There's a hole in the bucket, dear Liza
The benefits of insulation

Richard Keech found many hidden benefits from plugging the last thermal 'hole' in his house.

THIS article considers the many hidden benefits of insulation following the upgrade of my own home. The house is a renovated 200 m² period timber dwelling in Melbourne and is home to a family of two adults and two children.

The value of completeness

Heat flowing uncontrolled through the external surfaces of a home is like water leaking through holes in a bucket. With the leaky bucket, it probably makes sense to plug the worst hole first. However, until all holes are substantially plugged, it's still a leaky bucket.

Likewise, with insulating a home, it usually makes sense to first address the biggest source of uncontrolled heat transfer—the ceiling. However, the full benefit from insulating won't be realised until all external surfaces are improved.

The implications of this thinking are that it's really important not to leave the task of insulation incomplete. Features such as floors and walls, if left badly insulated, can seriously compromise the overall thermal performance.

This is borne out by my own experience where plugging the last thermal 'hole'—the walls in my case—made an enormous difference to the home's apparent thermal comfort and air conditioning system performance.

↑ Many older homes have little or no insulation. This one has floor, wall and ceiling insulation and a better than 5 Star energy rating (the original energy rating was less than 1 Star).

The hidden benefits

Most people understand intuitively that insulating a home means that heating and cooling systems don't have to work as hard to maintain a set temperature. This is the central and obvious point of insulation—better-insulated homes can maintain a given temperature more easily. However, there are a number of second-order benefits of insulation which I would argue make properly installed and complete insulation even more valuable and effective than is perhaps generally realised.

I think that people's concept of thermal comfort is often based mainly on air temperature, but there are other factors. It might not be a surprise that mean radiant temperature, air velocity and humidity all contribute to thermal comfort. However, it might be a surprise just how important some of these other factors actually are.

RELAXED SET POINTS

We're familiar with the idea of radiant heat from high-temperature surfaces such as from a radiant heater. However, inside our homes, the temperature of all surfaces—walls, ceilings, floors etc—surrounding us causes them to radiate in the long-wave infrared band. Engineers and physics nerds call this 'black-body' radiation.

In calculations of thermal comfort, the average temperature of all the surrounding inward-facing surfaces is the 'mean radiant temperature' (MRT). MRT has a huge bearing on thermal comfort and improved MRT is an important hidden benefit of a well-insulated home. It is the reason why you need a higher indoor air temperature in winter than in summer for the same level of comfort.

A person inside on a hot summer day might find themselves with ideal thermal comfort at an air temperature of 20 °C when the MRT is 24 °C. However, if, for example, the walls, ceiling and floor are better insulated, then less of the outside heat will transfer through, so the wall surfaces will be slightly cooler and radiate less into the interior. So the MRT might be lower, say 22 °C.

In this case, the same thermal comfort will be achieved with a slightly higher indoor air temperature of about 21 °C. This example illustrates the trade off between MRT and air temperature in achieving thermal comfort.

The equivalent winter-time scenario is illustrated in Figure 1. The blue line shows points of equal thermal comfort. In other words, any point on the line corresponds to an air temperature and a radiant temperature which, together, give the same comfort as for every other point on the line.

The implication is that better-insulated homes can use more relaxed temperature set points to achieve the same level of comfort—that is, the air conditioner temperature can be set higher in summer and lower in winter. They are relaxed in the sense that the heating/cooling system doesn't need to work as hard.

This became apparent in my home following the installation of wall insulation. After wall insulation, I found that I could back-off the set point by about 2 °C . The result is that not only is my air conditioner working less hard to keep the temperature at a given set point, but by operating at a lower set point it uses less energy still.

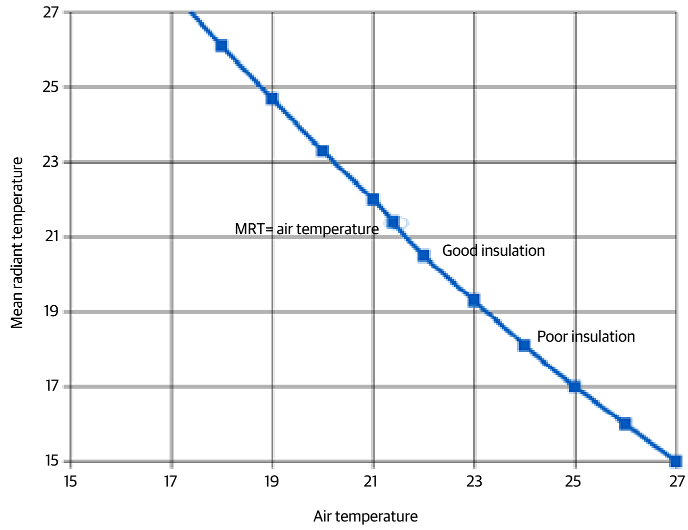

Figure 1. Equal thermal comfort, winter scenario. Any point on the line corresponds to an air temperature and a radiant temperature which, together, give the same comfort as for every other point on the line. (pmv=0.0, clo=1.0, met=1.2, v=0.05; these values are given for the benefit of those with expertise in thermal comfort—we will be looking at them in more detail in a follow-up article.)

SLOWER AIR

Anyone who stands in front of a fan knows that, for better or worse, the movement of air makes a big difference to the perception of thermal comfort.

In a well-insulated home in winter or summer, heating or cooling needs can be satisfied with a lower average fan speed, so there will be fewer draughts and associated changes in comfort levels as occupants move between zones of still air and moving air.

Additionally, at the times when the air conditioner happens to be stopped, the natural convective air movement will be less because the temperature difference between the surfaces (floors, ceiling, walls) and the indoor air is less.

MORE PASSIVE-COMFORT TIME

The next indirect benefit of insulation is that homes will tend to stay within a comfortable temperature range more often without any active heating or cooling. Thus, there are fewer times that the occupants need to even think about heating and cooling. And you might find you can turn your air conditioning system off at the meter box to entirely eliminate the standby load for a few months of the year.

QUIET TIME

Another side effect of improved thermal insulation is improved acoustic insulation. A well-insulated home, especially if you've got double glazing, has the extra bonus of being naturally quieter inside in the presence of street noise, aircraft noise etc.

CONDENSATION

When it's cold and humid, and when you're heating inside, there is a risk that warm air will condense on cool surfaces such as the inside of uninsulated outer walls. Likewise in summer there is a risk that warm outside air will condense inside the wall space on outside walls adjoining air conditioned rooms.

Properly installed wall insulation could lead to a lessening of this condensation risk because the temperature profile through the wall is smoother and the relaxed set points lessen the temperature difference across the wall. On the other hand, where there is moisture, insulation might sometimes lessen the ability of the moisture to fully dry out.

SMALLER, CHEAPER SYSTEMS

The improved thermal efficiency of an insulated home means that heating and cooling systems can be smaller and therefore cheaper. Also, if an air conditioning/heating system is working less hard then it's probably going to operate more reliably. Another advantage of smaller systems is that they generally operate more quietly (all other things being equal).

DECREASED AIRCON USE ANXIETY

When an air conditioning system is more efficient and effective, owner anxiety about when to use it may be lessened. Many people are concerned about the potential for high operation costs or, in overnight operation, noise disturbance. As I write this I've just slept through a very hot Melbourne night (minimum 30 °C) and I had my upstairs bedroom air conditioner running (very quietly) the entire night. In my home prior to the insulation and air conditioning upgrades I would never do this because of concerns about cost and noise.

Aircell Retroshield was stapled to the underside of the roof as part of the roof space insulation.

RESILIENCE

In an uncertain climate future, it's important that we can safely cope with contingencies such as power outages during heat waves. A properly insulated house is going to reduce the risk of heat stress in these situations, even if the absence of active cooling means indoor temperatures get outside the ideal range. It's been widely reported that many lives are lost during heat waves, so it's not too much of a stretch to suggest that better-insulated homes could save lives.

My insulation

CEILING INSULATION

The main ceiling insulation was improved by adding R3.5 polyester bulk batts over the top of existing R2.5 batts. Over and above this, I used Aircell Retroshield stapled to the underside of the roof as shown in the photo. The manufacturer's specifications indicate that the Aircell provides R values of 3.3 down (i.e. summer) and 1.4 up (winter). In my case I was lucky not to have downlights to deal with (downlights and insulation are discussed in the Insulation Buyers Guide on p. 64).

UNDERFLOOR

The home has a suspended timber floor which has been insulated using R2.5 polyester batts fixed in place with staples. Current industry guidelines suggest that this type of insulation is best kept securely in place using cross-strapping with nylon wire secured with non-conductive staples. Installing this insulation is a messy and uncomfortable job but well worth doing if the underfloor space is accessible.

WALLS

Improving the wall insulation was the most difficult part and the only part where DIY was not an option. It was left until last. I chose a product called EcoFoam which is an injected foam providing improvement in insulation of about R2.5 in a standard stud-frame wall.

EcoFoam is an expanding two-part water-based foam that goes in with the consistency of shaving cream and sets to a brittle white solid foam. It enters the wall cavity pre-expanded, so there's no risk of bursting the plaster. As shown in the photo, in my house it was injected through holes drilled in the weatherboards. These holes were then plugged with wooden disks. Finishing by sanding and painting was done by me. The foam is injected through a small hole in the sarking, if present, and fills the space between the plasterboard and the sarking. Only the downstairs part of the house was done.

There are precautions with EcoFoam to do with in-wall electrics. As part of the provided service, I was visited by an electrician who de-rated my electrical circuits from 20 amps to 16 amps (by replacing circuit breakers) and installed shrouds behind power points on affected walls. The shrouds are to stop the wet foam from fouling the back of the power points. The circuit de-rating is to ensure compliance with Australian electrical standards and might not be required in all homes.

After installation of the foam I found that there was a lemony smell for about two weeks as the foam cured. Another issue is that the entrained water vapour dissipates through the outside walls so any walls with legacy lead paint (which is impermeable to water vapour) are prone to bubbling.

Results

For our house, the wall insulation plugged the final hole in the metaphorical bucket, at least downstairs.

Across the course of a year in Melbourne the results have been impressive. As already described above, I find that the air conditioner/heater set point can now be relaxed by about 2°C compared to the year before in both summer and winter.

The house is noticeably warmer in the bedrooms on cold winter mornings even when no active heating has been used overnight. I now have measurements of air conditioning and heating energy used from month to month. Winter 2013 (with walls done) used 25% less heating energy than the preceding year (with ceiling and floor insulated, but not walls). Table 1 shows these figures.

In 2013, overall energy use is 75% less than in our baseline year of 2006. Note that this

	Pre wall insulation kWh/year	Post wall insulation kWh/year
Heating	2256	1691
Cooling	256	Not yet available

Table 1. Energy use before and after wall insulation.

results from the combined effect of many improvements including insulation. Table 2 shows these results.

Performance rating

Assessing the dwelling using industry-standard tools indicates that it rates as shown in Table 3. The baseline year is 2006, i.e. before improvements. The improved years are 2012 (without wall insulation) and 2013 (with wall insulation). Note that the improvement indicated in the table arises from the insulation, as well as improvements to other things such as glazing and draught proofing. The measured improvement from 2012 to 2013 (25%, as noted above) agrees closely with the modelled improvement shown in the table.

If the final rating of 5.1 Stars looks low, it's probably because the upstairs part of the house has not been able to be fully improved because of the design. This part of the house includes the study and master bedroom and is built with no accessible ceiling space.

→ EcoFoam is injected into wall cavities through small holes in the outer walls, which are then sealed over and painted.

Conclusion

My experience shows that sustainability improvements—mainly insulation—can reduce heating and cooling energy requirements significantly, in my case by about 75%. The additional benefits to thermal and acoustic comfort are an unexpected bonus for me. ✳

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More info:

Insulation Council of Australia and New Zealand, 2012, *ICANZ Insulation Handbook – Part 2: Installation*, www.insulation.com.au/_literature_84803/ICANZ_Handbook_Part_2_Installation

Australian Government, 2013, *Your Home, 5th Edition*, Part 2, Section 8 'Insulation Installation', yourhome.gov.au

Year	Total energy (electricity & gas) GJ/year	Heating/cooling energy GJ/year
2006	80	29 (estimated)
2012	23	9.5 (estimated)
2013	20	7.3

↑ Table 2. Total and heating/cooling energy use reduction since improvements.

Stage	Star rating (out of 10)	Estimated heating and cooling improvement(%)
Baseline (2006)	0.9	-
Improved (2012)	3.3	57
Improved (2013)	5.1	75

↑ Table 3. Modelled Star rating changes and estimated energy improvements for heating and cooling since the baseline year of 2006.

DIY warning

As with any household maintenance activity, adding or changing insulation carries safety risks. If you plan on doing it yourself, please carefully read the ICANZ Insulation Handbook—Part 2: Installation, and be particularly mindful of the sections on hazards.

Foil installation warning

Aircell is metalised foil insulation. Stapling of foil insulation needs to be done with extreme caution because of the possibility of accidental contact with electrical cabling leading to the risk of injury or death by electrocution.

Although electrical cables are required to be installed in such a manner as to be protected from damage (which means they must not run over joists unless encased in conduit), many homes have wiring that simply does not meet this requirement.

Use of plastic staples is recommended (this may be a requirement in some areas). Please check before you try this yourself or use a professional installer.