Weather-tightness, Insulation, Air-tightness, Ventilation, and Condensation

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An evolving lifestyle

- In the mid 20th century, it was not uncommon to find it cooler outside the house in summer and warmer outside the house in winter.
- For productivity reasons, many workplaces have become air-conditioned (heated and cooled) since the 1960’s
- Our cars became air-conditioned from the 1990’s
- As national wealth increased a change in conditioning patterns occurred in our homes, where the heating or cooling of more than a single room has become more common.
- Would I still feel comfortable driving my EJ Holden today?

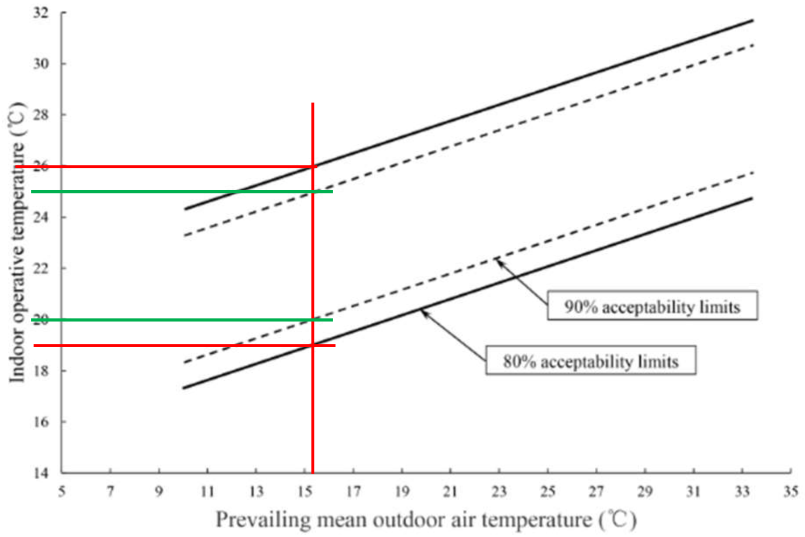
NCC2022 – Energy Efficiency - 7 Stars

- A 25% reduction in simulated heating and cooling energy use when compared to a 6 Star design.
- 4 Star homes were mostly Deemed To Satisfy (DTS) designs.
- 5 Star homes saw up to 50% of Class 1 and Class 2 designs utilising NatHERS.
- 6 Star homes saw more than 90% of Class 1 and Class 2 designs utilising NatHERS.
- 7 Stars – it is expected that close to 100% of Class 1 and Class 2 designs will utilise NatHERS.

Thermal comfort

Mean Temp Melbourne
15.1 °C

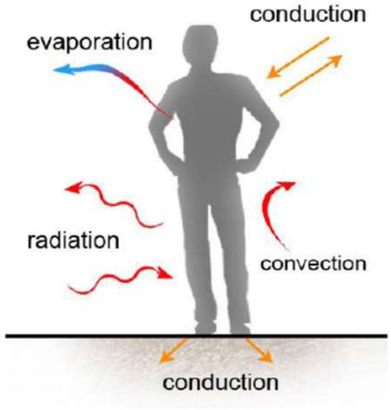
For long term health reasons, no habitable room should have an air temperature of less than 15 °C. (cardio-vascular and respiratory)

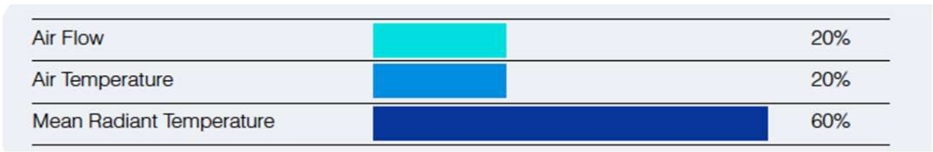


ANSI/ASHRAE 55:2017

Figure 2: Adaptive comfort models represented in ANSI/ASHRAE 55:2017.

Thermal Comfort
Mean Radiant Temperature





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More than 60% of how we experience temperature in the built environment is governed by Mean Radiant Temperature.
MRT is the temperature of the surfaces that surround us – floor, walls, windows, doors, ceiling.
Air temperature affects about 20-35% of our experience.
The rest is governed by air flow. In still air, we feel more MRT, whilst in a breezy situation we feel more Air temperature.
The focus of energy efficiency regulations and simulation is to establish MRT within expected thermal comfort bandwidths.
A comparison can be an uninsulated house in summer with a hot ceiling and hot walls. The air is cooled by the reverse-cycle air-con but you still feel hot (MRT). Or an uninsulated house in winter with a cold floor, walls and ceiling. The reverse-cycle air-con is pumping air out at 27degC but you still feel cold (MRT).

Weather Resistance

- Weather resistance during construction

We need to protect the structure of our buildings during construction. As as practically possible, we wrap our walls and enclose our roof system to keep the built fabric and the interior dry.

Weather Resistance

• Weather Resistance after construction

After we apply roofing and external wall cladding, these elements provide a first layer of moisture and wind/air control. But our cladding system should have a cavity and our roof system should be ventilated. This means that the air temperature under our roofing and inside our cladding, is close to outdoor air temperature.

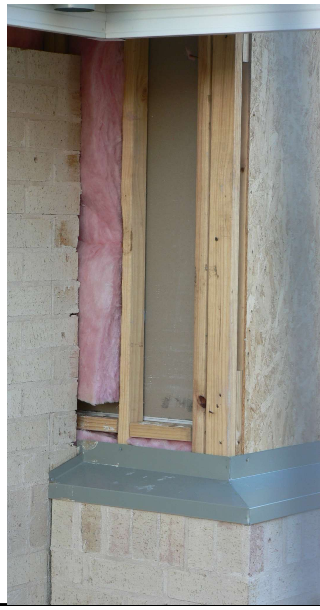
NCC2022 – Rain Screen/ Cavity wall construction

- Aside from clay masonry there is no requirement to provide a vented and drained cavity behind the cladding system.
- This seems to ignore the decades of international experience that has identified moisture and wind driven rain ingress past the cladding system.
- One could argue that this is where the term ‘rain screen’ came from.
  That is…. NOT a rain Barrier

Internationally, and within Australia, it has been known for decades that moisture is apparent on the inside of the cladding system. This may be caused via small gaps, wind pressure, air flow and heavy rain.
Other nations require a drainage plane behind most cladding systems, which allows for this moisture to drain, without impacting the structural and insulation layers.

Weather Resistance

- Wind / cold air resistance after construction



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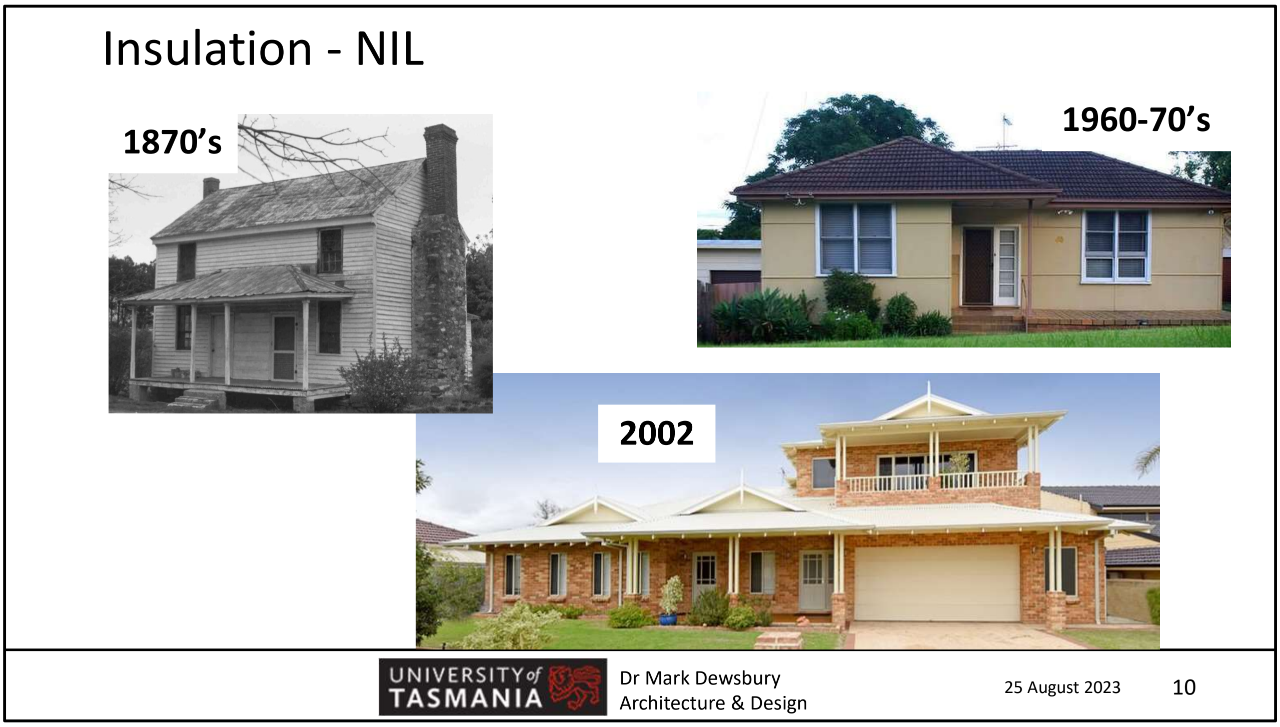
In many parts of Australia, a building wrap is still not used on the outside of the timber frame. From a weather resistance perspective, this allows for the cold wind and any moisture to enter the structural and insulation layers. This can lead to compromised wet insulation and structural decay.
We have not used old growth hardwood in our buildings for a few decades now. Softwood is not as durable. We need to design and make buildings that recognise this difference.



Until 2003, there was no national requirement to insulation ceilings, external walls and suspended floors.

Insulation

- Quality of Installation (AS4859)
- – snug and no gaps



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Insulation needs to be well installed, snug and with no gaps. Even 5% of gaps will significantly reduce the overall insulation of an external wall, floor or ceiling.
Wall Batt – R 2.5
Pine Stud – R 0.9
Air Gap – R 0.13

Insulation

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Insulation

- Prevent exterior hot/cold cold air from washing against the insulation ……. We need an exterior membrane layer

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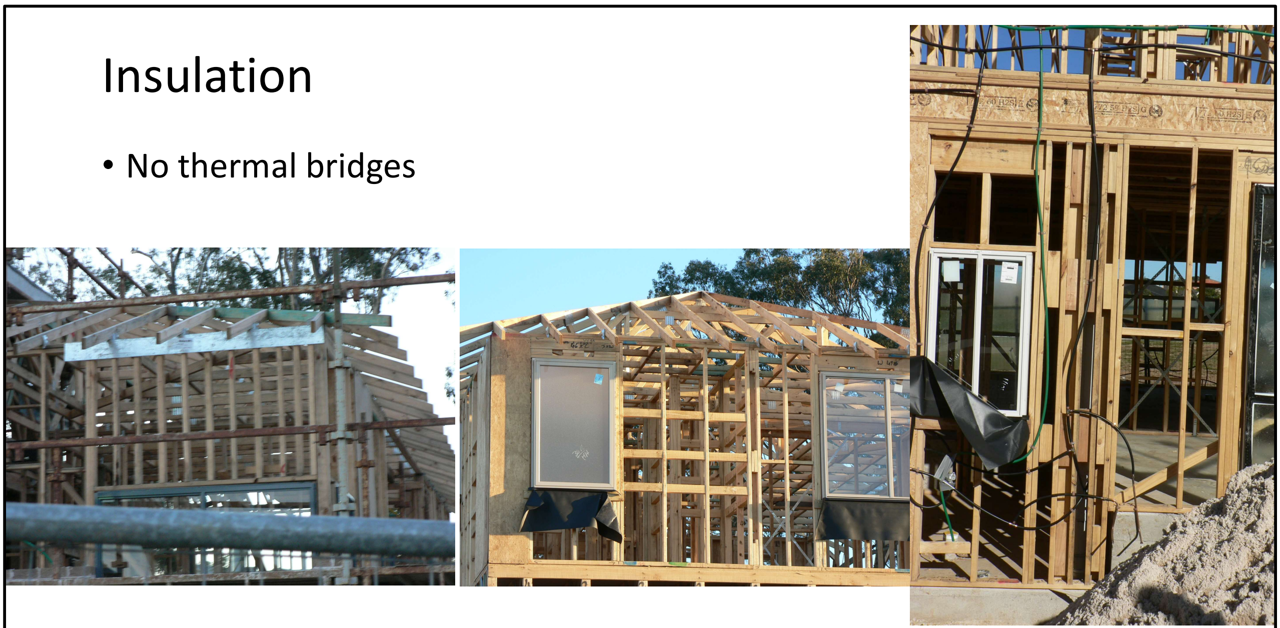
The other aspect is the need to restrict the flow of cold air around the exterior side of the insulation. Gaps in the insulation promote air flow, such that the outside surface of the paper-faced plasterboard is at outdoor air-temperature. Additionally, air flow past the insulation wicks energy off the batts and timber, thus making them colder – this is referred to wind-washing.
By applying an exterior membrane, we improve the chances for the insulation to do its job.

Insulation

- No thermal bridges



Thermal bridges will significantly impact a buildings performance in summer and winter.
Remember a Pine Stud/plate/nogging has an R value of 0.9. The wall batts R2.0 to 2.7. Ceiling batts R4.0 or more.

Insulation

- No thermal bridges

Steel has an R value of 0.00

Calculating an envelope system u-value

System		Thickness	K Value	R Value
Inner Surface		na	na	0.12
Internal Lining	Plasterboard	0.010	0.170	0.06
R-2.0 Batt Insulation	Glass wool	0.090	na	2.00
Pliable membrane		0.001	na	0.00
Cavity	Non-ref	0.040	na	0.25
Cladding		0.020	0.160	0.13
Outer Surface		na	na	0.06
			R- Value	2.62
u-value = 1/R value			u-Value	0.38

u-value - 0.38 Watts/m^2.K

This table shows the calculated R-Value for an external wall.
The inner and outer surface is the fraction of a mm of air that exists between the material and the interior/exterior air.
We can see that:

- The inner surface has twice the R-value of the plasterboard
- The outer surface has half the value of the timber cladding
- The R 2.0 insulation is providing 2/2.62 = 76% of the insulation properties of the wall system.

- This table also shows that the U-value for this wall system is 0.38. This means that 0.38 watts of energy will flow through this wall, per degree difference in temperature.
- If indoors is 21degC and outdoors is 7deg C…. 0.38 x (21-7) = 5.32 watts of heat flow per m2 of wall area.

u-value – so what

System	u-value	Area (m2)	T_{inside}-$T_{outside}$	Watts of heat flow
Insulated wall	0.38	50	17	323.0
Single glazing	5.67	50	17	4,819.5
Un-insulated ceiling	2.04	50	17	1,734.0
Un-insulated wall	1.16	50	17	986.0

This slide shows the relative heat flow through 50m2 of an insulated wall, single glazing, uninsulated ceiling and an uninsulated wall.
This indicates in this scenario, to maintain the room temperature at 21 deg C:

- the insulated wall area would need 323 watts of heating,
- The single glazed area would need 4,819 watts of heating,
- The uninsulated ceiling would need 1,734 watts of heating, and
- The uninsulated wall would need 986 watts of heating.

Materials for envelope insulation

Different materials have very different properties

Material	Thickness mm	Thermal Conductivity W/(m K) – 1m	Thermal Resistance R-value (m.k)/W
General fabric materials			
Aluminium	90	221.000	0.000
Steel	90	45.300	0.002
Glass	4	1.000	0.004
Paper Faced Plasterboard	10	0.160	0.063
Clay Brick Extruded	110	0.614	0.179
Timber – Hardwood	90	0.176	0.523
Timber – Softwood	90	0.110	0.818
Insulation products			
Glass Wool Insulation	90	0.044	2.045
Expanded Polystyrene	90	0.039	2.308

This slide shows dome relative R-Values for some common construction materials

Materials for envelope insulation

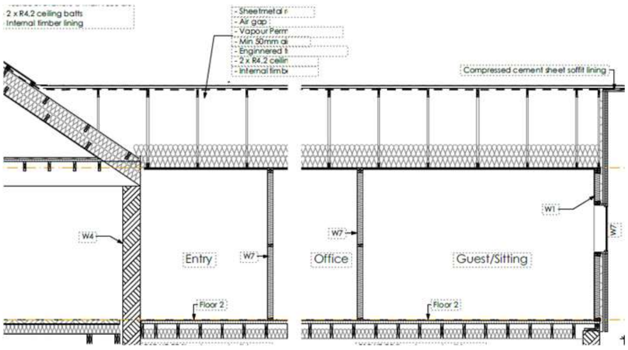
Different materials have very different properties

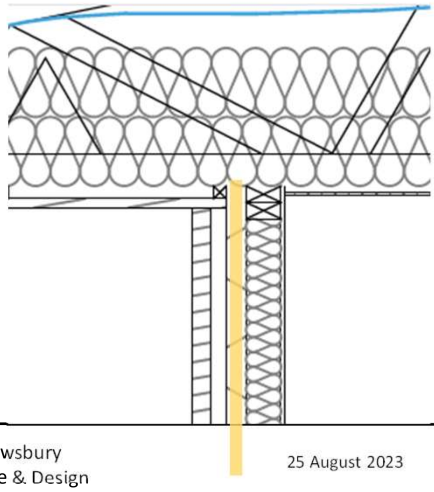
Material	Thermal Resistance R-value (m2.k)/W
Glass-wool (7 kg/m³)	R 1.754
Glass-wool (12 kg/m³)	R 2.273
Mineral-wool (37 kg/m³)	R 2.500
Polyester (8 kg/m³)	R 1.587
Polyester (16 kg/m³)	R 2.222
Lamb's wool (16 kg/m³)	R 2.222
Expanded polystyrene	R 2.564
Extruded polystyrene	R 3.571
Spray-in-place foam	R 3.571

This slide shows dome differences in the R-value of insulation products. This shows that the different R-Values are established based on the material physical properties and the density of the material.

Insulation

- Should we over-clad the frame – France, Canada, US 1990's





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Adding two layers of insulation in a roof space, eliminates thermal bridges caused by the ceiling structure.
Adding a layer of insulation on the outside of the timber frame (EPS, XPS, Wood fibreboard, Rockwool) can stop the thermal bridging caused the wall system structure. Overcladdding of the wall frame must also consider climatically appropriate water vapour control.

Air-tightness 20 to 50 ACH

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Until 2004, there was no requirement to consider air-tightness in Australian buildings.

Air-tightness

• exterior

Exterior airtightness achieved through the use of pliable membranes and plywood type products stop the cold/hot exterior air interacting with the insulation layer.

Air-tightness

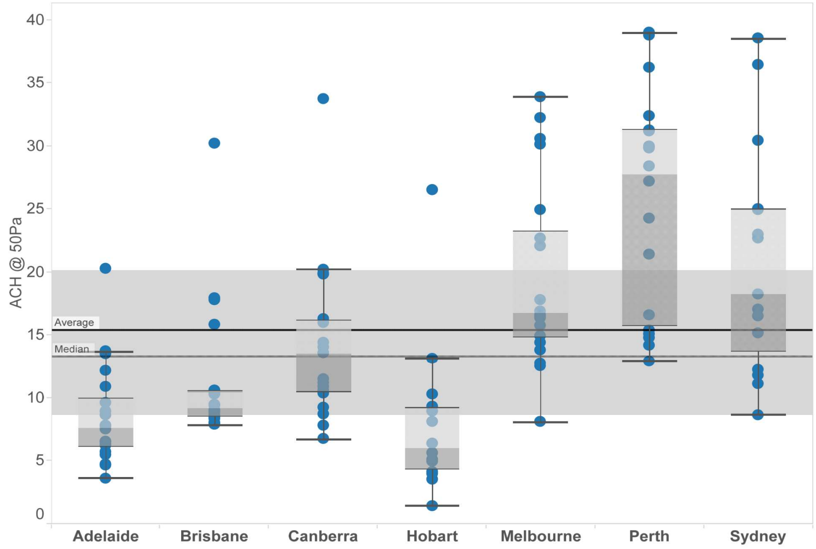
- interior

The NCC classes glued and screwed plasterboard and close-fitting trims, cornices, and skirting boards as the DTS method to achieve air-tightness. But we all know about the gap caused by the glue between the timber frame and the plasterboard, and the gaps at the junction of floor/wall and wall/ceiling. And this is before we consider services penetrations.

Measures of air-tightness

Australian houses

- AMBROSE, M. & SYME, M. 2015. House energy efficiency inspections project: final report. Australia: CSIRO.

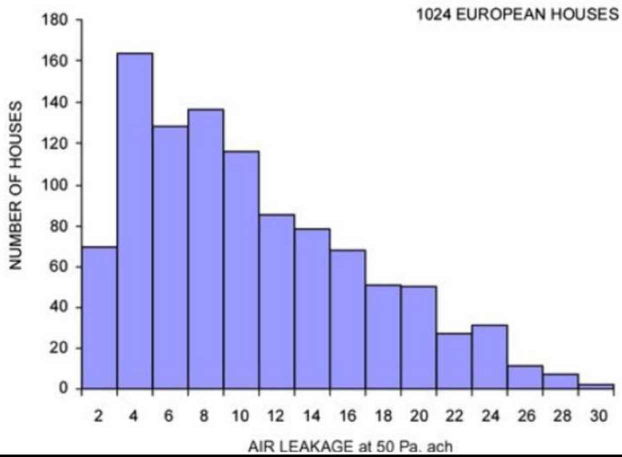


This graphic shows the measured airtightness of new homes conducted in 2015 by the CSIRO.
These values are at a pressure difference of 50Pa and have been established by using the Blower-door method.
As a rule of thumb, we can divide the @50Pa value to obtain a generic value.
The Ave for Melbourne was 20ACH@n50.
20/20 = 1. This indicates that the entire conditioned air of the house interior changes once per hour, when the outdoor air is relatively still, and 20 times per hour if the breeze was at 60km/hr. All that air warmed by the heat pump, needs to be reheated every hour.

Measures of air-tightness

1024 EU houses

ASHRAE 2017



This graph is showing 2017 values from Europe. Most are between 4 and 10 ACR@n50. This is between 2 and 5 times more air-tight than the tested homes in Melbourne. That would establish a big difference in heating and cooling energy.

Interior Air Control Layers

This slide shows the internationally common use of interior air control layers. The images also show the battens/top hats for ceiling and wall lining. This method provides and airtight wall system. Bets practice includes the installation of all services (electrical, plumbing, data) in the batten space zone.

Ventilation – not required due to leaky-ness

Generally, we have not needed to open windows or doors for fresh air supply in Australian buildings, as they have been very leaky. As we make homes more air-tight, less leaky, we need to learn how to ventilate our homes.

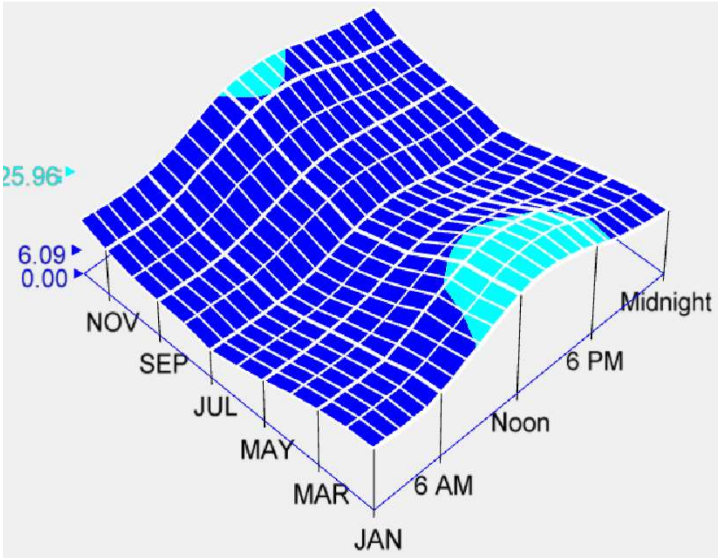
Ventilation

- The NCC requires ventilation openings to be a minimum of 5% of floor area.
- But every habitable room in the house requires 0.25 air changes per hour?
- How does this suite modern urban environments – noise, security
- How does this relate to when people are home, the outdoor air temperature, and when the breeze is juuusssstttt right?

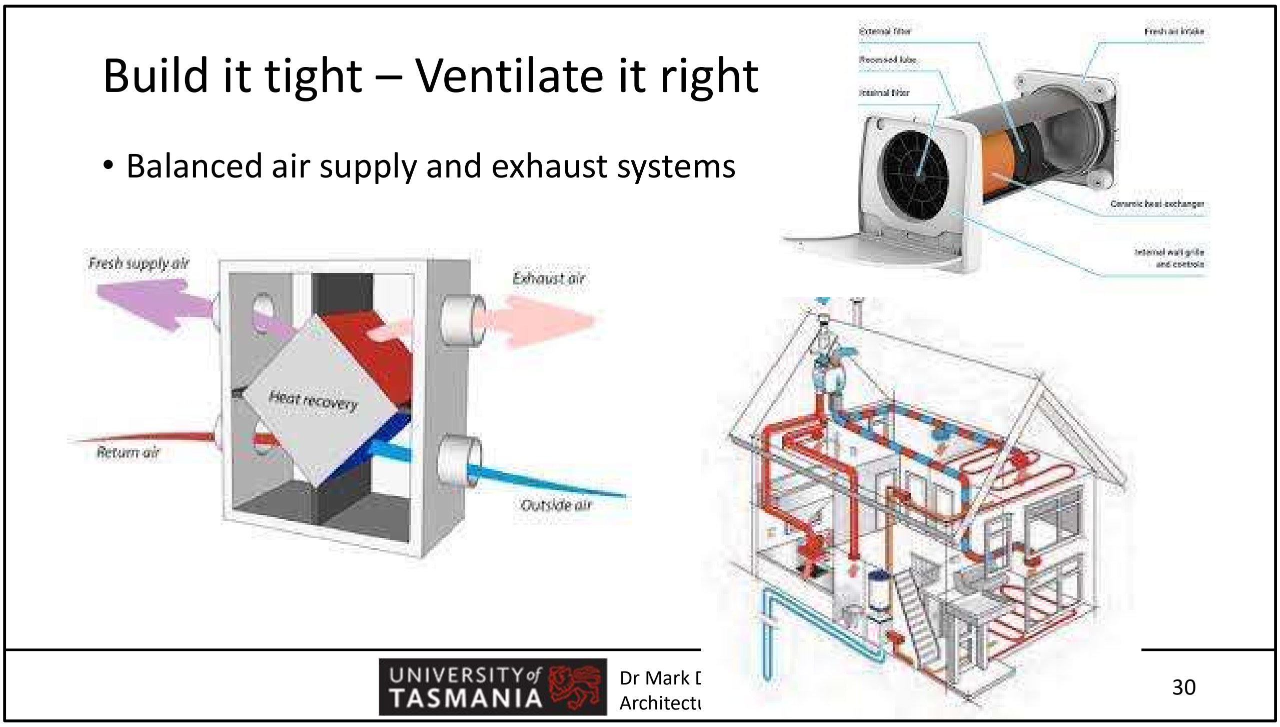
Ventilation

Melbourne NCC CZ-6

- 88% below 20^0C
 (Dark Blue)



This graph shows the outdoor air temperature for Melbourne. The light blue areas show when the outdoor air temperature is within the thermal comfort rage. The dark blue area is when the outdoor air is less than 20deg C.
This highlights a challenge for many in Victoria. We have heating on to make the room warm. But we also need to ventilate. But the outdoor air is cold and will increase the energy we use to heat the home.
BUT when are we home? Are we at work all day. Who is moving around the whole house opening and closing windows and doors to ensure we have 0.25 air changes per hour?



This slide shows internationally common Enthalpy Recovery Ventilation (ERV) systems. In cooler climates, they are often referred to as Heat Recovery Ventilators (HRV).

These units measure the interior carbon dioxide and relative humidity. When either become too high, they use a few watts and take the bad exhaust air out. The conditioned out-going air passes by a heat exchanger. The system then brings fresh air in, which passes by the heat exchanger. This process pre-heats the air in winter and precools the air in summer. Most systems are more than 90% efficient.

In small houses, a few single units may be required (top right).

But in Australia’s Mansions, we need mansion sized systems.

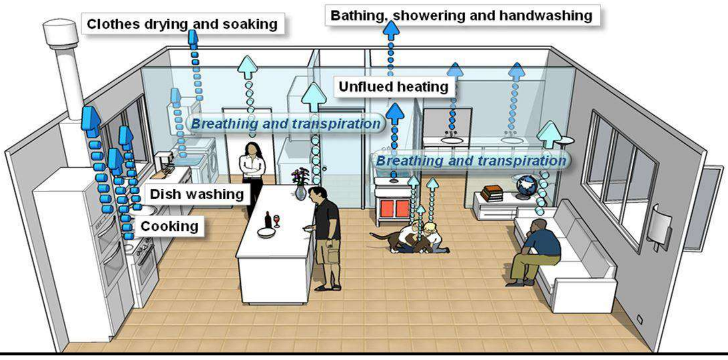
A typical home in the UK is 76m2. A typical home in Au is 250m2.

Water vapour

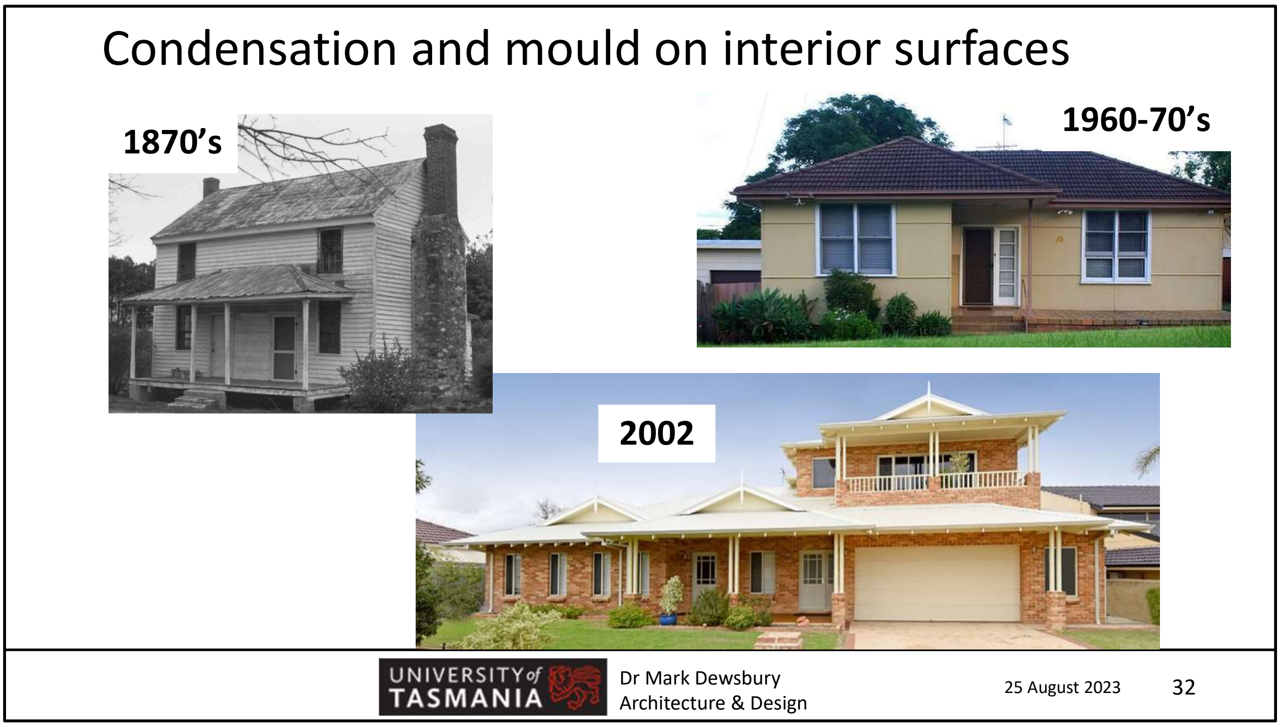
Created by

- *breathing*
- *cooking*
- *clothes drying*
- *domestic activities (washing up)*

Depends on:
lifestyle
how many people
how much time at home
season



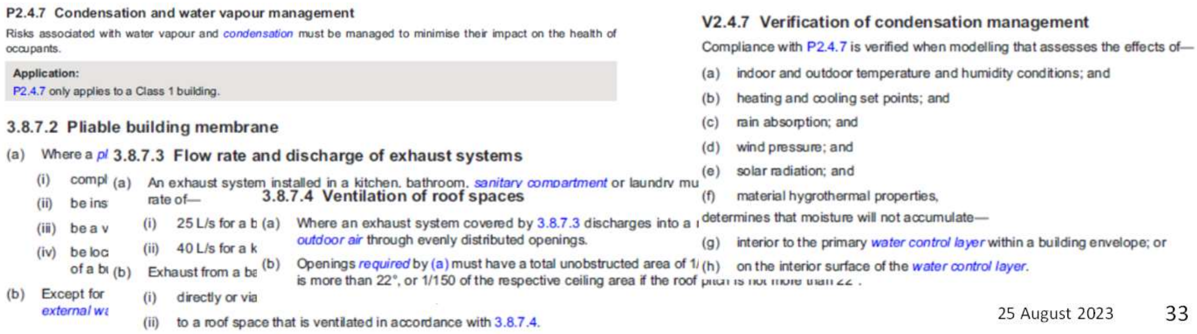
But what about water vapour
This slide shows typical activities that we undertake in our homes.
Unless we stop breathing, we are always adding water vapour to our building interiors.



In older homes in temperate and cool-temperate Australia, we would often have mould and/or condensation form on the inside surface of walls and ceilings in winter. As we have installed insulation, this same process occurs. But we have shifted the process into our external wall systems. We only have interior moisture and mould if the interior relative humidity is too high, or we have thermal bridges (standard aluminium frames on double glazed windows).

Condensation

- In 2019 we gained some climate type limited regulations regarding condensation and mould in Australian homes.
- For many Australian climate zones, we are now required to consider roof space ventilation, permeable membranes in external walls and some forms of exhaust ventilation.



P2.4.7 Condensation and water vapour management

Risks associated with water vapour and *condensation* must be managed to minimise their impact on the health of occupants.

Application:
P2.4.7 only applies to a Class 1 building.

3.8.7.2 Pliable building membrane

(a) Where a *pl*

(i) compl

(ii) be ins

(iii) be a v

(iv) be loc of a bu

(b) Except for *external wa*

3.8.7.3 Flow rate and discharge of exhaust systems

(a) An exhaust system installed in a kitchen, bathroom, *sanitary compartment* or laundry mu rate of—

(i) 25 L/s for a b

(ii) 40 L/s for a k

(b) Exhaust from a ba

(i) directly or via

(ii) to a roof space that is ventilated in accordance with 3.8.7.4.

3.8.7.4 Ventilation of roof spaces

(a) Where an exhaust system covered by 3.8.7.3 discharges into a *outdoor air* through evenly distributed openings.

(b) Openings *required* by (a) must have a total unobstructed area of 1/ is more than 22°, or 1/150 of the respective ceiling area if the roof

V2.4.7 Verification of condensation management

Compliance with P2.4.7 is verified when modelling that assesses the effects of—

(a) indoor and outdoor temperature and humidity conditions; and

(b) heating and cooling set points; and

(c) rain absorption; and

(d) wind pressure; and

(e) solar radiation; and

(f) material hygrothermal properties,

determines that moisture will not accumulate—

(g) interior to the primary *water control layer* within a building envelope; or

(h) on the interior surface of the *water control layer*.

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Our first regulations were introduced in 2019, with a focus on condensation. Even though the verification method was quite comprehensive, the acceptable construction requirements were very brief

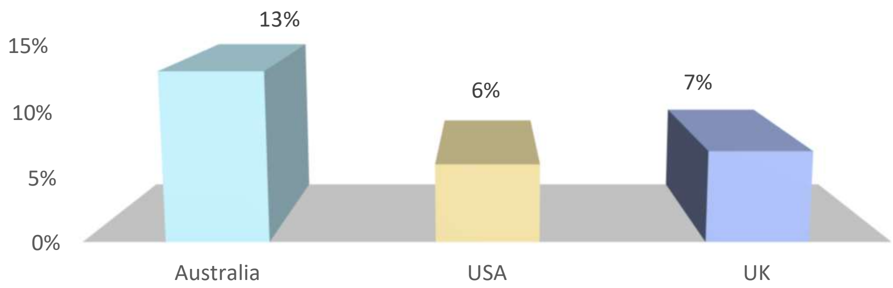
Condensation >>> Mould index of 3

- In 2022 we gained some enhanced climate based limited regulations regarding condensation and mould in Australian homes.
- In cool temperate climates a Class 4 vapour permeable weather resistive pliable membrane is now required
- In some other climates, a class 3 slightly vapour permeable weather resistive pliable membrane is now required.
- The requirements for fan systems with volume of air movement for rooms with a high interior vapour load.
- Increased roof space ventilation requirements for above the sarking layer and between the insulation and sarking layer.

The 2022 regulations are still too simplistic, but the terms shifted from condensation to Mould Index.

Why a mould index – Asthma in Australia

- 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.

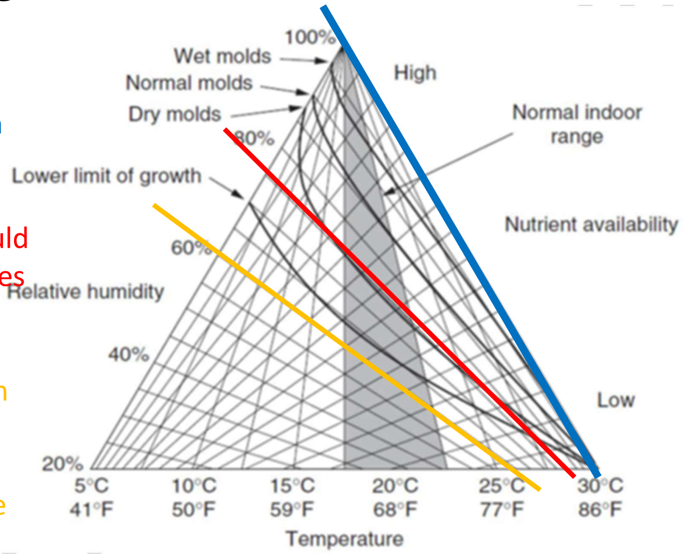


Is new housing a health hazard? Nath, Dewsbury, Orr,. 2018

Why a Mould Index - In 2018 Shruti Nath's research identified that Australia had twice the asthma rate of the OECD. And up until mid 2019, Australia was the only developed nation that did have any regulation regarding condensation and mould for buildings. For many decades, it has been accepted within the medical profession that breathing mould spores is linked to a range in allergic and immunology conditions. Asthma is one of these conditions.
This research provided our first evidence to push for greater regulatory change in the 2022 building regulations and highlights why these regulations are within Health and Amenity, and not structures or Energy Efficiency.
But why Condensation Versus Mould

When does Mould grow

- The blue line represents condensation – NCC 2019, when RH is 100%
- The red line indicates when mould will grow in well-ventilated spaces – NCC 2022, when RH is >70%
- The orange line represents when mould will grow in a poorly ventilated space (i.e. inside external wall systems), when the RH is >60%



Clarke, J., et al., A technique for the prediction of the conditions leading to mould growth in buildings. Building and Environment, 1999. 34(4): p. 515-521.

Mould growth and the mould growth index (MI)

Mould Index	Definition	Explanation
Nil	No simulated mould growth	Nil mould growth
</=1.0	Acceptable level of mould growth was simulated	Mould growth just starting, invisible growth acceptable in indoor and interstitial spaces.
>1.0 to <3.0	An amount of mould growth was simulated that requires further investigation	$1 \leq MI < 2$: invisible growth, recognizable only by microscope, and $2 \leq MI < 3$: growth **starts** to become visible to the naked eye.
3.0 to >5.0	Unacceptable amount of mould growth was simulated	$MI \geq 3$: growth is **visible** to the naked eye and starts covering the surface.

How much mould is bad? And what does a mould index of 3 mean.
After decades of medical research, in 2009 the World Health Organisation clearly stated that the visible presence of mould within buildings is a risk to human health.
Importantly mould is all around us, but it is microscopic.
A Mould index of less than 3.0 indicates that the mould is in its microscopic range.
But it should also be noted that some countries now require the Mould Index in external walls to be less than 2.0.
A mould index of 3 or more indicates that mould is optically visible by the human eye.
So, the question is not how much mould, The question is, can you see mould with the human eye? If mould is visible, it is a risk to human health.

Can we calculate when air releases moisture?

dew point temperature

Td = T - ((100-RH)/5)

Dew point T for 20^0C / 60% RH

Td = T – ((100 – RH) / 5)

Td = 20 – ((100 – 60) / 5)

Td = 12.0^0C

Dew point T for 23^0C / 75% RH

Td = T – ((100 – RH) / 5)

Td = 23 – ((100 – 75) / 5)

Td = 18.0^0C

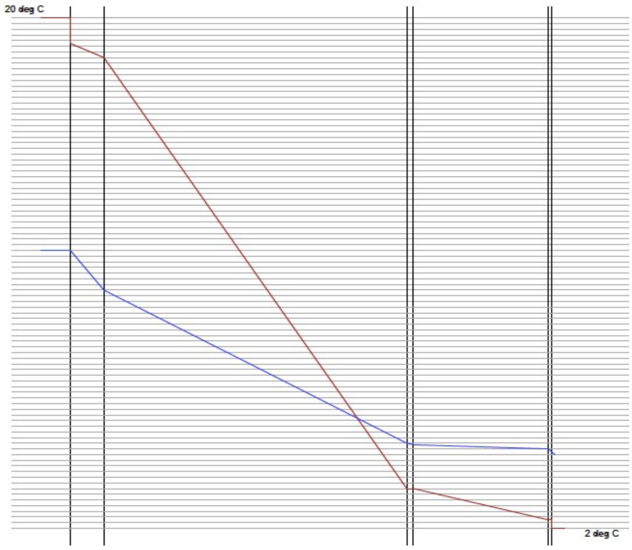
I often get asked about dew point temperature.
This simple formula allows us to calculate when moisture in the air will condense on a thermally bridged element.
In the example where interior air is at 20 deg C / RH60% any surface that is at 12 deg C will likely have condensation.
In the example where interior air is a 23 deg C / RH75% any surface that is as 18 deg C will likely have condensation.
How often are houses heated to 23 deg C and how often is the outdoor air less than 18 deg C.
This directly relates to thermal bridging and interior relative humidity control.

Envelope analysis – 1950's style

Red = Temp

Blue = dew-point

But how did we get here?

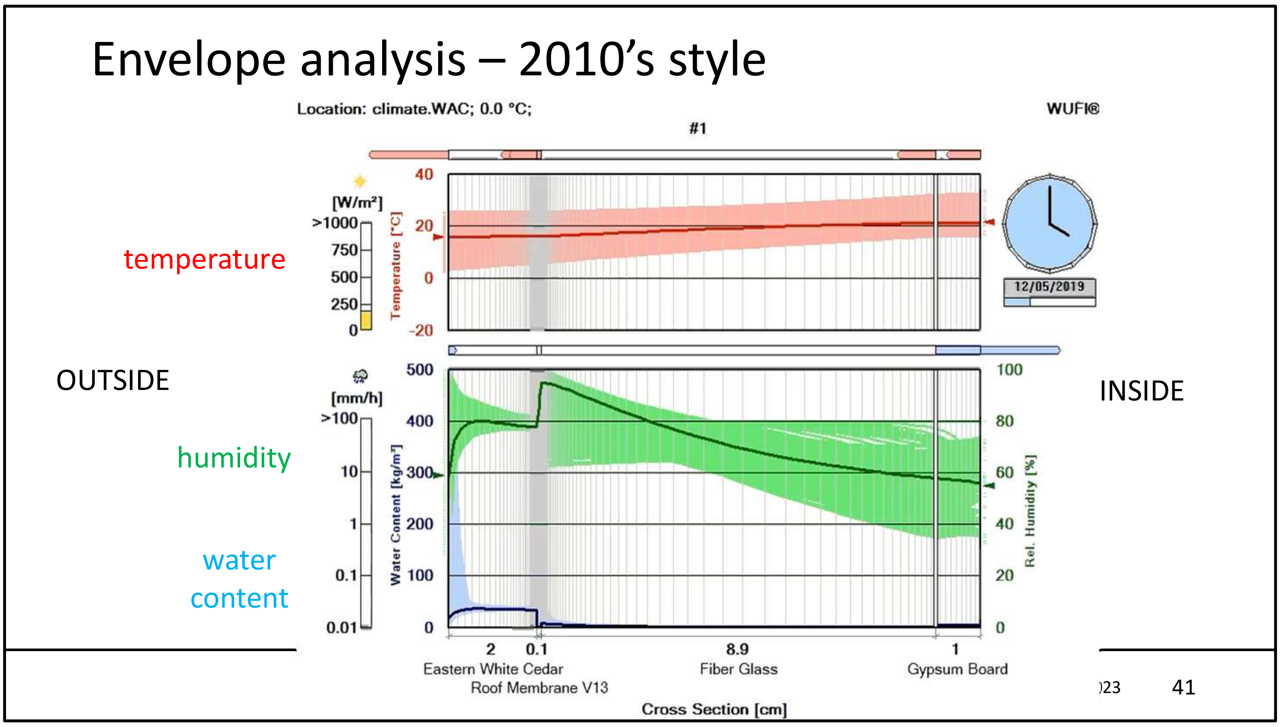


Since the 1950's building physicists and technical Architects have been calculating the flow of heat and water vapour through building envelopes.
The red line indicates the temperature profile through the wall.
The blue dashed line indicates the dew-point temperature in the wall.
This wall comprises, left to right, 10mm plasterboard, 90mm insulation, 1mm pliable membrane, 40mm cavity, 1mm cladding.
In this examples condensation is forming within the insulation layer close to the pliable membrane.

Water vapour profile through a wall

Layer	Thickness M	Conductivity	Thermal Resistance (m2 K/W)	Temperature Drop	Boundary Temperature deg C	Vapour Resistivity	Vapour Resistance	Vap. Pres. Drop	VP at Boundary	Dew Point at Boundary
Inside Air					20.0			1401		11.8
Internal Surface			0.12	0.91						
Boundary					19.1					
Plasterboard	0.0100	0.17	0.06	0.45		30-60 (45)	0.45	111.7		
Boundary					18.6				1289	10.7
Insulation	0.0900		2.00	15.20		5-7 (6)	0.54	134		
Boundary					3.4				1155	9.1
Building Wrap	0.0010		0.00	0.00		1,000	1	248.2		
Boundary					3.4				907	5.6
Cavity	0.0400	(0.15 to 0.62)	0.15	1.14		0.2	0.008	2.0		
Boundary					2.3				905	5.5
Sheet-metal	0.0004	45	0.00	0.00		1,000	1	248.2		
Boundary					2.3				657	1.0
External Surface			0.04	0.30						
Outside Air			2.37		2.0			657		
							3.998	744		

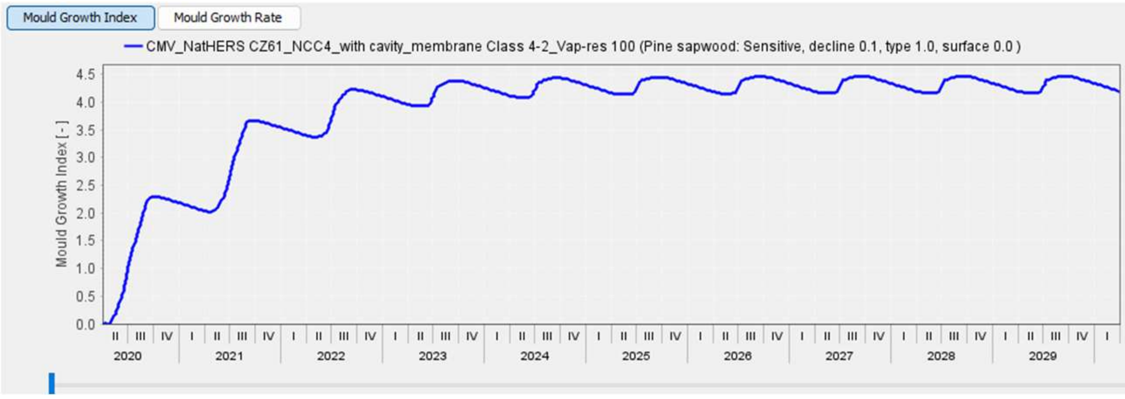
This table is showing the calculation method used to create that graph.
But this is for one moment in time.
There are 8760 hours in a year.
And there is rain, sunshine and windpressure



This graph is showing the calculation of heat and moisture within a similar wall system. This calculation is completed hourly, for a period of ten years.
Now the interior is on the right and the exterior is on the left. This method also considers solar radiation, shading, wind pressure, rain and limited moisture ingress.
The red section shows the temperature profile.
The green section shows the relative humidity profile
The blue section shows moisture. We can see moisture through the cladding system, on the inside surface of the cladding system and on the inside surface of the pliable membrane.
Slide 36 highlighted that when the RH is greater than 70% in a well-ventilated space mould can grow. Slide 36 also showed that when the RH is above 60% in a poorly ventilated space mould could grow. A lot of the green data is above 60%RH.
We need to use a different software to post-process these results to understand if this wall system is promoting mould growth.

Simulation Outputs

Calculated Mould Index (MI)



This graph is showing data that had been processed by mould growth software.
The left axis is showing the mould index value (from 0.0 to 4.5)
The bottom axis is showing the ten years of calculation.
The graph clearly shows mould growth in winter, followed by limited mould death in simmer.
However, the graph also clearly shows that this wall system exceeds the Mould Index of 3.0 in the second winter. This indicates that this wall system does not meet the verification method described in the NCC.

NCC 2022

10.8.1 External wall construction

[2019: 3.8.7.2]

(1) Where a *pliable build*
(a) comply with AS 4
(b) be installed in ac
(c) be located on the of a building.
(2) Where a *pliable build* *primary insulation lay*
(a) in *climate zones*
(b) in *climate zones*
(3) Except for single skir *external wall*, the prin

10.8.2 Exhaust systems

[2019: 3.8.7.3]

(1) An exhaust system installed in a kitchen, bathroom, *sanitary compartment* or laundry must have a minimum flow rate of—
(a) 25 L/s for a ba
(b) 40 L/s for a ki
(2) Exhaust from a kit via a shaft or duct
(3) Where a venting cl
(4) An exhaust system in accordance with
(a) be interlocked
(b) include a run- turned off.
(5) Except for rooms th (1) must be provide
(a) via openings t
(b) in accordance

10.8.3 Ventilation of roof spaces

[2019: 3.8.7.4]

(1) In *climate zones* 6, 7 and 8, a roof must have a roof space that—
(a) is located—
(i) immediately above the *primary insulation layer*; or
(ii) immediately above sarking with a *vapour permeance* of not less than 1.14 µg/N.s, which is immediately above the *primary insulation layer*; or
(iii) immediately above ceiling insulation that meets the requirements of 13.2.3(3) and 13.2.3(4); and
(b) has a height of not less than 20 mm; and
(c) is either—
(i) ventilated to *outdoor air* through evenly distributed openings in accordance with Table 10.8.3; or
(ii) located immediately underneath the roof tiles of an unsarked tiled roof.
(2) The requirements of (1) do not apply to a—
(a) concrete roof; or
(b) roof that is made of structural insulated panels; or

DRAFT

The Acceptable Construction requirements have increased. Which must be good, mustn't it?
We have the requirement for a Class 4 pliable membrane on walls.
We have more requirements for exhaust systems
We have requirements for ventilation of roof spaces

Will NCC 2022 solve the problem?

- Will a DTS Acceptable Construction method create a mould free building (only Class 1 and class 2 buildings)….. Probably NOT
- Class 4 pliable membrane but no requirement for a vented and drained cavity.
- Exhaust ventilation, but where is the supply air coming from?
- Roof space ventilation, which in the 2022 NCC is now reasonably aligned with regulations in other developed nations.

Will a DTS Acceptable Construction method create a mould free building (only Class 1 and class 2 buildings)….. Probably NOT

The enhanced regulations require a Class 4 pliable membrane. But is this enough for more air-tight homes in Australia?

Aside from Clay masonry walls, there is still no requirements for vapour and drainage cavities behind the cladding system.

Exhaust ventilation has been expanded but where is the supply air coming from? We are relying on the leaky home to provide supply air for kitchen and bathroom exhaust systems. But if we are making our homes more airtight….?

Roof space ventilation, which is now reasonably aligned with regulations in other developed nations. We have required subfloor ventilation for-ever. If we look at old buildings we see all sorts of approaches to roof space supply and exhaust ventilation.

Better than NCC2022

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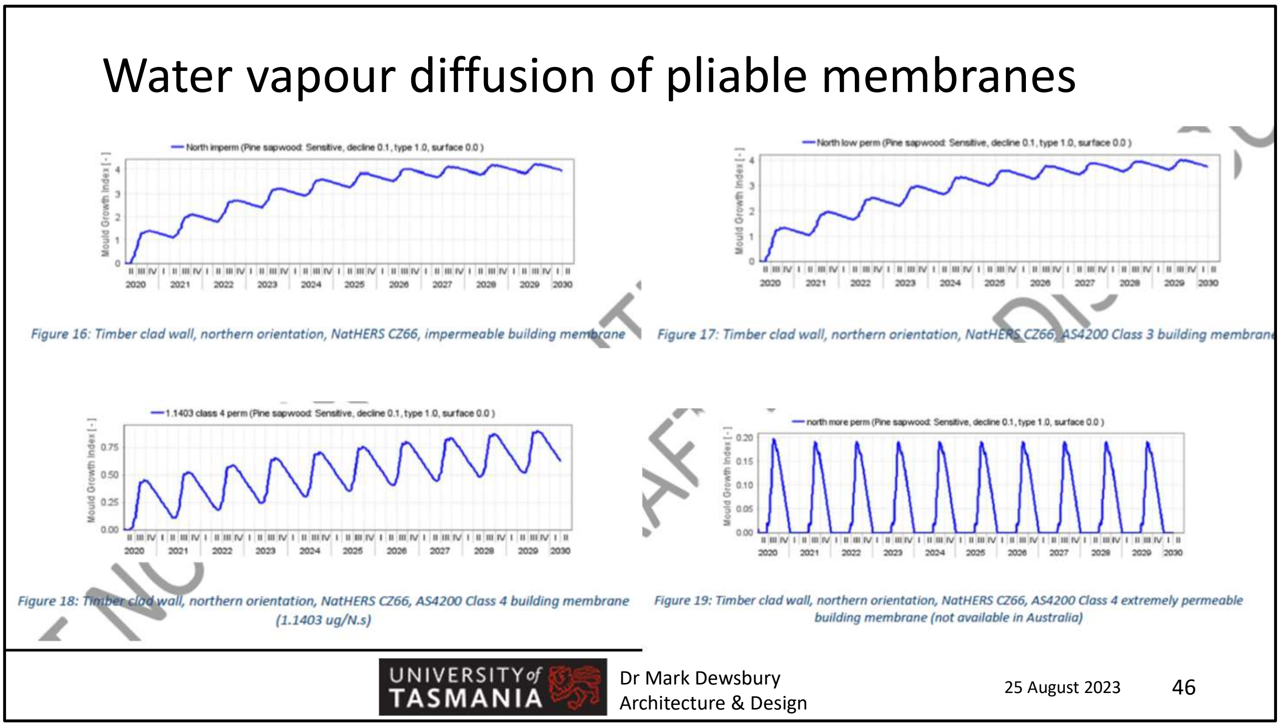
Do we need to design and build better than the NCC.
The NCC is not GOOD construction. It is the current worst method to build, based on economic data regarding durability, occupant safety and greenhouse gas emissions. Anyone who has tried to make a claim regarding a mouldy building would know that there is no insurance. Insurance is for events. Moisture and mould is not an event by a flaw in design and construction.



Why a class 4 membrane.
This slide shows the calculated Mould Index for the same wall system but with four different pliable membranes.
The top left shows the result from a Class 1 pliable membrane, with a Mould Index greater than 3 in the fourth year.
The top right shows the result from a Class 3 pliable membrane, with a Mould Index greater than 3 in the fourth year.
The bottom left shows the result from a Class 4 pliable membrane, with a Mould Index that does not exceed 1.0 but has an ongoing upward trend.
The bottom right shows the result from a very water vapour permeable Class 4 pliable membrane, with a Mould Index that does not exceed 1.0 but has an ongoing downward trend.

Drained and Vented cavities

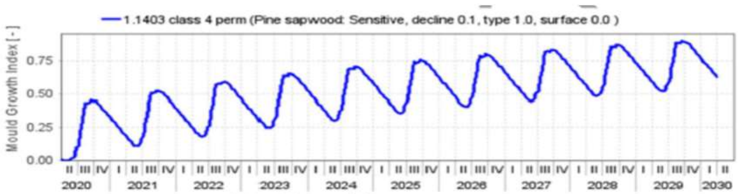


Figure 20: Timber clad wall, northern orientation, NatHERS CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s)

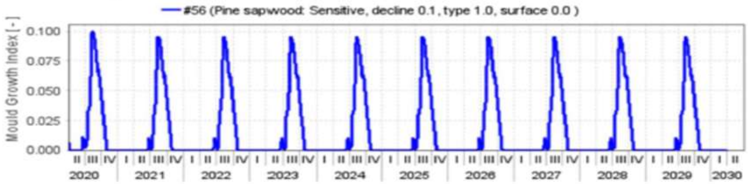


Figure 21: Timber clad wall, northern orientation, NatHERS CZ66, AS4200 Class 4 permeable building membrane (1.1403 ug/N.s)

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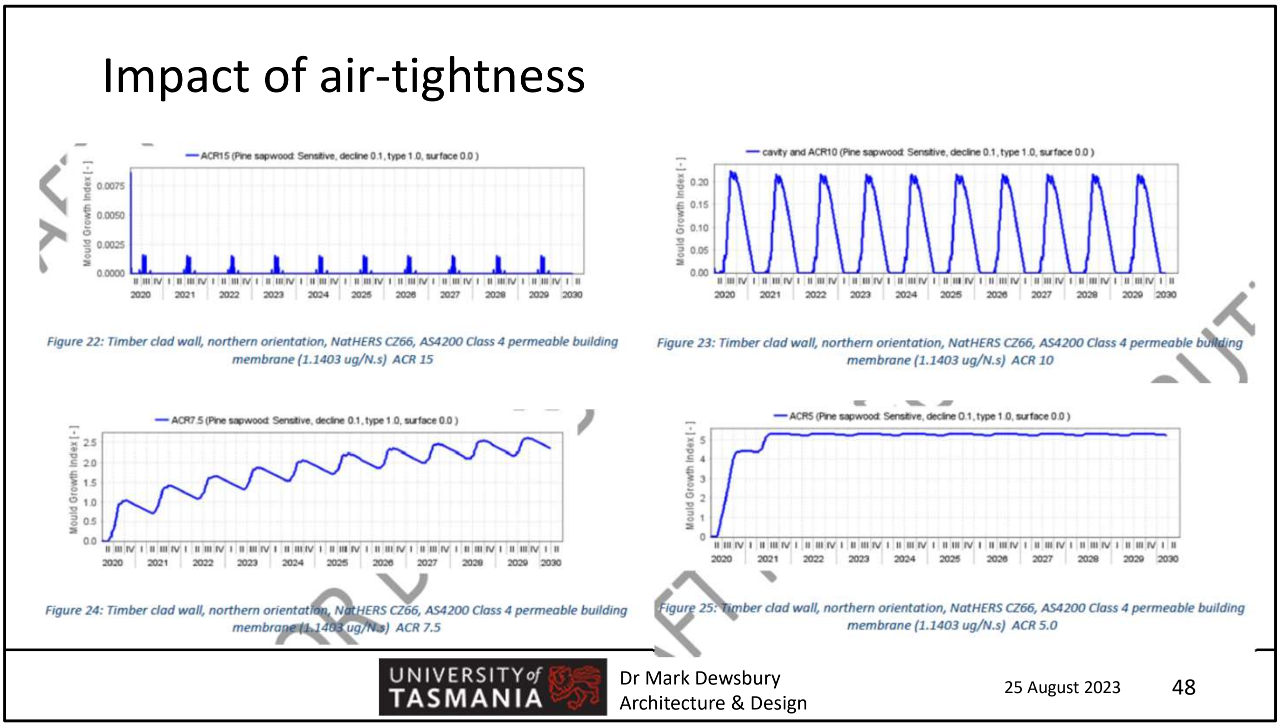
Why a vented and drained cavity
This slide shows the calculated mould index for an external wall system that includes a Class 4 pliable membrane.
The top graph shows the result from a wall system with no vented and drained cavity, with a Mould Index that does not exceed 1.0 but has an ongoing upward trend.
The bottom graph shows the result from a wall system with a vented and drained cavity, with a Mould Index that does not exceed 1.0 but has an ongoing downward trend.



Does Airtightness matter. In the mid 1980’s the North America established when the ACR@n50 is less than 8, we must consider how a wall system manages moisture.
This slide shows the calculated mould index for an external wall system that includes a Class 4 pliable membrane with a vented and drained cavity.
The top left shows the result with an ACR@n50 of 15 (more airtight than the 2015 Average for Melbourne). The Mould Index is less than 1.0.
The top right shows the result with an ACR@n50 of 10 (The maximum expected in NCC 2019). The Mould Index is less than 1.0.
The bottom left shows the result with an ACR@n50 of 7.5 (What we think many new houses are achieving). The Mould Index is just less than 3.0, with an upward trend.
The bottom right shows the result with an ACR@n50 of 5.0 (How airtight a home can be before mechanical ventilation is required). The Mould Index exceeds 3.0 in the first year.
This shows that as we move to more airtight homes with an ACR@n50 between 5 and 8 that the inclusion of a vented and drained cavity and a class 4 membrane may not provide an MI of less than 3.

Orientation of mould growth risks

NatHERS CZ	Bio-h (Highest calcula			
	Air change rate 10 (ACR 10)			
	North	East	South	West
21	<1.0	<1.0	>1.0	<1.0
22	<1.0	>1.0	>4.5	>2.5
27	Nil	<1.0	>1.0	<1.0
60	<1.0	<1.0	>3.0	>1.25
61	<1.0	>2.0	>4.5	>3.5
63	<1.0	>2.0	>4.5	>3.5
64	<1.0	<1.0	>1.5	<1.0
66	>2.0	>4.0	>4.5	>4.5

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It is also important to understand the effect of Solar based drying. This table shows some calculation results for a code compliant wall system, and the impact of orientation and wall shading.

The left column lists some NatHERS climates. The numbers under the headings North, East, West and South document the calculated Mould Index values. These range from Nil to >4.5 subject to climate and wall orientation.

In most cases, the north facing wall, if unshaded, receives on average 4 hours of solar radiation per day. This solar driven drying potential establishes that an unshaded north facing wall has the lowest calculated mould index.

The unshaded east facing wall would receive an average of 2 hours of solar radiation per day. This solar driven drying potential shortly after the coldness of night, establishes that an unshaded east facing wall performs slightly worse than a northern wall, but better than a western or southern facing wall.

The unshaded west facing wall would receive an average of 2 hours of solar radiation per day. However, this solar radiation is not received until after midday. This wall would have the coolness of night and the coldness of morning before receiving a few brief hours of solar based drying. This establishes that an unshaded west facing wall performs worse than a northern or eastern facing wall but better than a southern facing wall.

The southern facing wall receives no solar based drying potential between March and September. The drying potential for this wall is based in the interior temperature and ventilation within the cavity.

There are two other key items to note:

1. The NCC does not have different requirements for wall design and construction based on orientation
2. A norther facing wall that is shaded would perform the same as a southern facing wall.

Climate dependant envelope design

Temperate climate

- The yellow highlight represents NCC 2019
- The blue highlight represents NCC 2022

	Cavity	Exterior membrane	Interior membrane	AER 10	AER 7.5	AER 5
RR1 6 Star	No	Class 1 (200000)	Nil	>1 to <3		
RR2 7 Star	No	Class 3 (1398)	Nil	<1	>3	>5
Case 2	No	Class 3 (1398)	Nil	<1	5	6
Case 3	No	Class 4 (175.4)	Nil	<1	>1 to <3	6
Case 4	No	Class 4 (100)	Nil	<1	<1	6
Case 5	No	Class 4 (21)	Nil	<1	<1	4
Case 7	Yes	Class 3 (1398)	Nil	4	<1	6
Case 8	Yes	Class 4 (175.4)	Nil	<1	<1	5
Case 9	Yes	Class 4 (100)	Nil	<1	<1	>1 to <3
Case 10	Yes	Class 4 (21)	Nil	<1	<1	<1
Case 12	No	Class 3 (1398)	Yes	<1	<1	<1
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

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This table then explores these matters further for southern oriented walls. This wall system is simulated in a Temperate climate like shepparton.
The first column just contains a simulation reference number i.e, Case10
The second column explores the impact of a vented and drained cavity behind the cladding systems (Yes/No). NCC 2022 only requires a vented and drained cavity for clay masonry construction.
The third column explores the impact of different water vapour resistivity properties for a pliable membrane. (Note a Class 4-175.4 is the most vapour resistive a Class 4 membrane can be, whilst Class 4-100 and Class 4-21 have increasingly lower water vapour resistance properties. In essence a Class 1-200000 is the most vapour impermeable, and a Class 4-21 is the most water vapour permeable.
The fourth column explores the addition of an interior vapour control membrane.
Columns 5, 6 & 7 show the calculated Mould Index results based on ACH10@n50, ACH7.5@n50 and ACH5@n50. ACH10 representing the current maximum leakiness expected in a new home, and ACR5 representing the most airtight a home may be before background mechanical ventilation is required.
Case RR1 6 Star represents a code compliant wall until NCC 2019.
Case 2 represents a NCC 2019 code compliant wall
Case 3 represents a NCC 2022 code compliant wall
If it is a new home and the airtightness is 7.0ACH@n50, we really need to look at the AER 5 column, where cases 9, 10, 12 and 14 have a MI of less than 3.0. Cases 9 and 10 include a vented and drained cavity and a very vapour permeable membrane. Cases 12 and 14 include an interior vapour control membrane.

Climate dependant envelope design

- Slightly cooler Temperate climate
- The yellow highlight represents NCC 2019
- The blue highlight represents NCC 2022

	Cavity	Exterior membrane	Interior membrane	AER 10	AER 7.5	AER 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
Case 1	No	Class 3 (1398)	Nil	5	6	6
RR2 7 Star	No	Class 4 (175.4)	Nil	>1 to <3	>1 to <3	>3
Case 2	No	Class 4 (175.4)	Nil	3>	4	6
Case 3	No	Class 4 (100)	Nil	>1 to <3	4	5
Case 4	No	Class 4 (21)	Nil	>1 to <3	4	5
Case 5	Yes	Class 3 (1398)	Nil	4	5	6
Case 6	Yes	Class 4 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>1 to <3	4	5
Case 10	Yes	Class 3 (1398)	Yes	<1	>1 to <3	4
Case 11	No	Class 4 (175.4)	Yes	<1	>1 to <3	>1 to <3
Case 12	Yes	Class 4 (175.4)	Yes	<1	<1	<1

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This table then explores these matters further for southern oriented walls. This wall system is simulated in a cool-temperate climate, like Seymor.
The first column just contains a simulation reference number i.e, Case10
The second column explores the impact of a vented and drained cavity behind the cladding systems (Yes/No). NCC 2022 only requires a vented and drained cavity for clay masonry construction.
The third column explores the impact of different water vapour resistivity properties for a pliable membrane. (Note a Class 4-175.4 is the most vapour resistive a Class 4 membrane can be, whilst Class 4-100 and Class 4-21 have increasingly lower water vapour resistance properties. In essence a Class 1-200000 is the most vapour impermeable, and a Class 4-21 is the most water vapour permeable.
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Case RR1 6 Star represents a code compliant wall until NCC 2019.
Case 1 represents a NCC 2019 code compliant wall
Case 2 represents a NCC 2022 code compliant wall
If it is a new home and the airtightness is 7.0ACH@n50, we really need to look at the AER 5 column, where cases 6, 7, 8, 11 and 12 have a MI of less than 3.0. Cases 6, 7 and 8 include a vented and drained cavity and a Class 4 vapour permeable membrane. Cases 11 and 12 include an interior vapour control membrane.

Interior Vapour Control Layers

This slide was shown previously to illustrate interior air control layers. Many of these propriety interior air control layers are also interior vapour control layers. That is, they control how much water vapour enters and external wall system, thus assisting in the management of moisture and mould in external walls.
As we make houses more energy efficient and airtight in southern Australia, this type of product will become a key component of new buildings.

Key Principles for Effective External Envelopes

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

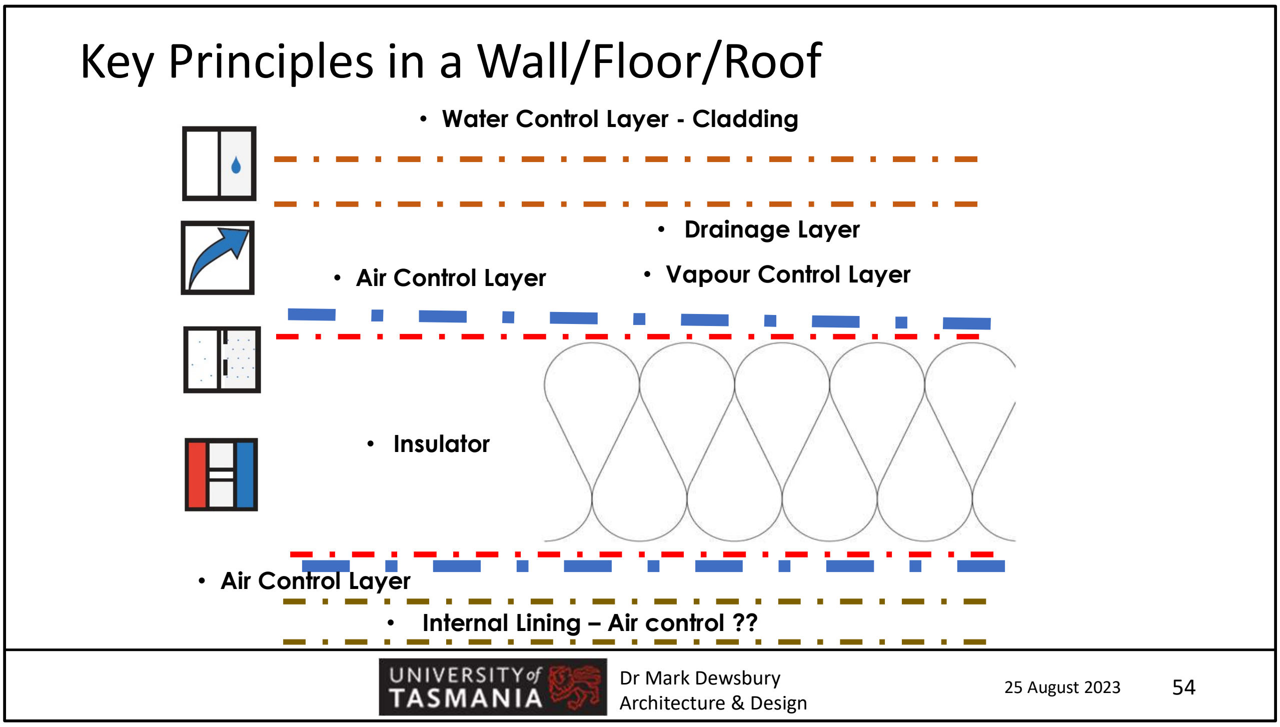
Vapour control layers – Materials that allow the climatically appropriate passive flow of water vapour

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

Drainage Planes – A space between the roofing and sarking, or a space between the cladding and the exterior membrane, which promotes drying and allows moisture to drain

Since 2008, I have been pushing four key principles for the Design and Construction of platform floors, external walls and roof spaces.
Continuous thermal control – no gaps, no bridges
Continuous vapour control – climatically appropriate pliable membranes to manage water vapour diffusion
Continuous water control – Moisture will be forced or form on the interior side of roofing and walling. There needs to be a gap that allows moisture to form. This gap is also ventilated, which promotes passive drying.
Ventilation of subfloor spaces, roof spaces and external wall systems. We have required subfloor ventilation to ensure structural durability for decades. Roof spaces used to be ventilated and thankfully, NCC 2022 is starting to address this issue again. However, the only wall system that requires a vented and drained cavity is clay masonry construction. All cladding systems should have a vented and drained cavity.



Applying these principles is simple

1. The cladding system is the initial weather resistive layer, but we accept moisture exists on the interior side of the cladding system.
2. A vented and drained cavity. This allows for moisture to drain and for water vapour to vent away passively.
3. A pliable membrane that provides weather resistance, provides an insulation protecting air control layer, and provides climatically appropriate water vapour diffusion.
4. A continuous and well install insulation layer
5. As we make homes more airtight, we need to install a pliable membrane on the inside of the insulation layer to improve air control and to assist in water vapour diffusion control.
6. A well installed lining system that does not compromise the air control and thermal; control layers.

Weather-tightness, Insulation, Air-tightness, Ventilation, and Condensation

Questions

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