Information Sheet 12:

# The importance of airtightness in low energy buildings

**The recent change to the National Construction Code (NCC) 2022, which requires new residential buildings (Class 1, Class 2 and Class 4) to have a minimum thermal performance level of 7 stars under the Nationwide House Energy Rating Scheme (NatHERS), will in theory improve the thermal performance of new buildings.**

However, building thermal efficiency, air leakage, thermal bridging and condensation control are interconnected and optimising thermal performance of a building requires a holistic approach and cannot be addressed on a piecemeal basis. If you don't reduce air infiltration you cannot optimise thermal performance nor control condensation because air leakage is 100 times more important for carrying moisture into a building element than moisture permeability of building components!

## Major disconnect between "as built" and "as designed" energy efficiency performance in Australian homes

Simply adjusting the stringency of NatHERS will not adequately address the major disconnect between "as designed" by simulation software, such as NatHERS and BASIX, and "as built" energy efficiency performance in Australian homes. A CSIRO study[1] of actual energy usage in 5-star houses found that compared to nominally 4-star rated houses; the 5-star houses reduced energy consumption to maintain comfort in winter, but the cooling energy used in summer was higher than in the 4-star houses. A follow-on study by the CSIRO[2] found that over 50 per cent of houses were excessively leaky beyond the level of assumed air tightness in the NaTHERS software (15 ACH@50Pa) when tested with a blower door test. Further, they also had a high level of insulation workmanship problems with 10 per cent of houses having poorly installed ceiling insulation, 22 per cent having poor or no weather sealing around doors and 5 per cent with poor or no weather sealing around windows.

Another report on the discrepancies in "as built" versus "as planned" energy consumption through BASIX also stressed the need for improving construction and building envelope quality control.[3] In a subsequent report they identified the root causes[4] of the performance gap observed in the earlier CSIRO study as being related to workmanship (excessive air-leakage and poorly installed insulation) plus "trade-offs" on the thermal performance of one building component against another (eg windows versus walls). The impact of variable air infiltration rates and insulation installation on residential energy performance was simulated by DRET[5] using NatHERS. The study demonstrated that the presence of uncontrolled air infiltration can reduce "as-built" star-ratings by over 1.0-star alone but if combined with poorly installed insulation can have a dramatic effect on the "as-built" star-rating of up to 1.7-stars under NatHERS.

In one study[6] in 2008 of an actual NatHERS 7-star rated brick veneer home in Victoria the measured air-leakage at $ACH_{50}$ = 26.8 increased the heating /cooling energy usage from the NatHERS 7-star target of no more than 83 MJ/m2/year to 293 MJ/m2/year (about a 2.5-star performance) costing the homeowner around $400-500 per annum (in 2013 adjusted energy prices). It was estimated by the builder to cost around $5,000 to remedy the air-leakage post construction versus $600 during construction.

NatHERS is a useful design tool which provides guidance on optimising the thermal performance of a home but it cannot guarantee that "as designed" equals "as built".

## Practical limitations to software modelling such as NatHERS

NatHERS includes formulas for estimating the factors that influence the energy efficiency of the building envelope. However, according to the CSIRO[7] the modelling of air infiltration rates, which can account for up to 30 per cent of space heating and cooling load, for **building energy simulation 'is very difficult (if not impossible)**". Even using their latest "multi-zone model" compared to an actual blower door test they found that the new model still underestimated the air infiltration rate by around 12 per cent which they attribute to "cracks/holes such as those in walls and joints between wall/ceiling, wall/wall and wall/floor".

While the Australian Modern Building Alliance (AMBA) supports ongoing efforts to improve the NatHERS modelling, including the effect of air infiltration, on building energy usage AMBA strongly recommends that the ABCB be pragmatic and consider adopting proven prescriptive methods from California that will reduce air infiltration and building energy usage.

## No mechanism to address workmanship issues in NatHERS or the NCC

There is no mechanism to address workmanship problems relating to the energy efficiency of the building envelope in the NCC. While the simplest method to evaluate insulation and air-barrier defects[8] is onsite visual inspection during construction, AMBA recognises that re-introduction of visual inspection of the building fabric, as used to happen by building surveyors prior to deregulation, maybe outside of the scope of the NCC. Thus, AMBA strongly recommends that the ABCB be pragmatic and consider adopting proven prescriptive methods from California that will help to achieve a better outcome in terms of air-barrier and insulation installation quality.

## The National Construction Code inadequately addresses building sealing (air leakage)

Air-leakage (infiltration) has been estimated by the Sustainable Energy Authority of Victoria as responsible for up to 25 per cent of heat losses/ gains in a house in a temperate climate. There are three factors[9] to an energy efficient building; airtight construction, continuous insulation (including no thermal bridges[10] and moisture control[11]. The most important factor is airtight construction followed by continuous insulation and then moisture control. Wall and ceiling assemblies do not need to "breathe" but should be "built tight and ventilated right".

The Building Science Corporation has conducted a lot of research for the Department of Energy[12] on this issue. The fallacy of "breathability" of building elements has also been nicely summarised in a document by PU Europe.[13] AMBA agrees with the ABCB scoping study on condensation in residential buildings that "some of the underlying building science informing the code is outdated" and there is a need "for more education and information that is both easily understood and accessible"[14]. AMBA also supports the need to introduce hygrothermal (condensation) analysis at the building design stage as recommended in the same document because air-leakage is a significant factor in potential building condensation.

"Air sealing reduces heat flow from air movement (convection) and prevents water vapour in the air entering the wall" which can lead to problems such as loss of R-value in traditional fibrous insulation, growth of mould and deterioration of building materials such as timber framing. Ignoring rain leaks, sealing air leaks is 10 to 100 times more important than installing a vapour barrier as most moisture enters walls either through fluid capillary action or as water vapour through air leaks. Vapour barriers retard moisture due to diffusion but air movement accounts for more than 98per cent of all water vapour movement in building cavities.[15] This however does not mean that vapour barriers are unimportant and AMBA agrees with the ABCB scoping study on condensation in residential buildings[14] that there is a need for more education and guidance on the use of vapour barriers, as well as the role of thermal bridges, in condensation control.

Australian residential buildings are excessively leaky compared to international standards. In fact, at 19.7 $ACH_{50}$, they are roughly equivalent to pre-1950's houses built in the USA and significantly worse than newer houses (6.2 $ACH_{50}$) in the USA.[16] **The NCC 2022 contains a target airtightness (10 $ACH_{50}$) but there is still no mechanism to address the related workmanship issues ("as built" performance). Further, there would be significant energy savings if the target air leakage level was reduced to 5 $ACH_{50}$** as the reduction in energy demand due to air infiltration rate (air leakage) is proportional to the reduction in infiltration rate[4]. A more stringent target of 5 $ACH_{50}$ would seem reasonable as it is comparable to what is achieved in the USA yet is considered on the border for not requiring a permanent ventilation system.[15, 17] Targets below this value, such as the Passive House standards, may be overkill given the much milder climate in Australia versus Europe.

There are two problems with the way NatHERS treats air leakage in buildings; it ignores air leakage through building elements/products (air permeability) and it ignores air leakage due to gaps that need to be sealed during the construction phase. NatHERS includes formulas for estimating the air infiltration rate based on a simple checklist ie number of ceiling penetrations such as exhaust fans, presence of roof sarking, subfloor access


***Figure 1:** One Component Froth (OCF) a) sealing of wall penetrations, b) sealing of door frame to building frame (photos courtesy of Huntsman Polyurethanes).*

***Figure 2:** Application of SPF between Timber studs (photo courtesy of Huntsman Polyurethanes).*

to the wall cavity, weather stripping of windows and doors.[18] While such an approach addresses weather sealing
of a building at the design level (ie avoid downlights etc) and post occupancy level (ie fit weather seals between the door and the door frame) it completely ignores workmanship and the need for sealing certain building elements at the construction phase. The CSIRO[19] has previously highlighted "cracks/holes such as those in walls and joints between wall/ceiling, wall/wall and wall/floor" as areas of significant air leakage.

Sealing of door and windows during construction is commonly solved in Europe using OCF (one component froth or foam) which expands to form an airtight seal between the window/door frame and the building structure (Figure 1). Similarly, sealing of all plumbing, electrical or HVAC penetrations is commonly solved in the USA by using OCF or SPF (polyurethane sprayfoam). Because these materials expand and self-adhere to common building substrates it reduces the level of workmanship required to seal a building.

Similarly, in terms of air leakage through building elements/products it is well known that traditional fibrous insulation[20] is difficult to install without defects such as air gaps and compression around wires, pipes and electrical boxes. Experimental work on fiberglass batts installed in walls by the Oak Ridge National Laboratory[21] in 1998 found that the "*clear wall R-value*" was 11 per cent less than the labelled R-value when "*installed perfectly*" and 28 per cent less when "*commonly installed*". In contrast modern insulation materials such as SPF between the studs (figure 2) and polyisocyanurate (PIR) board insulation (figure 3 and figure 4) externally applied to the studs with joints sealed with tape are both considered air barriers under Californian prescriptive codes and do not require the installation of a separate air barrier like fiberglass insulation.[22] The "taped" PIR board insulation (called polyiso in the USA) passes ASTM E331 as a weather resistive barrier and also reduces thermal bridging.

AMBA suggests that further improvements need to be made in the NCC 2022 to address workmanship in regard to residential building air leakage; either the blower door testing should be made mandatory (verification Method JV4 and V2.6.2.3)[23] prior to issuing an occupancy certificate and/or the ABCB should be pragmatic and consider adopting proven prescriptive methods from California that will reduce air infiltration and building energy usage.

In terms of the first option there is already significant precedence for mandatory blower door testing in other jurisdictions or voluntary schemes. States in the USA, which use the 2015 IECC standards, require mandatory blower door testing by an independent third party. The UK Building regulations (Part L) require representative sample testing for domestic new dwellings in a development by blower door testing and a penalty applies for the builder for non-compliance to the air permeability limit leakage. Sampling rules also exist in France and Germany. Finally, several voluntary schemes such as the Passivhaus (Germany), Minergie® (Switzerland) and Minergie-P®, LEED (USA), BREEAM (UK) also include mandatory blower door tests.

In terms of the second option, the Californian Building Energy Standards include a prescriptive insulation installation (QII) measure in the 2019 code. The insulation inspection pro forma[24] for residential buildings which is used at the framing stage specifically requires a separate *air-barrier* in all buildings using fibreglass insulation. However, it specifically exempts the need for a separate *air-barrier* if SPF is used between the studs or taped PIR board insulation is used externally on the timber frame because closed cell SPF has an air permeance of 0.0002L/s.m$^2$ @ 75Pa while PIR board insulation (polyiso as it is called in the USA) has a negligible air permeance due to the foil facing. The use of exterior rigid insulation board to replace a separate air barrier reduces the amount of labour needed in the construction of a house and the amount of on-site waste generated.

Many practical examples of how the closed cell structure, ability to bridge cracks and gaps and self-adhering properties of SPF can dramatically reduce heating/cooling costs in a house by preventing air leakage have been reported. Typical older timber frame houses in the USA which are insulated with glass wool batts between the studs often exceed 1.0 air change per hour (ACH) when subjected to a blower door test. Simply substituting closed cell SPF[25] for the glass wool batts reduces air leakage to between 0.1 and 0.2 ACH which significantly reduces heating/cooling loads and improves comfort substantially. While the HVAC unit must be correctly specified to control ventilation and humidity typically it can be down sized by at least half!

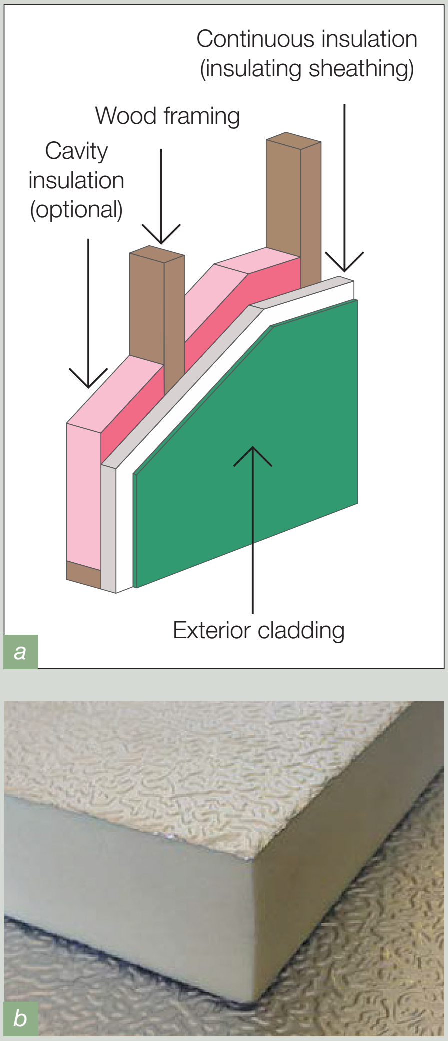


***Figure 3:*** *a) Schematic Illustration of the continuous insulation concept for a timber frame wall, b) PIR board insulation with foil facers (photo courtesy of Pirmax Pty Ltd).*


***Figure 4:*** *Foil faced PIR insulation board being installed: a - b) external to a timber frame, and c) to the inner sheath of a double brick cavity wall (photos courtesy of Pirmax Pty Ltd).*

Thus, in summary AMBA strongly recommends that the ABCB should be pragmatic and at a minimum consider adopting the mandatory use of exterior rigid insulation board into the NCC like California which would allow Australia to significantly close the gap on air-tightness standards between Australia and the USA.[16] Further, the NCC 2022 Part 10.8.1 (and F8D3) should be modified in the NCC 2025 because currently, as written, it is based solely on the use of porous insulation, such as FG batts, which requires building elements such as walls (for example) to have a vapour permeable air barrier external to the insulation in cold climates but a vapour barrier air barrier in hot climates due to internal AC usage.

**Suggested modification of "F8D3 and 10.8.1 external wall construction" in the NCC 2025**

(1) All porous insulation, with a vapour permeance of greater than 0.143 µg/N.s, installed in an external wall must be accompanied by a pliable building membrane -

a) which complies with AS/NZS 4200.1 and
b) is installed in accordance with AS 4200.2 and
c) is located on the exterior side of the insulation and
d) the pliable membrane, sarking type material, must have –
   a) in climate zone 1,2 and 3 a vapour permeance of no more than 0.002 ug/N.s,
   b) in climate zone 4 and 5 a vapour permeance of no less 0.143 ug/N.s and
   c) in climate zone 6,7 and 8 a vapour permeance of no less 1.14 ug/N.s.

(2) Vapour impermeable board insulation, with a vapour permeance less than 0.002 ug/N.s, does not need to be accompanied by a pliable building membrane provided it is installed as continuous insulation external to the frame in lightweight framed construction or external to the inner leaf in double brick construction.

(3) Except for single skin masonry and single skin concrete, where a pliable building membrane is not installed in an external wall, the primary water control layer must be separated from water sensitive materials by a drained cavity.

## Conclusion

Building thermal efficiency, air leakage, thermal bridging and condensation control are interconnected and require a holistic solution. To further improve energy efficiency in residential buildings there needs to be greater focus on air leakage and thermal bridging where most energy is currently wasted. To this end:

- the pragmatic adoption of prescriptive methods, such as the use of *continuous insulation* external to the frame or polyurethane sprayfoam between the studs, currently used in California to reduce air leakage and thermal bridging is recommended,
- that mandatory blower door testing be introduced to drive improved workmanship of insulation and air barriers is recommended.

**More information:**
**www.australianmodernbuildingalliance.org.au**

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