2024 MBV
Green Living Conference
Building for the Future

Controlling human generated water vapour

Dr Mark Dewsbury
University of Tasmania
(mark.dewsbury@utas.edu.au)

Occupant generated water vapour

Table D.6 **Typical moisture generation rates for household activities**

Household activity	**Moisture generation rates**
People	
asleep	40 g/h·person
seated, office work	70 g/h·person
standing, housework	90 g/h·person
moderate manual work	300 g/h·person
Cooking	
electricity	2 000 g/day
gas	3 000 g/day
Dishwashing	400 g/day
Bathing/washing	200 g/day·person
Shower (15 min)	600 g/shower
Washing clothes	500 g/day
Drying clothes indoors	1 500 g/day
Washing floors	200 g/day
Plants	20 g/day·plant

BS5250-2011

This table is from the 2011 edition of British Standard 5250 which shows the typical water vapour generation by building occupants. This is not liquid water; this is just water vapour. The first edition of this standard was in 1970. It is now 2024 and there have been many revisions to this standard. Sadly. In Australia we still don't have a National Standard addressing moisture and mould in buildings?

Occupant generated water vapour

Table D.4 Moisture production rates in housing

Number of occupants	Average moisture production rate, kg/day		
	Low (One or two people, no children)	Medium (Average family with children)	High (Family with teenage children, indoor drying of laundry etc).
1	3 to 4	6	9
2	4	6	11
3	—	9	12
4	—	10	14
5	—	11	15
6	—	12	16

BS5250-2011

This table is also from the 2011 edition of British Standard 5250 which shows what this water vapour generation would equate to for a family household. If we pick a family of 4, we can see that the range of occupant generated water vapour is typically from 10kg to 14kg per day.

Medium family of 4 makes 10kg of moisture per day

MASTER BUILDERS GREEN LIVING

UNIVERSITY of TASMANIA

Dr Mark Dewsbury
Architecture & Design

05/09/2024

4

10kg of occupant generated water vapour per day

How to remove 10kg of moisture per day?

- Mass air transfer (Ventilation)
- Diffusion

MASTER BUILDERS GREEN LIVING

UNIVERSITY of TASMANIA

Dr Mark Dewsbury
Architecture & Design

05/09/2024 5

We generally have two methods to remove occupant generated water vapour in temperate climates, namely:

- Mass air transfer, more commonly known as ventilation, and
- Water vapour diffusion

Moisture transport over six months

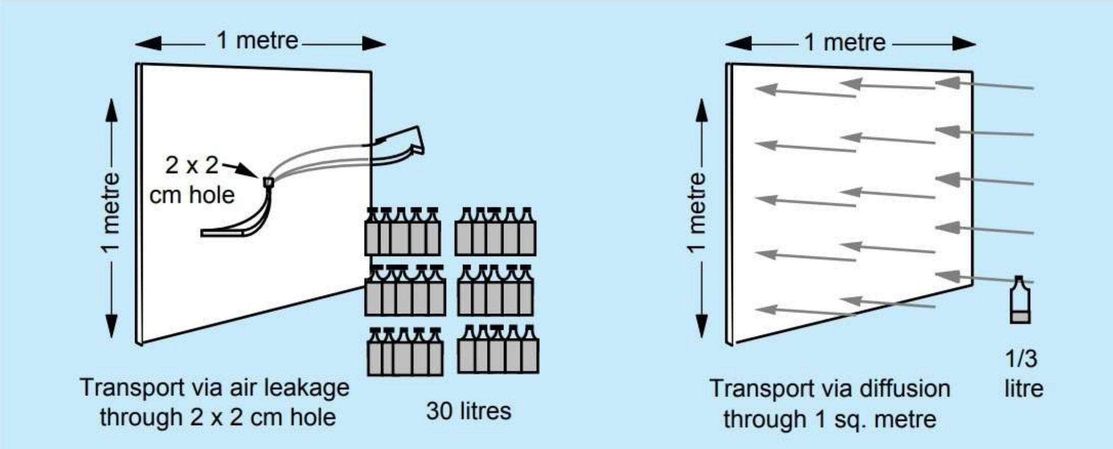


Figure 2.10 Moisture Transport Over One Heating Season (Ottawa Conditions)

MASTER BUILDERS GREEN LIVING

UNIVERSITY of TASMANIA

Dr Mark Dewsbury
Architecture & Design

05/09/2024 6

If we compare mass air transfer and water vapour diffusion through a sheet of painted paper-faced plasterboard, we can see from this 2000 Canadian graphic that

- A 2cm by 2cm hole allows 30 litres or 30kg of moisture to leave the building interior,
- whilst a painted paper-faced plasterboard wall only diffuses 0.3 litres or 300 grams of moisture during the same period of time. Or 75g grams per square metre.

This raises two dilemmas:

How big is an electrical switch, or other service penetrations and how much moisture are we allowing into the exterior wall system? And

We can see that 100 times the moisture that diffuses through a wall is removed by a small amount of ventilation.

The house as a context

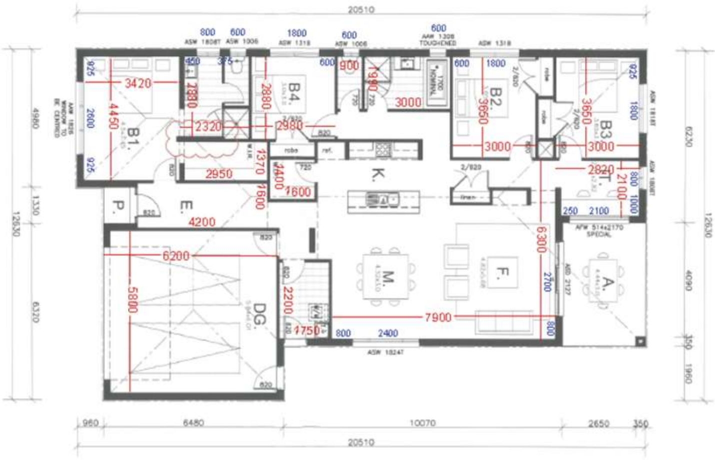


Figure 47 – House 2 – medium free-standing – floor plan

Dr Mark Dewsbury
Architecture & Design

How might we apply these numbers to a typical four bedroom home

The house as a context

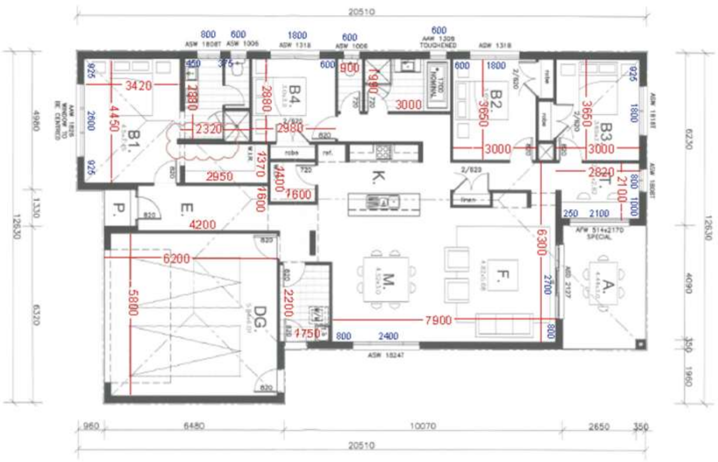


Figure 47 – House 2 – medium free-standing – floor plan

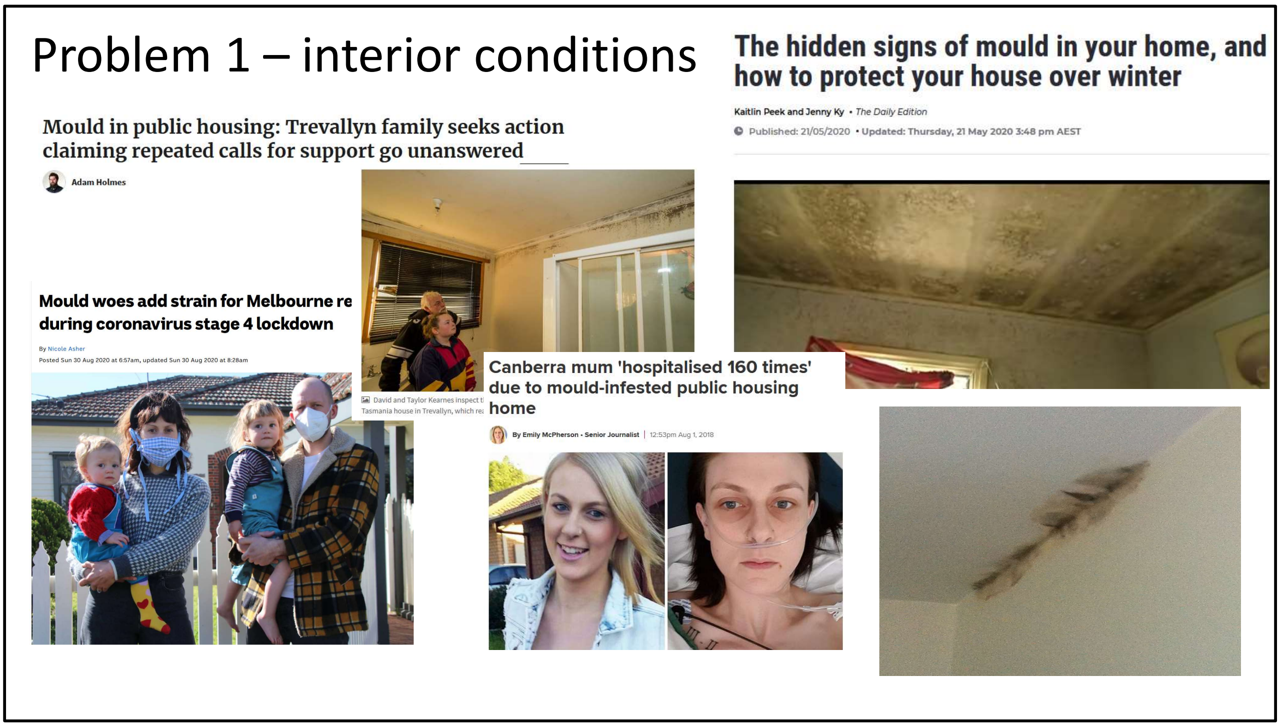
Exterior walls – 160m^2
Ceiling – 210m^2
Floor – 210m^2??

Approx:
370 x 0.075 = 27.75 kg

But 6 months of occupant water vapour generation = 1800kg

1772.25g deficit

In this example we can calculate the surface area of floors and walls. I won't include a concrete slab floor, as it includes a plastic liner.
We end up with a surface area of 370 square metres.
We can multiply that by 75 grams for a heating season and we end up with 27.75kg of water vapour diffusing through the exterior walls and ceiling.
But during that same period the family of 4 generated 1800kg of water vapour.
That leaves a deficit of 1772.25 kg of water vapour.

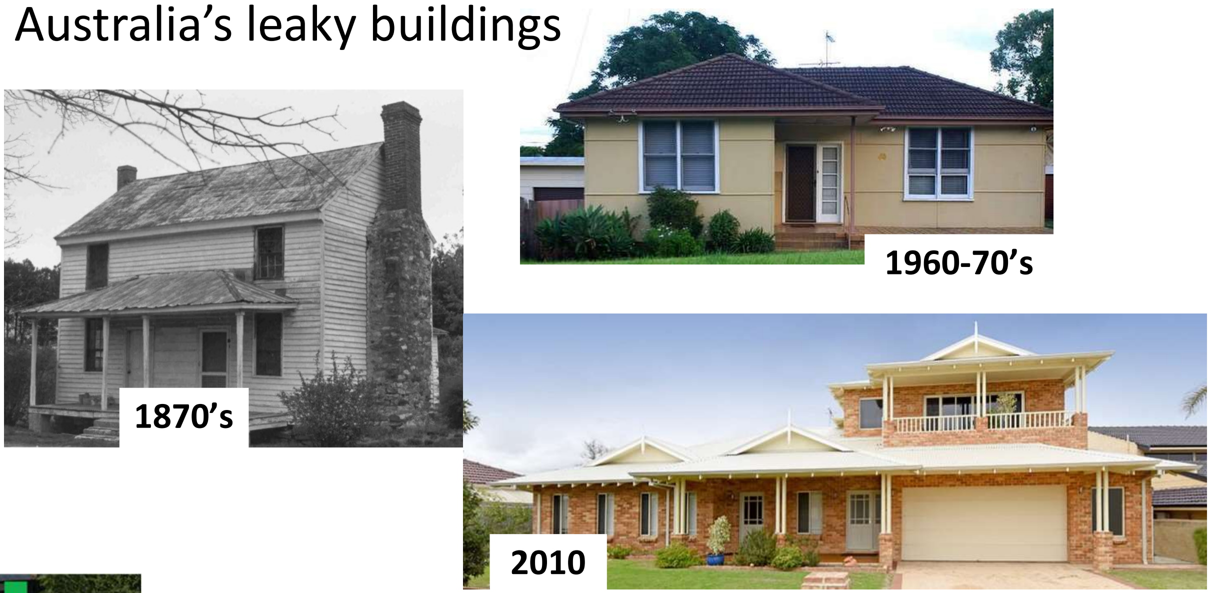


Which if unmanaged results in mouldy building interiors and sick building occupants.

Problem 2 – interstitial conditions

And mouldy, rotting subfloor spaces, exterior wall systems and roof spaces.

Australia’s leaky buildings



Realistically whether it was an 1800’s home or an early 2000’s home, they we generally very leaky

Mass air transfer (Ventilation)

In Australia, have we ventilated, or have we relied on leaky buildings?

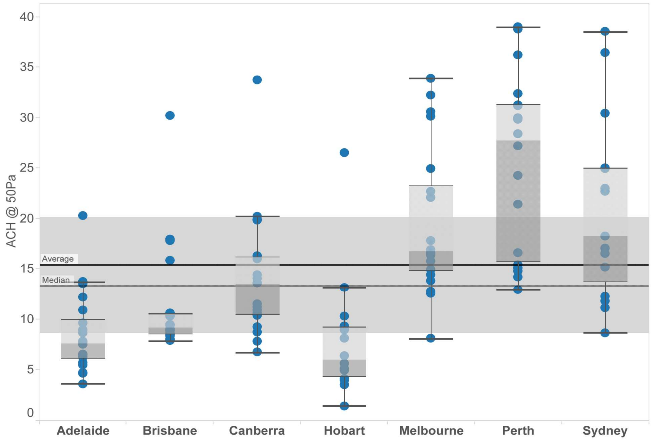
Pre 2003

- Up to 40 Air Changes per Hour

2013

- <5 to >30
- Average 15 ACH

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



MASTER BUILDERS GREEN LIVING

UNIVERSITY of TASMANIA

Dr Mark Dewsbury
Architecture & Design

05/09/2024

12

But did we ever have a culture of ventilating our homes in Australia, or did we just have leaky buildings.
Even in 2013 houses in Victoria had an Air Change Rate @ n50 of greater than 30.
When a breeze at 32km is blowing, the air in the house changes 30 times in 1 hour.
That is a lot of water vapour mass transfer.
If a stiff breeze isn't blowing that house would still have an air change rate greater than 1.5 air changes per hour.
Aside from the insulation issue, this is why most Australians living in older housing can't afford to heat or cool their homes. Whenever they turn on a heating appliance, they are just heating the local suburb.
But even in 2013, the average ACR@N50 was 15, or a passive leakage rate greater than 0.75 Air Changes per Hour.

Mass air transfer

2024 single storey house (Vic)

- 3.3 to 11.3 ACH

- Average 6.3 ACH

Dwelling Type	ACT	NSW	QLD	SA	VIC	All
Average Permeability (m³/h/m² @ 50 Pa)						
Apartment	6.71	6.34	4.28	5.93	5.65	5.80
Single Storey House	5.42	6.35	6.61	7.65	6.30	6.77
Two Storey House	9.57	9.07	8.16	7.61	8.44	8.55
Minimum Permeability (m³/h/m² @ 50 Pa)						
Apartment	3.49	1.77	0.86	4.34	0.79	0.79
Single Storey House	5.38	1.63	4.39	3.70	3.29	1.63
Two Storey House	8.18	2.74	5.50	4.38	4.34	2.74
Maximum Permeability (m³/h/m² @ 50 Pa)						
Apartment	11.16	13.25	10.45	7.98	15.94	15.94
Single Storey House	5.45	12.61	10.68	10.98	11.31	12.61
Two Storey House	11.11	14.15	12.73	11.33	17.46	17.46

MASTER BUILDERS GREEN LIVING

UNIVERSITY of TASMANIA

Dr Mark Dewsbury
Architecture & Design

05/09/2024

13

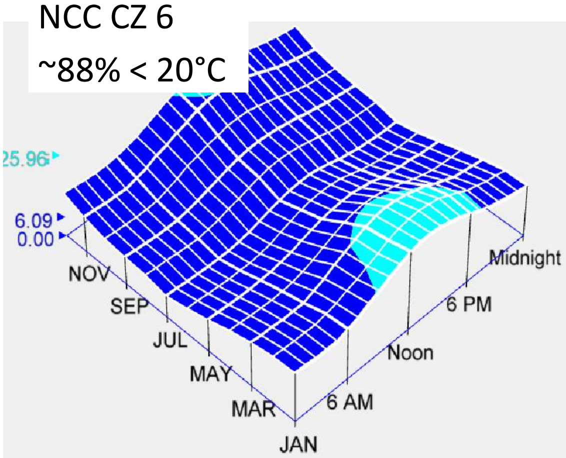
Fast forward to 2024… and the most recent research by the CSIRO, who went out and measured new homes, found the average air changes per hour for a single storey home in Victoria was 6.3. From an energy efficiency perspective, this is great.
But we have two concerns.
From a condensation and mould perspective, when we have an ACR of <8, we need to ensure we have addressed hygrothermal design considerations, which includes vapour permeable exterior membranes, vented and drained cavities and an interior vapour control membrane.
From an indoor air quality perspective, we need to be considering mechanical balanced ventilation to manage both the relative humidity and other indoor air pollutants.

- xx

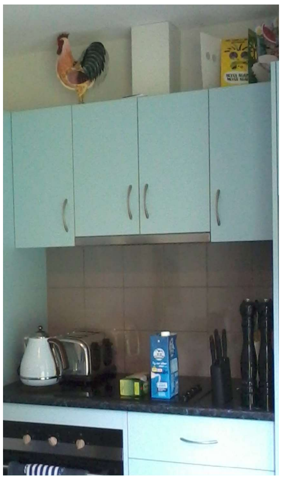
We need to ventilate - But when and how?

NCC CZ 6

~88% < 20°C



But where is the supply air?



(Climate Consultant 6.0, 2021)

To address some aspects of occupant generated moisture we might install bathroom and kitchen extraction systems. But in a reasonably airtight home, where is the supply air coming from?

But ask most people – where is the mould

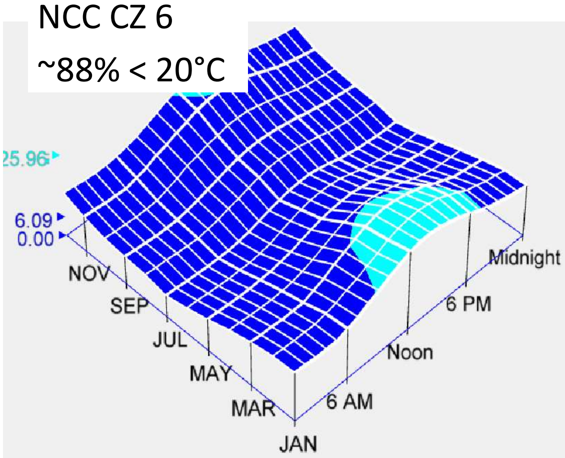
1. BEDROOMS

2. LIVING ROOMS

Where do we spend the most hours?

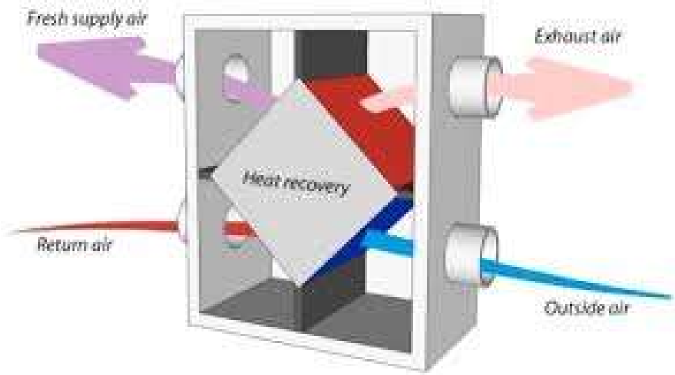
Why don't we open the windows?
Because it is too cold / noisy / insecure, ….

NCC CZ 6
~88% < 20°C



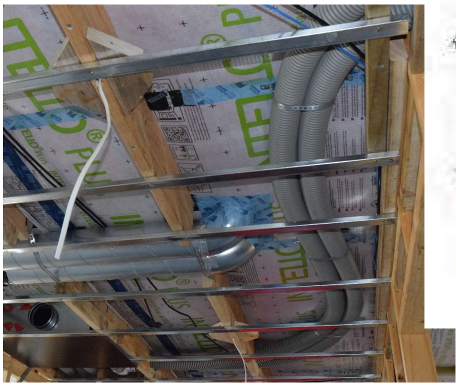
But when people often contact me re mould in their homes, they rarely mention bathrooms. They normally mention bedrooms and occasionally living rooms. If we think about this, it makes total sense. Most of the water in a bathroom is liquid, which flows into the drain, we rarely heat this room, and we only occupy it for a short period each day.
If we consider a bedroom, we occupy the room for at least 6 hours every night and continuously add moisture through our breathing.
But how do we remove this moisture?
How do we ensure the room is ventilated?
And for human health reasons, how do we ensure the room is heated or cooled, when the outdoor air is often too cold or too hot?

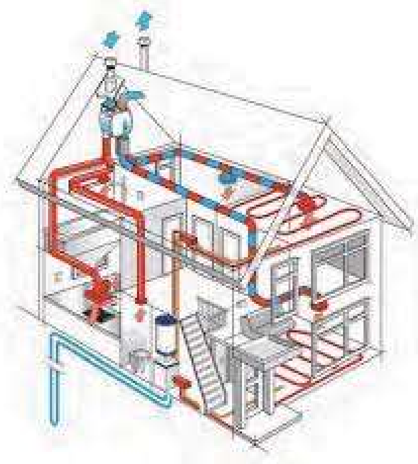
Modern RH and CO2 balanced ventilation



Other countries adopted enthalpy recovery ventilation decades ago. They realised that people do not open their windows to ventilate a home for a myriad of reasons, including, they are at work, security, noise, and smog reasons and the air temperature outside is too hot or too cold, just to mention a few. They identified the need to use high efficiency split systems for heating and cooling, paired with Enthalpy recovery ventilation to manage interior relative humidity, carbon dioxide, and other indoor pollutants. These ventilation systems range from single push-pull systems up to ….

Modern RH and CO_2 balanced ventilation





Davies Construction - Tasmania

Full house sized systems. But this only addresses the mass water vapour transfer via ventilation side of the equation. We are still left with managing the water vapour pressure within the exterior walls.

By reducing the RH to Max 65% we reduce condensation and mould growth risks

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

Interior dew point T for 22^{0}C / 80% RH

Td = T – ((100 – RH) / 5)

Td = 22 – ((100 – 80) / 5)

Td = 18.0^{0}C

Interior dew point T for 22^{0}C / 65% RH

Td = T – ((100 – RH) / 5)

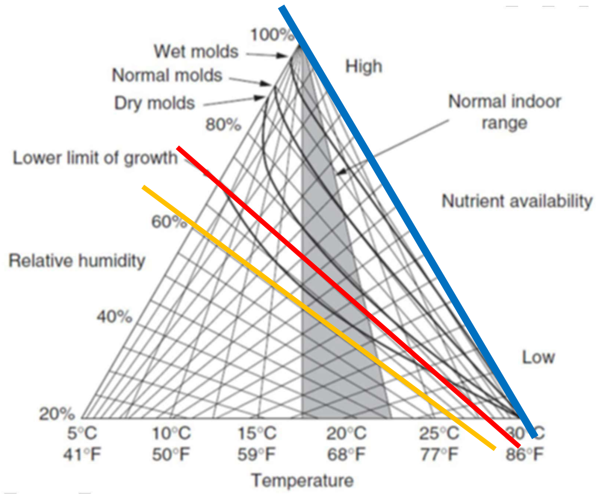
Td = 22 – ((100 – 65) / 5)

Td = 15.0^{0}C

For those that were here last year, I showed a simple formula to calculate dew-point temperature.
If we aren’t ventilating, the dewpoint temperature could be 18 degrees Celsius or higher.
But by managing interior relative humidity we can reduce the dew-point temperature to 15 degrees Celsius.
But we also know how often the exterior temperature is less than 15 degrees Celsius.

Does interior RH control stop interstitial mould growth?

- 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 less 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.)

Then there is the surface and/or interstitial mould growth issue.
The 2022 NCC shifted the focus to mould growth which directly affects human health, and we know that mould will grow in poorly ventilated interstitial spaces when the relative humidity exceeds 60%

Management of sub-floor and roof water vapour diffusion

Subfloor ventilation

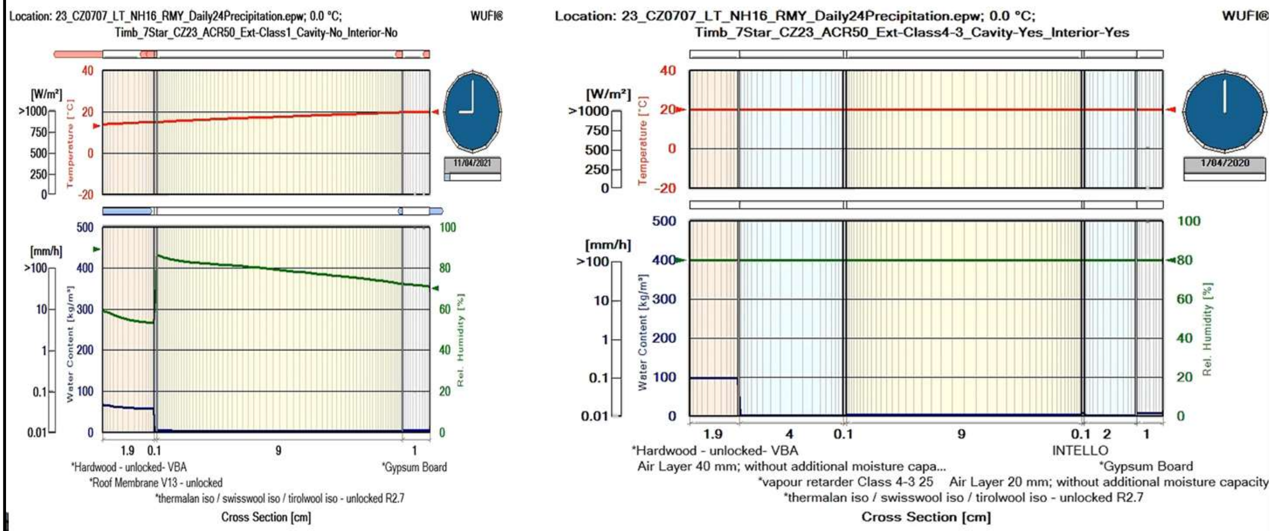
- NCC requirements for subfloor ventilation are the minimum and the relevant clauses also mention several scenarios where the ratio should be increased.

Roof Space ventilation

- NCC 2022 includes much more explicit requirements regarding the minimum amounts of supply and exhaust ventilation for 'unconditioned' Aussie roof spaces.

The NCC ventilation requirements for subfloor and roof space zones should address most issues.
But what about walls?

Management of external wall system water vapour diffusion



MASTER BUILDERS GREEN LIVING

UNIVERSITY of TASMANIA

Dr Mark Dewsbury
Architecture & Design

05/09/2024

21

This slide shows the hygrothermal simulation of a 2018 NCC compliant timber clad exterior wall and a better than 2025 code timber clad exterior wall with a vented and drained cavity, class 4 vapour permeable exterior membrane and an interior vapour control membrane,
Let’s watch the two movies and observe the green line for relative humidity and the blue line for moisture accumulation.

What we observe quite quickly is the relative humidity in the 2018 wall often exceeds 80% and we see moisture accumulating inside the wall system.
Whilst the better than 2025 wall system has a much lower relative humidity and no moisture accumulation.

Table 26: Bio-hygrothermal simulation results from 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 60, NCC CZ 6 with rain data

	Cavity	Exterior membrane	Interior membrane	AER 10	AER 7.5	AER 5	
RR1 6 Star	No	Class 3 (1398)	Nil	>3			NCC 2019
RR2 7 Star	No	Class 4 (175.4)	Nil	<1	>1 to <3	>5	NCC 2022
Case 2	No	Class 4 (175.4)	Nil	>1 to <3	5	6	
Case 3	No	Class 4 (100)	Nil	>1 to <3	5	6	
Case 4	No	Class 4 (21)	Nil	<1	>1 to <3	5	
Case 6	Yes	Class 4 (175.4)	Nil	<1	4	6	
Case 7	Yes	Class 4 (100)	Nil	<1	<1	5	
Case 8	Yes	Class 4 (21)	Nil	<1	<1	<1	
Case 10	No	Class 4 (175.4)	Yes	<1	<1	<1	
Case 12	Yes	Class 4 (175.4)	Yes	<1	<1	<1	

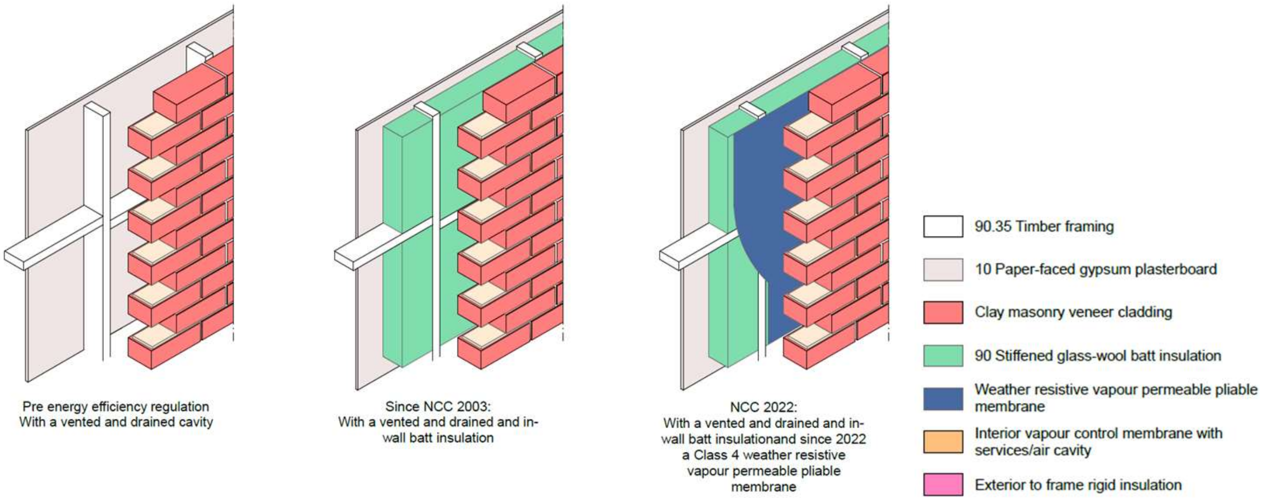
This table shows the hygrothermal simulation results for a compressed fibre cement sheet external wall system within NatHERS climate zone 60.
The left column shows various iterations of the exterior wall system which includes the water vapour permeance of the exterior pliable membrane, the inclusion of a vented and drained cavity and the last two cases include an interior vapour control membrane.
NCC 2022 states that an external wall system should have a Mould Index of <3 with a simulated ACR of 5. Only cases 8, 10 and 12 provide a suitable result.

Table 30: Bio-hygrothermal simulation results from 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 66, NCC CZ 6 with rain data

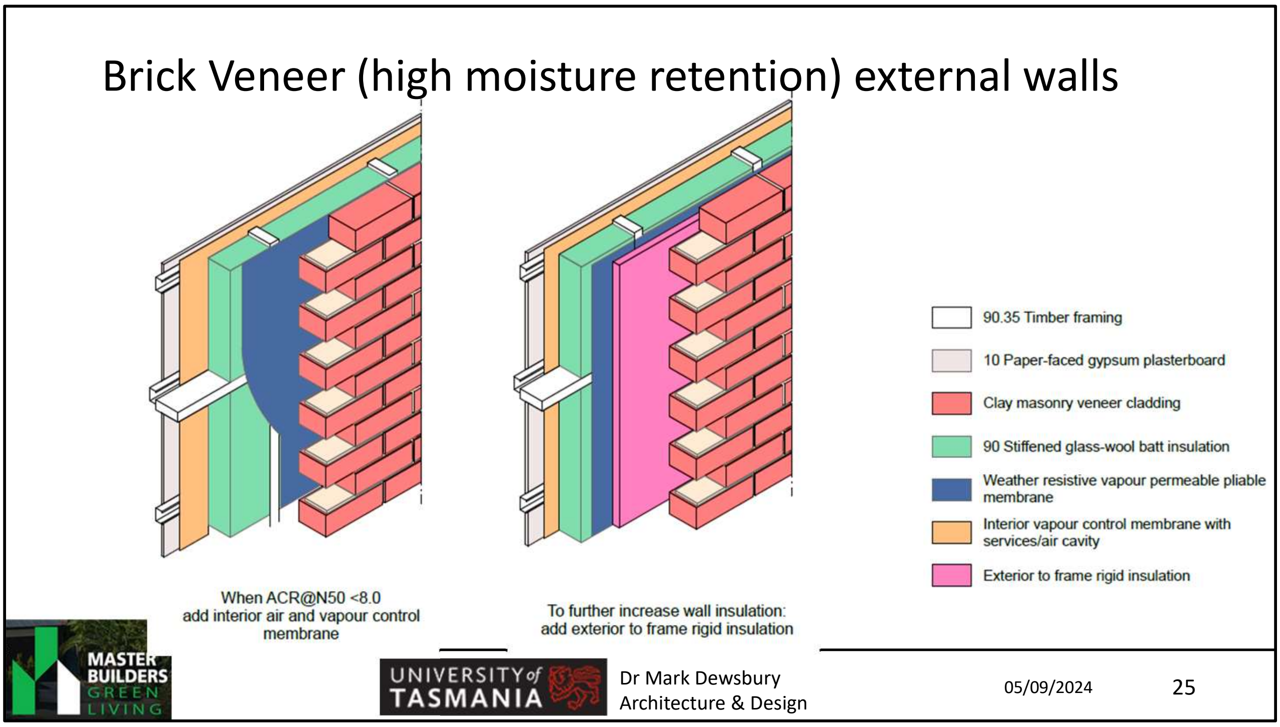
	Cavity	Exterior membrane	Interior membrane	AER 10	AER 7.5	AER 5	
RR1 6 Star	No	Class 3 (1398)	Nil	>4			NCC 2019
RR2 7 Star	No	Class 4 (175.4)	Nil	>1 to <3	>4	>5	NCC 2022
Case 2	No	Class 4 (175.4)	Nil	6	6	6	
Case 3	No	Class 4 (100)	Nil	6	6	6	
Case 4	No	Class 4 (21)	Nil	5	6	6	
Case 6	Yes	Class 4 (175.4)	Nil	5	6	6	
Case 7	Yes	Class 4 (100)	Nil	4	6	6	
Case 8	Yes	Class 4 (21)	Nil	>1 to <3	4	5	
Case 10	No	Class 4 (175.4)	Yes	<1	<1	<1	
Case 12	Yes	Class 4 (175.4)	Yes	<1	<1	<1	

This table shows the hygrothermal simulation results for a compressed fibre cement sheet external wall system within NatHERS climate zone 66.
The left column shows various iterations of the exterior wall system which includes the water vapour permeance of the exterior pliable membrane, the inclusion of a vented and drained cavity and the last two cases include an interior vapour control membrane.
NCC 2022 states that an external wall system should have a Mould Index of <3 with a simulated ACR of 5. Only cases 10 and 12 provide a suitable result.

Brick Veneer (high moisture retention) external walls

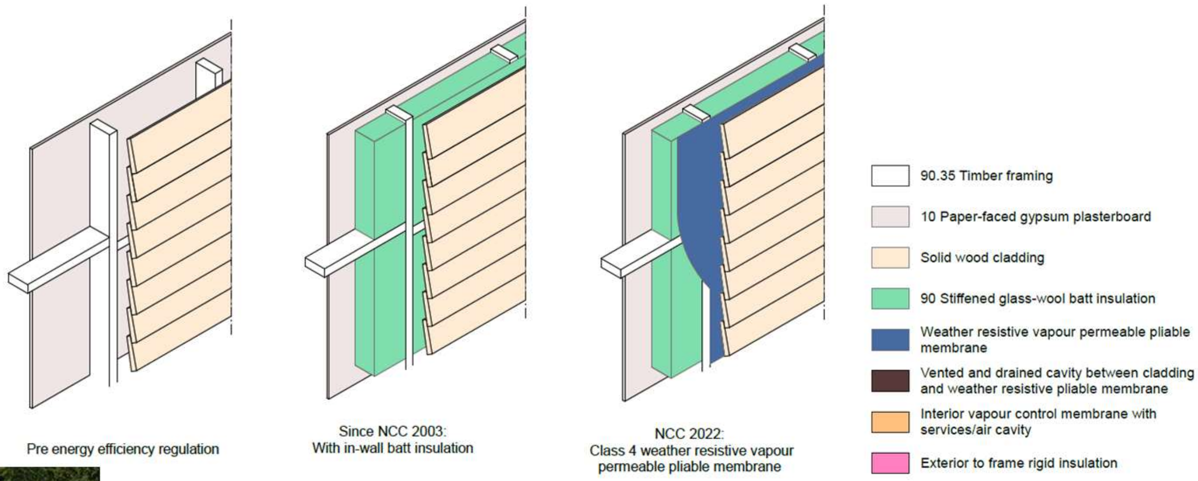


This slide shows the evolution of the brick veneer exterior wall from 1927 until NCC 2022, which requires a class 4 vapour permeable membrane on the exterior side of the insulation in climate zones 6, 7 and 8



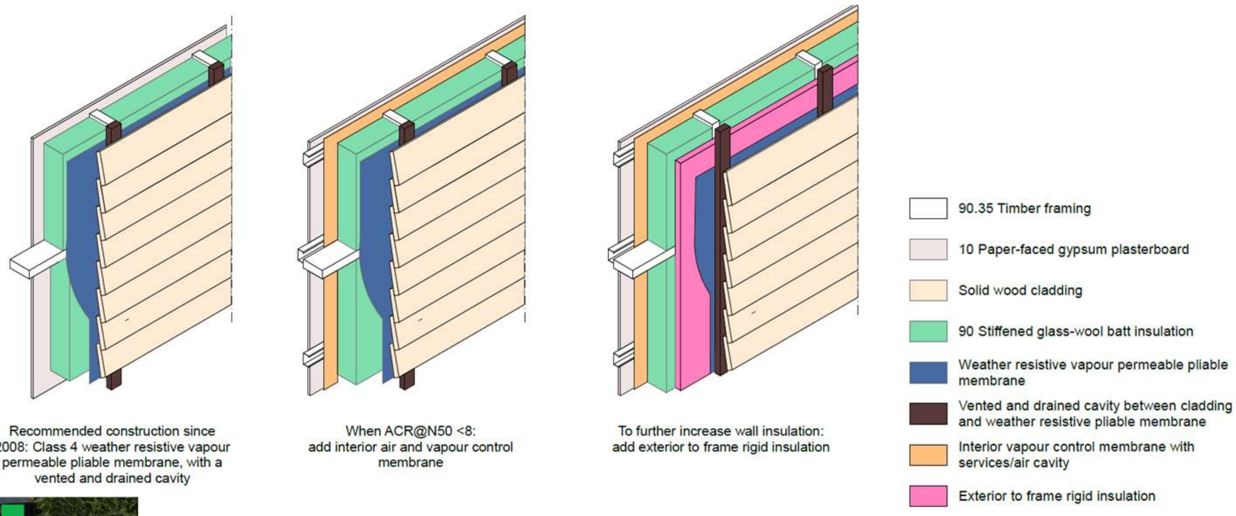
This slide shows the next evolution of the brick veneer external wall system which could include an interior vapour control layer and the addition of exterior rigid insulation.

Low moisture content clad timber frame



These same principals apply to other forms of clad timber or steel framed exterior wall systems, where we have evolved to insulated walls with an exterior vapour control layer, but to date there is no requirement for a vented and drained cavity,

Low moisture content clad timber frame



MASTER BUILDERS GREEN LIVING | UNIVERSITY of TASMANIA | Dr Mark Dewsbury Architecture & Design | 05/09/2024 | 27

Looking ahead, we should be adding a vented and drained cavity which could be teamed with an interior vapour control membrane and an exterior rigid insulation

Summary

We need

- Well insulated walls to reduce heating and cooling energy use,
- Strong solar control to reduce overheating,
- An airtight building envelope,
- A mix of passive and active ventilation to control interior generated relative humidity and other pollutants,
- Passively ventilated subfloors, roof spaces and external walls,
- A highly weather resistive and vapour permeable exterior pliable membrane, and
- When the ACH is <8.0 an interior vapour control membrane.

2024 MBV
Green Living Conference
Building for the Future

Controlling human generated water vapour

Dr Mark Dewsbury
University of Tasmania
(mark.dewsbury@utas.edu.au)