED INTERIOR - CLIMATE ZONE 69

VALL 2.3
0mm Plasterboard/90mm R2.0 Insulation/*Vapour Impermable Membrane*/*5mm Cavity*/19mm Weatherboard
- R Value (out) = 3.27 m²K/W
- Thickness = 144 mm

WALL 2.4
10mm Plasterboard/90mm R2.0 Insulation/*Vapour Permable Membrane*/*25mm Cavity*/19mm Weatherboard
- R Value (out) = 3.27 m²K/W
- Thickness = 144 mm

nnual oisture ccumulation 0 kg/m²

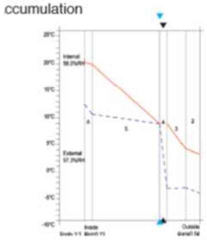

Fig. 53

ondensation Layer: Insulation
eak uildup: 0.69253 kg/m²

Annual Moisture Accumulation 0 kg/m²

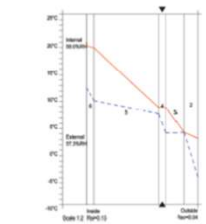

Fig. 55

Condensation @ Layer: N/A
Peak Buildup: 0 kg/m²

nnual oisture ccumulation 0 kg/m²

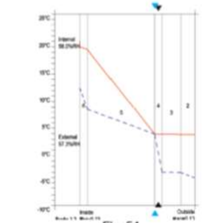

Fig. 54

ondensation Layer: Insulation
eak Buildup: 0.69253 kg/m²

Annual Moisture Accumulation 0 kg/m²

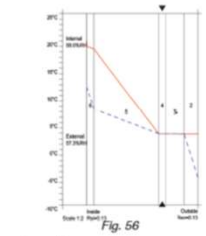

Fig. 56

Condensation @ Layer: N/A
Peak Buildup: 0 kg/m²

COMMENTARY

LEGEND
- Vapour Barrier
- Condensation Point
- Air Temperature
- Dew Point Temperature

11

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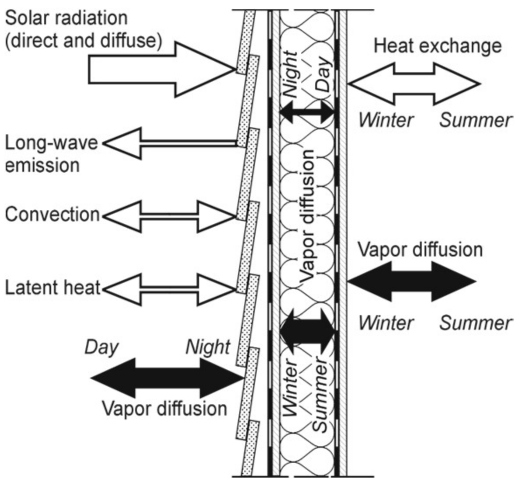
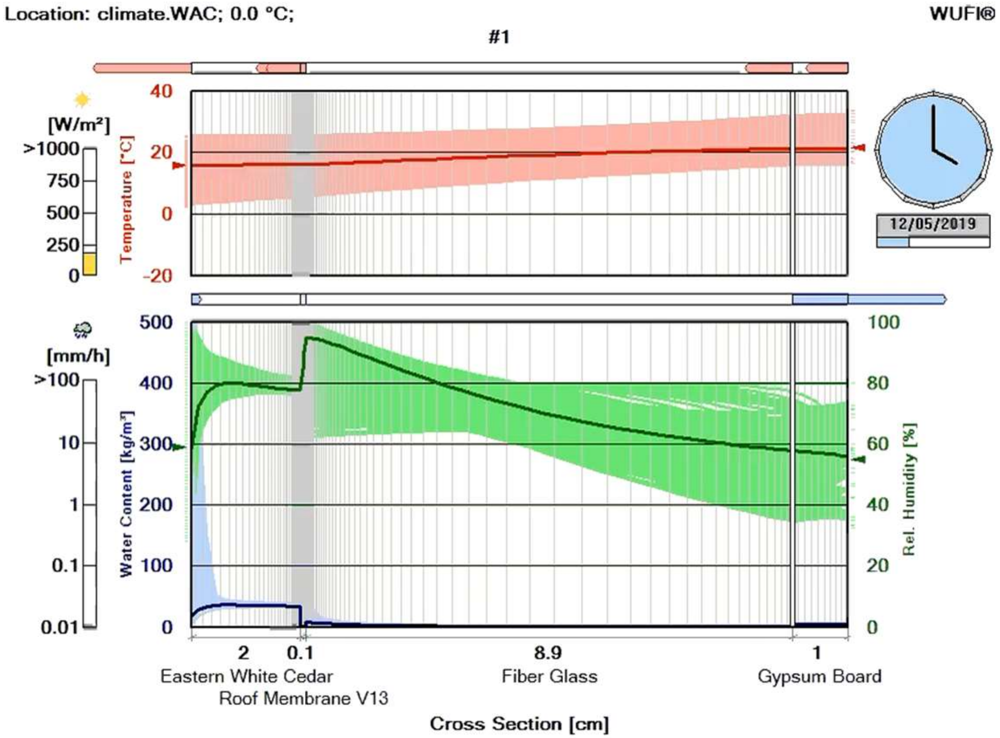
Transient Hygrothermal Calculation Method

- Dynamic temperature (top) and moisture (bottom) in a timber frame wall

SO 2020





Kunzel, H, (2019) Fraunhofer IBP

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https://www.researchgate.net/profile/Mark_Dewsbury

Regulatory inadequacy

Orientation	VTT	source	paint	permeable	membrane
North					
South					
East					
West					
North					
South					
East					
West			5629		
North					
South					
East					
West			0	0	
North					
South			0		
East					
West			1	9	11
North					
South			0		
East			0		
West			0	0	10
North					
South			0		
East			0		
West			0	0	

East		0		
West		0	3	0
North		0		
South		0		
East		0		
West		9	8	0
North		0	0	0
South		0	0	0
East		0	0	0
West		0	6	0

membrane - 10 years calculation (Heating only)

Map/Ashrae160

Orientation	VTT	With moisture source	with latex paint	latex +vapour permeable
North				
South				
East				
West				
North				
South			0	0
East				
West			0	0
North				
South			10	0
East				
West			0	0
North				
South			0	0
East			0	
West			1	0
North			0	0
South			0	0
East			0	0
West			0	0
North			0	0
South			0	0
East			0	0
West			0	0

10 years calculation

160

		VTT	With moisture source	with latex paint	
			0		
			0		
			0		
			0	3303	
			0		
			0		
			0		
			0	2	0
			0		
5&6 star- permeable	South		0		
5&6 star- permeable	East		0		
5&6 star- permeable	West		0	0	0
7 star - permeable	North		0		
7 star - permeable	South		0	0	0
7 star - permeable	East		0		
7 star - permeable	West		1	0	8

East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				

membrane - 10 years calculation (Heating only)

Map/Ashrae160

Orientation	VTT	With moisture source	with latex paint	latex +vapour permeable
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				
North				
South				
East				
West				

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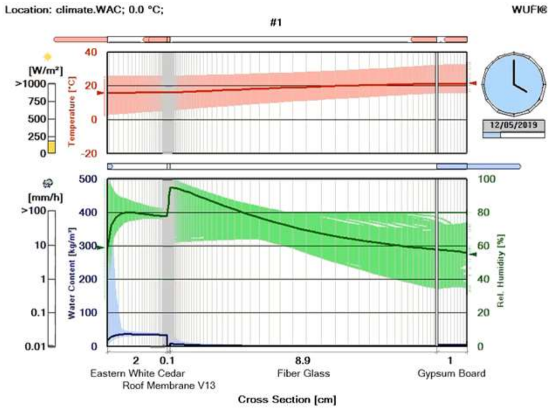
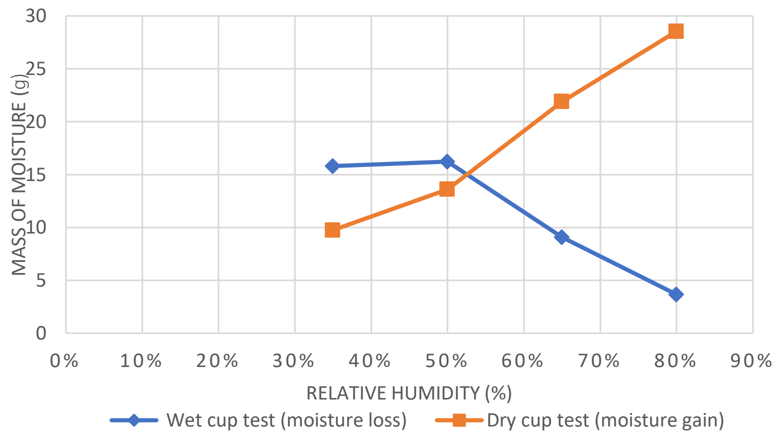
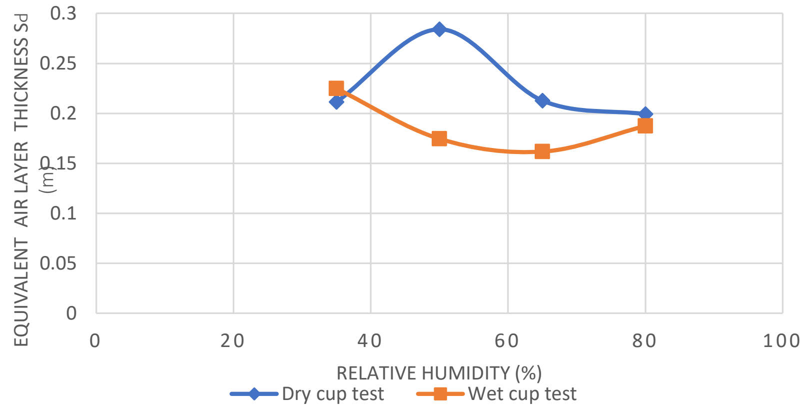
Vapour resistivity & the single point testing method?





Transfer of moisture in varying relative humidity for sample A



Dynamic characteristics of the equivalent diffusion air layer thickness for Sample B

- 23^{0}C & 35% RH
- 23^{0}C & 50% RH
- 23^{0}C & 65% RH
- 23^{0}C & 80% RH

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Five Key Principles for Effective External Envelopes

Thermal control layer – Reduce contact between warm and cool building materials (thermal bridging)

Vapour control layer – Materials that allow the climatically appropriate passive flow of water vapour

Water control layer – Moisture forms on the interior and exterior surface of cladding materials. A systems approach is needed.

Ventilation – The design of passive ventilation strategies for unconditioned roof spaces, wall cavities and subfloor space, (includes supply and exhaust)
** And occupant controlled or mechanical ventilation of habitable rooms

BAL – Where required ventilation includes materials that apply AS3959 principles

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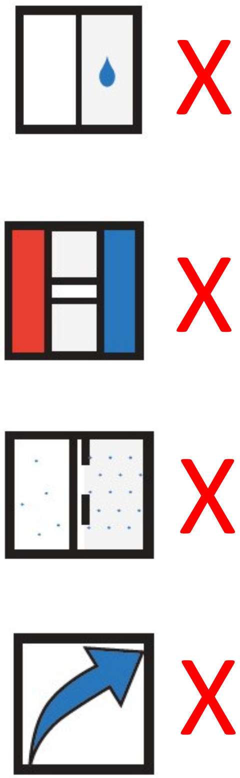
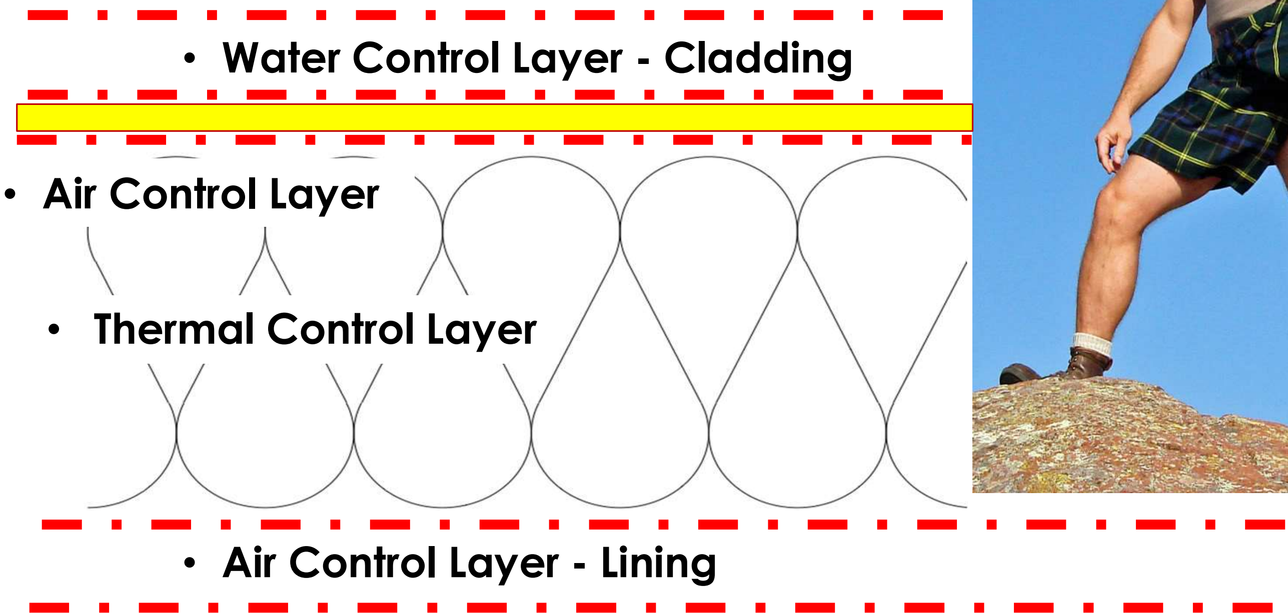
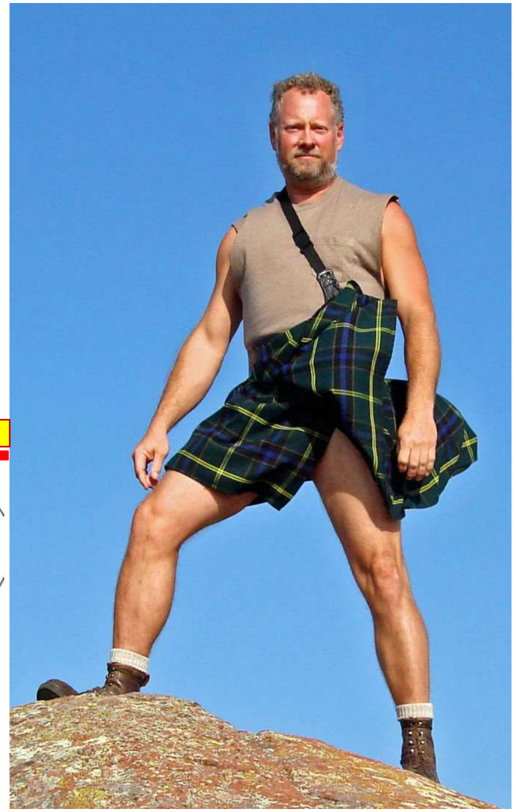
4 Key Principles







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4 Key Principles

- **Water Control Layer – Cladding external surface**
- **Water Control Layer – Cladding internal surface**
    - Vented cavity zone
- **Vapour Control Layer**
- **Air Control Layer**
- **Thermal Control Layer**
- **Air Control Layer - Lining**

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Mould Index	Definition
Nil	No simulated mould growth was simulated
</=1.0	Acceptable level of mould growth was simulated
>1.0 to <3.0	An amount of mould growth was simulated that requires further investigation
3.0>	Unacceptable amount of mould growth was simulated

Membrane Permeance

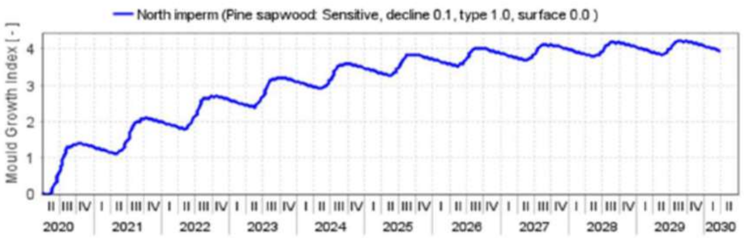

Figure 17: Timber clad wall, northern orientation, Nathers CZ66, impermeable building membrane

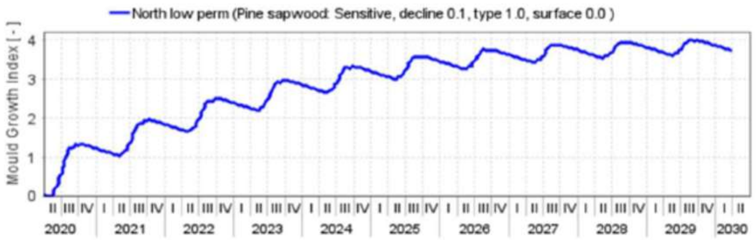

Figure 18: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 3 permeable building membrane

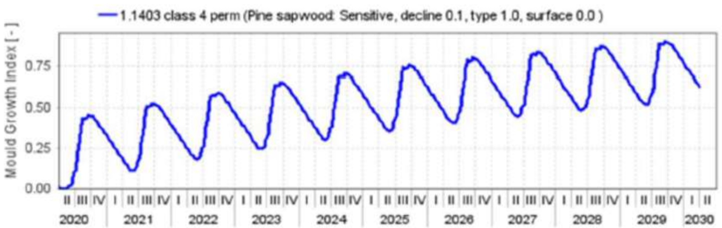

Figure 19: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s)

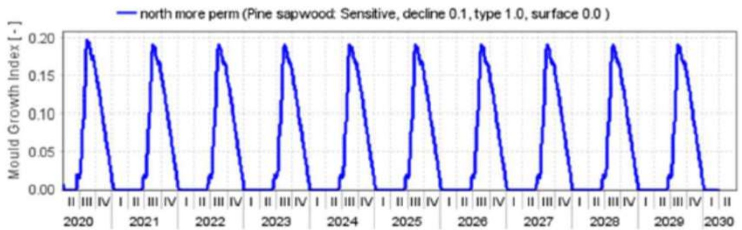

Figure 20: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 extremely permeable building membrane (not available in Australia)

Building air-tightness

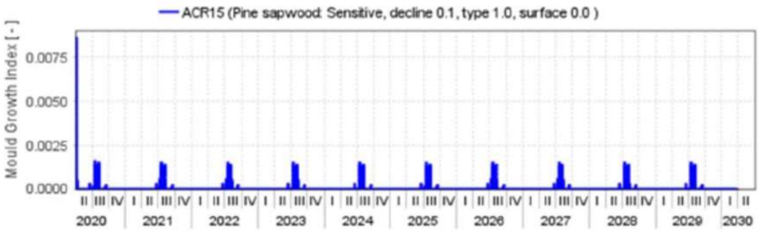

Figure 23: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s) ACR 15

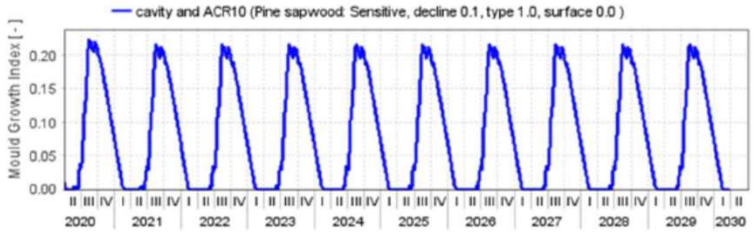

Figure 24: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s) ACR 10

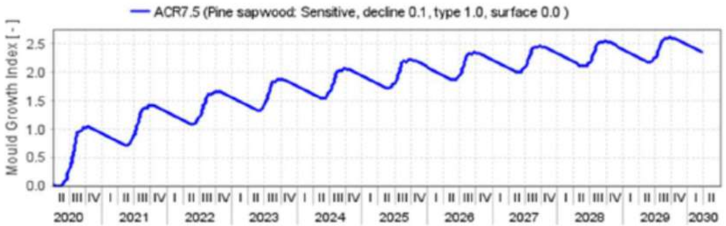

Figure 25: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s) ACR 7.5

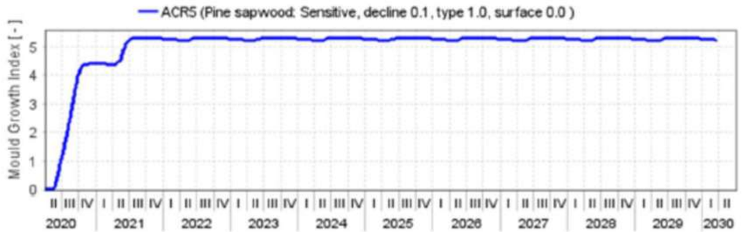

Figure 26: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s) ACR 5.0

Vented cavity systems (mass vapour transport)

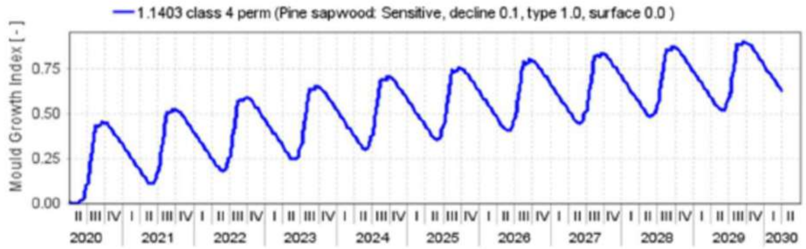

Figure 21: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s)

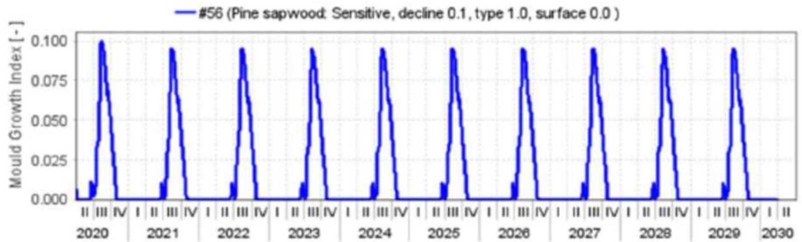

Figure 22: Timber clad wall, northern orientation, Nathers CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s)

Designing Healthy Homes

Questions?

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