INSULLIVING HOUSE

POST-OCCUPANCY ENERGY PERFORMANCE REPORT

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Disclaimer

This research was commissioned by Metecno Pty Ltd, trading as Bondor®. The InsulLiving house was designed and constructed by Bondor®. The house instrumentation (electricity circuits, indoor environment, weather station) was provided by Bondor and supplied and installed by independent contractors. The InsulLiving house was occupied by a family of four (two adults and two children) for the monitored period.

Queensland University of Technology advised on the type and quality of instrumentation required for post occupancy assessment, but had no involvement in the final selection or installation of the equipment. As part of the research process, the validity of the data provided by the instrumentation was assessed. Research staff had no previous personal connections with the occupying family, but engaged with them during the one year performance evaluation.

This report is a general audience overview of the research conducted. A more detailed academic paper will be published through an appropriate research journal in 2014.

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Executive Summary

This report contains analysis of data collected from the InsulLiving house at Burpengary during 1 year of occupancy by a family of four for the period 1 April 2012 – 31 March 2013.

Data collection included:

- electrical energy consumption (logged consumption per electrical circuit) and solar power generation (logged generation);
- internal room temperatures and solar cell temperatures;
- external wall material temperatures (exterior skin, inner and interior skin);
- micro climate (onsite weather station: temperature, relative humidity, rainfall etc);
- Internal air quality (CO_2);
- Thermal imaging and air tightness;
- Occupant behaviour; and
- Visual inspection

The data was analysed by Dr Wendy Miller, Faculty of Science and Engineering, Queensland University of Technology, with assistance from Hoda Shah-Nazari, a Masters by Research student.

The findings of the post-occupancy assessment can be summarised in six key messages:

Message #1: Comparison of InsulLiving data with regional electricity consumption data shows that the daily average electricity consumption of the InsulLiving house (for the monitored period of 1 year) was 48% less than the south-east Queensland average (adjusted for family size).

Message #2: The InsulLiving house required much less space heating and cooling than the national average (13% compared with 39% of energy use). The minimum need for space heating and cooling to meet the comfort needs of this family allowed them to manage their electricity consumption through managing their use of lighting and appliances.

Message # 3: Using software approved by the NCC, the InsulLiving house was modeled for climate 9, achieving a 9 star rating. In occupancy, for the monitoring year, it achieved a 9.5 star rating. This means that the house provided a high level of comfort for the occupants whilst requiring very little energy for heating and cooling. The daily average energy consumption for heating and cooling for this family, for the monitored period, was 1.74kWh. This equates to a heating / cooling bill for the year of $160 (assuming $0.25378c per kWh).

Message 4: A high star rated house (9 stars) in this climate, provides a very high level of thermal comfort (87% of the year) without additional space heating or cooling. If occupants choose to provide additional comfort through the use of heating or cooling appliances, the energy required to provide this additional comfort is very minimal (about one third of the energy that a 6 star house would need to provide the same level of comfort).

Message #5: The InsulLiving house, for the monitored period, was 'net zero energy' for space heating and cooling, lighting and most water heating. The renewable energy was supplied from a modest solar power system (2.1 kW). A 5kW solar power system would be sufficient to enable this home (for these occupants) to be net zero energy solar home. Alternatively, occupants with different comfort requirements and efficient appliance use (reducing general power) could live within the generation capacity of the current solar power system, achieving a net zero energy lifestyle.

Message #6: The InsulLiving construction method, with structural insulated panels, provides a more consistent and reliable insulation quality for the building envelope, compared with other construction methods inspected.

INTRODUCTION

This report examines "**energy use**" and "**thermal comfort conditions**" for Bondor's InsulLiving House in Burpengary, Queensland. This report is based on a range of data sources: energy and temperature data collected from the occupied house for the period 1 April 2012 – 31 March2013; energy and temperature data collected from a selection of houses in South East Queensland (SEQ) for the period February 2012 – March 2013; and regional electricity consumption data provided by Energex, the local distribution company. Comparisons are drawn between the InsulLiving House and other SEQ houses in terms of electricity consumption, output of solar power systems, internal thermal comfort conditions and insulation quality.

AVERAGE DAILY ELECTRICITY CONSUMPTION

The daily average electrical energy consumption per season of the InsulLiving House, another monitored house in the same region (QLD09), the 'average' South-east Queensland (SEQ) houses and Currumbin Ecovillage houses are compared in Table 1.

The QLD09 house, occupied by a family of 4, is predominantly electric, with the exception of solar water heating. It has a 1.6kW solar power system. The net electricity figures shown in row 1 are taken from electricity bills. These figures have been adjusted downwards by 2.15kWh / day to enable comparison with the InsulLiving house with a PV system that is 0.5kW larger.

The InsulLiving House is predominantly all electric, with gas used for a secondary water heater (for laundry and kitchen). The net electrical energy data is based on measured gross electricity consumption and measured gross solar generation (from a 2.1kW system) for the period March 2012 – February 2013 (note that the house was unoccupied for March 2012). Because the InsulLiving house was occupied by a family of 4, the second row of data reflects the adjusted consumption assuming occupancy of 2.6 persons (the average occupancy for south-east Queensland residences). This enables comparison with regional energy consumption.

SEQ average daily electricity consumption has been provided by Energex[1] and represents net electricity consumption for 2011 (i.e. total electricity consumption less any generation from photovoltaic systems). The SEQ data is based on 1,217,105 residential customers and includes all residential dwelling types (houses, apartments, flats etc), including unoccupied and holiday rental dwellings. Residential use accounted for 38.98% of total south-east Queensland consumption in 2011. Neither the InsulLiving nor Energex data includes energy consumption for gas appliances.

The daily electricity consumption in the InsulLiving house, per season, was approximately half that of QLD09 for the same time period and climate zone. Both houses were occupied by a family of four (2 adults and 2 children). According to Table 1, during spring and autumn, the daily average electricity consumption (adjusted for family size) of the InsulLiving house was approximately 1/3 of the average daily consumption of SEQ homes for these seasons. In winter the difference was in the order of 30% and in summer the difference was in the order of 50%.

Message #1: Comparison of InsulLiving data with regional electricity consumption data shows that the daily average electricity consumption of the InsulLiving house (for the monitored period of 1 year) was 48% less than the south-east Queensland mean (adjusted for family size).

The InsulLiving data was then compared with other 'sustainable' homes. The Ecovillage house data is based on metered data of 40 homes over a 3 year period. The houses have solar/gas water heaters and use gas for cooking and (for some houses) space heating. Three figures are provided: GROSS electricity consumption (i.e.

[1] http://www.energex.com.au/electricity-network/understanding-the-network/about-your-power-supply/local-government-area-energy-consumption/lga-consumption-data

just electrical loads); GROSS stationary energy (i.e. electricity and gas consumption); and NET stationary energy (electricity and gas consumption less the contribution from solar power systems). The net electricity consumption of the InsulLiving home (adjusted for family size) is approximately equal to the gross electricity consumption of the Ecovillage homes. This difference is possibly due to differences in appliances (e.g. no electric space heaters in the Ecovillage; solar/gas water heaters and gas stoves in the Ecovillage), in house size and in occupant behaviour. More comparative analysis is required to support these assumptions (e.g. direct comparison of energy use between similar households 2 adults + 2 pre-school age children). Gas consumption data from InsulLiving house would also assist in this comparison.

TABLE 1: AVERAGE DAILY ELECTRICAL ENERGY (KWH) CONSUMPTION PER SEASON (3/2012 – 2/2013)

House	*Energy type*	*Autumn (Mar - May) kWh*	*Winter (Jun – Aug) kWh*	*Spring (Sept – Nov) kWh*	*Summer (Dec – Feb) kWh*	*Daily Average (yr) kWh*
QLD9 house 4p/hh (adjusted)	Net electricity (electricity bills)	14.1	40.81	17.5	29.76	27.7
InsulLiving 4p/hh	Net electricity (data logger)	10.45	20.14	8.23	15.06	12.85
InsulLiving Adjusted to 2.6p/hh	Net electricity	6.79	13.09	5.35	9.79	8.75
SEQ 2.6 p/hh	Net electricity	18.20	19.39	16.55	18.55	18.17
Ecovillage at Currumbin 2.9p/hh	Gross electricity	8.78	9.37	8.25	8.14	8.63
	Total stationary energy (elec. & gas)	12.4	16.82	11.83	11.37	13.1
	Net total stationary energy	6.69	11.94	5.73	6.46	7.7

CONTRIBUTORS TO ELECTRICITY CONSUMPTION

The electricity consumption of the InsulLiving house was monitored per circuit, allowing analysis of the services that contributed to the electricity consumption (Figure 1). The data for InsulLiving house for 2012/13 was compared with the Baseline Energy Estimates (2008) for Australian homes: where "heating and cooling is the highest energy use in the home" and space heating and cooling accounts for 38% of home energy use[2].

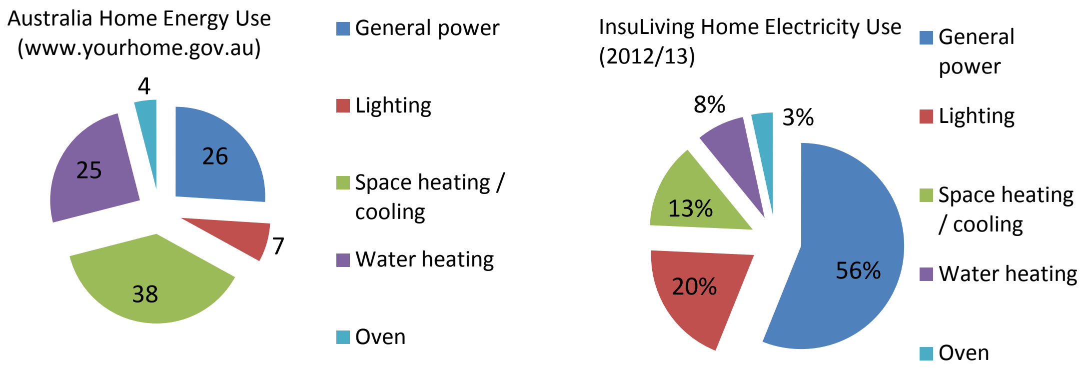


FIGURE 1: COMPARISON OF ENERGY END USE – AUSTRALIAN HOMES AND INSULLIVING HOUSE

[2] "Energy Use" from www.yourhome.gov.au/technical/pubs/fs61.pdf

Message #2: The InsulLiving house required much less space heating and cooling than the national average (13% compared with 39% of energy use). The minimum need for space heating and cooling to meet the comfort needs of this family allowed them to manage their electricity consumption through managing their use of lighting and appliances.

STAR RATINGS AND COMFORT

The thermal comfort of Australian houses is, to some extent, meant to be regulated by the National Construction Code (NCC) and the associated 'star rating' requirements. The Nationwide House Energy Rating Scheme (NatHERS) established the conditions under which the potential thermal comfort conditions of a house could be calculated. A number of software tools have been developed to do this task, and have been accredited by NatHERS. BersPRO 4.2 was the software used in this project to simulate the likely thermal performance of the InsulLiving House. Based on climate and materials science data bases, and specific house design parameters entered into the software, BersPRO simulates house thermal comfort conditions (temperature) for each zone of the house for every hour of the year, and provides an annual temperature histogram (a table that shows the number of hours that the house is within particular temperature ranges). The expected energy required to heat or cool a house to meet pre-determined comfort levels, is then calculated. Star bands are assigned in the NCC to reflect different levels of house energy efficiency according to the heating and cooling requirements. Table 2 shows the star bands for two climate zones (Brisbane, representative of eastern suburbs; and Amberley, representative of western / inland suburbs; Burpengary would have a climate somewhere between these two options). The table also shows the minimum star rating requirement in Queensland, the simulated performance of the InsulLiving house, and the actual measured energy consumption of the house (heating and cooling for the occupancy period).

TABLE 2: STAR BANDS AND INSULLIVING STAR RATING

	Energy Rating (stars)								
	3	4	5	6 (minimum requirement)	7	8	9	9.5	10
	Thermal energy loads in MJ/m2.annum (i.e. energy required to heat / cool the house)								
Climate 10 Brisbane	97	71	55	43	34	24	17	13	10
Climate 9 Amberley	157	113	85	67	52	38	24	18	12
InsulLiving House							Simulated as designed	12.76 (actual)	

Message # 3: Using software approved by the NCC, the InsulLiving house was modelled for climate 9, achieving a 9 star rating. In occupancy, for the monitoring year, it achieved a 9.5 star rating. This means that the house provided a high level of comfort for the occupants whilst requiring very little energy for heating and cooling. The daily average energy consumption for heating and cooling for this family, for the monitored period, was 1.74kWh. This equates to a heating / cooling bill for the year of $160 (assuming $0.25378c per kWh).

To understand why the space heating and cooling use was so low, the actual measured internal temperatures of the house were compared with the expected performance of the house as modelled in the simulation software. The house, as design, was modelled as conditioned (that is, assuming heating and cooling appliances would be used) and as free running (assuming that no heaters or air conditioners would be used). The comparison of the three modes (modelled air conditioned; modelled un-airconditioned; and actual use) is shown in Figure 2, representing the temperatures in the main living room. The green zones represent number of annual hours in the comfort zone of 18-28°C. (Refer to Appendix A for a discussion on how the comfort band for this climate was calculated.) The first two rows on the graph show that there is very little 'comfort' difference (5% of annual hours) between a 9 star house that is air-conditioned and a 9 star house that is not air-conditioned. The actual energy use for heating and cooling then becomes a matter of personal choice, allowing occupants a range of options for managing their comfort on the very few hours of the year that are outside of the comfort zone. This is shown in the graph, where the occupants of the InsulLiving house chose to use some airconditioning to increase the percentage of comfort hours to 96.5%.

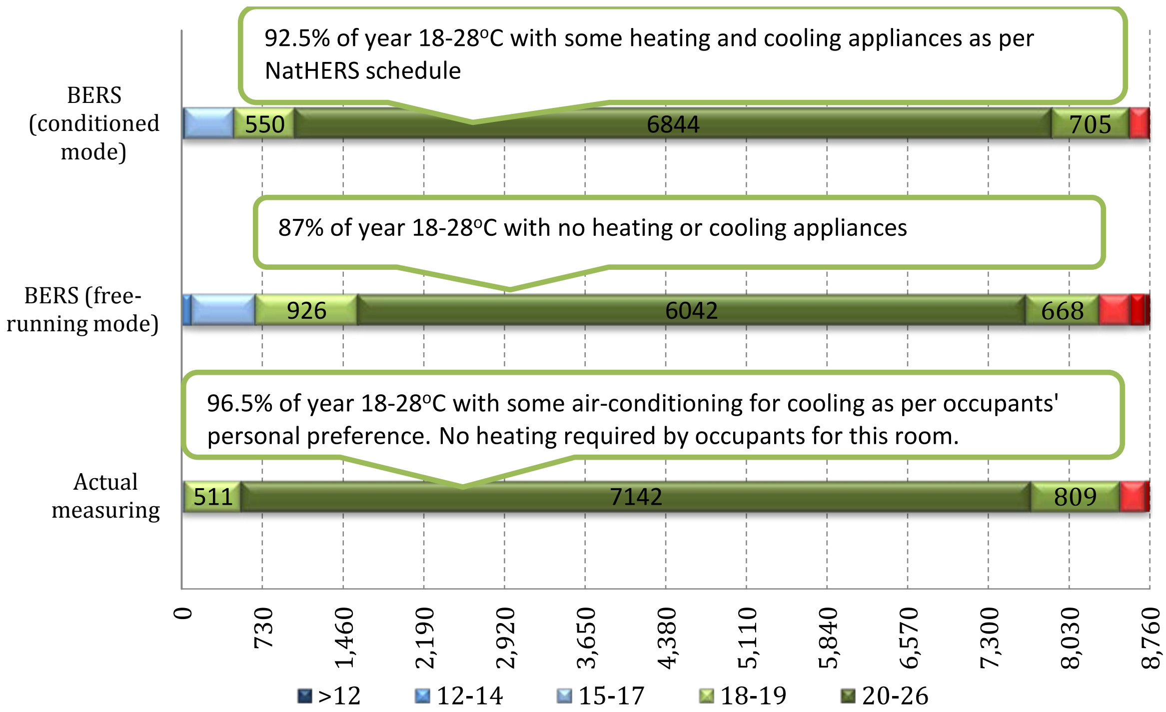


Figure 2: Comparison of temperature histogram for measured temperature data and software simulations for the main living room of InsulLiving house

Message 4: A high star rated house (9 stars) in this climate, provides a very high level of thermal comfort (87% of annual hours) without additional space heating or cooling. If occupants choose to provide additional comfort through the use of heating or cooling appliances, the energy required to provide this additional comfort is very minimal (about one third of the energy that a 6 star house would need to provide the same level of comfort).

Energy Balance - Towards Zero Energy

There are several common definitions of 'zero net energy' buildings[3]. The variations in these definitions depend on three conditions:

- What is being measured (all stationary energy; only some forms of energy e.g. electricity only; carbon emissions; cost)
- What energy services and forms are included (all services; space heating / cooling only; all heating and cooling, including water heating)
- What are the types of energy supply and their system boundaries (e.g. primary or end-use energy)

The four main definitions, in general terms, are:

- Net zero energy home: energy consumption versus energy generation (onsite/source).
- Net energy solar home: onsite generation is solar.
- Net zero energy costs: $ earned from exports versus $ spent on imports.
- Net zero energy emissions/zero carbon home: emissions from energy consumption are off-set by renewable energy (zero emission) generation.

The annual consumption of different services was measured and is shown in Table 3. The InsulLiving house has a 2.1 kW PV system on the north-facing (equatorial facing) roof of the house. The total solar generation recorded for the period 1/4/2012 – 31/3/2013 was 3285.55kWh, a daily average of 9kWh. Comparing electricity consumption with electricity generation, the InsulLiving house, for the monitored year, was net zero energy for space heating and cooling, water heating[4] and lighting.

TABLE 3: TOWARDS ZERO ENERGY – ENERGY BALANCE OF INSULLIVING HOUSE

	Space heating and cooling	Water Heating	Lighting	General Power
Demand	759 kWh	584 kWh	1655 kWh	4744 kWh
Supply (solar)	3286 kWh			X

Message #5: The InsulLiving house, for the monitored period, was 'net zero energy' for space heating and cooling, lighting and most water heating. The renewable energy was supplied from a modest solar power system (2.1 kW). A 5kW solar power system would be sufficient to enable this home (for these occupants) to be net zero energy solar home. Alternatively, occupants with different comfort requirements and efficient appliance use (reducing general power) could live within the generation capacity of the current solar power system, achieving a 'net zero energy' lifestyle.

Solar Power System Performance

The electricity output of the InsulLiving House's solar power system was compared with the solar output of Ecovillage houses (Table 4). Total solar generation was divided by system size (estimated for the Ecovillage), giving an output figure (kWh) per 1kW of system size. This is termed kWp and is a common metric used to compare solar power systems of different sizes. The difference shown between system output may be due to

[3] Marszal, A., Heiselberg, P., Bourrelle, J., Musall, E., Voss, K., Sarton, L., & Napolitano, A. (2011). Zero Energy Building - A review of definitions and calculation methodologies. *Energy and Buildings, 43*(4), 971-979.
European Parliament. (23/4/2009). All new buildings to be zero energy from 2019. Retrieved www.europarl.europa.eu
European Council for an Energy Efficient Economy. (2009). Net zero energy buildings: definitions, issues and experience *Steering through the maze #2*. Stockholm.

[4] Water heating is not fully accounted for, as the house has a secondary gas water heater that is not factored into this calculation. Gas consumption figures are not available.

differences in the microclimate (e.g. higher rainfall and hence cloud cover in Currumbin Valley compared with Burpengary) or an incorrect assumption of average system size in the Ecovillage.

TABLE 4: COMPARISON OF AVERAGE DAILY SOLAR ELECTRICITY GENERATED, AVERAGED OVER 12 MONTHS

House	*Solar electricity generated kWh per kWp (year)*
InsulLiving	4.29
Ecovillage	3.8 (range 3.5- 4.4)

The performance of the PV system installed on the InsulLiving house is within expected performance parameters and in line with good installation and design expectations. Over the year, the 2.1 kW system provided an average of 43% of the electricity demand. This percentage of electricity demand met by the roof top solar was greatest in spring (58%) and lowest in winter (29.5%).

CORRELATION BETWEEN SIMULATION SOFTWARE AND ACTUAL PERFORMANCE

To gain an appreciation for how accurately the simulated thermal performance reflects actual temperatures within the InsulLiving House, measured temperature data from the family room was compared with the simulated temperature for the hottest and coldest days in 2012 (4 July and 11 January). Figure 3 shows that the actual family room temperature on July 4 was very similar to the simulated temperature between 01:00 and 08:00, but that the actual temperature did not rise as much as predicted throughout the day (actual maximum temperature about 1^{o}C lower than simulated). In the evening (sunset to midnight), the actual temperature decreased more gradually than the simulated temperature. Whilst overall there is a strong correlation between simulated and actual performance for a cold day, *there is sufficient evidence to suggest that the simulation software may underestimate the potential for SIPS panels to slow the rate of heat loss in winter evenings.* Further investigation would be required to test this hypothesis, including a comparison of the weather data for this specific date with the 'reference mean year' data used in the modelling software.

Figure 3 also shows the actual outside temperature for this day, measured by the weather station on the roof of the InsulLiving House. The graph clearly shows a narrow internal temperature range (18-23^{o}C) compared to the wide external temperature range (2.5 – 18.5^{o}C). *This evidence supports the value of a well insulated home with low heat transfer properties* (refer to thermal imaging section).

FIGURE 3: FAMILY ROOM TEMPERATURE PROFILE FOR 4 JULY 2012

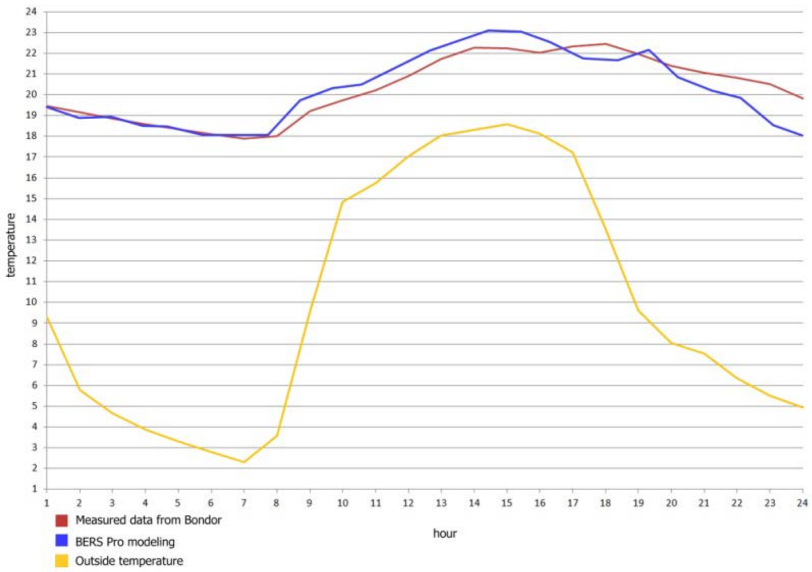
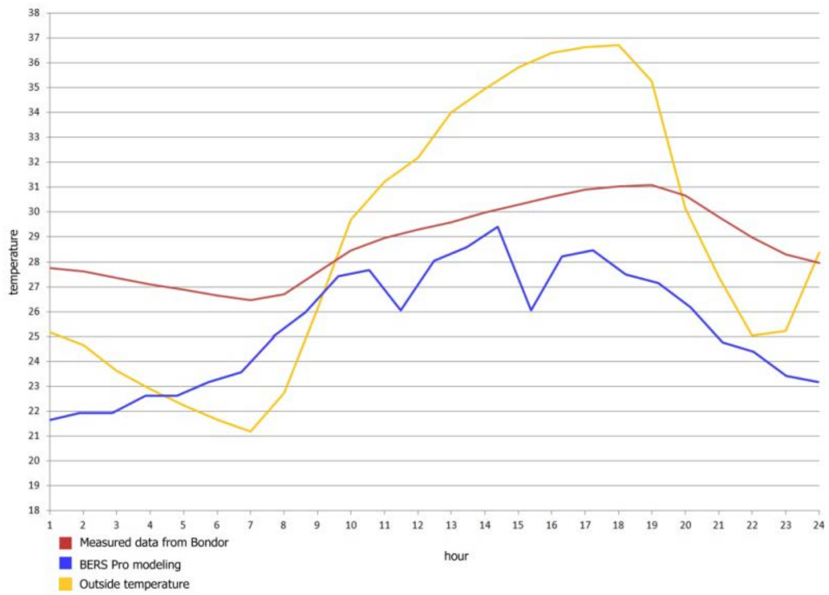


Figure 4 relates to the hottest day in 2012: January 11. The simulated temperature profile (blue line) assumes that a cooling device – an air conditioner – is used. The fluctuations in temperature indicate the cooling system turning on and off. The actual living room temperature - non-air conditioned – is obviously higher than the simulated temperature. *Compared to the outside temperature however, the internal temperature range (26.5 – 31°C) is much less than the external temperature range (21-37°C). The diurnal ranges are similar to winter performance ranges, with internal temperatures within a 5 degree band, and external temperature ranges of about 15°C. Again this shows the benefits of a well insulated building – a flattening and narrowing of the temperature profile.* However, Figure 4 also shows that the internal temperature did not drop overnight, taking advantage of the lower overnight external temperatures. The most likely explanation for this is that the house was unoccupied at the time, and all louvers designed for night ventilation, would have been closed. Analysis of data from summer 2013 has not yet been undertaken, but is expected to reveal how /if the occupants operated the house to take advantage of night ventilation to cool the building after hot days. Under normal occupancy patterns, one could assume that external doors and windows would be closed during the heat of the day, limiting heat transfer into the building. This is the behavioural assumption made by the simulation software.

FIGURE 4: FAMILY ROOM TEMPERATURE PROFILE FOR 11 JANUARY 2012



Living room temperatures were also compared with measured temperatures in 10 other houses in SEQ. Table 5 compares the mean, minimum and maximum temperatures recorded in the main living rooms of these houses in July 2012 and January 2013. Two sets of weather station data are included: Amberley (the climate file on which the simulations are based) and Archerfield (probably a closer match to the actual climate in the suburbs of the selected houses). These houses were constructed between 2007 and 2011. The houses have been ranked according to the simulated thermal performance (the higher the number of stars, the higher the number of hours within a nominated 'human comfort' range).

The mean indoor winter temperature of all homes was within 4 degrees of each other, and all were above the mean external winter temperature (as expected). There was no record of space heating being used in the living areas of any of these houses (it is possible small heaters were used in bedrooms). It is difficult to draw any conclusions from a comparison of the InsulLiving House with any of the other houses, as the houses are occupied by different family types, and the thermostat set point of houses with air conditioners varies. However, the InsulLiving house had a lower mean summer temperature then the 5.5 and 6 star houses that were airconditioned, despite having a higher thermostat set point. This would support the previously reported hypothesis that a higher star rated home can achieve good comfort levels with very minimal energy consumption.

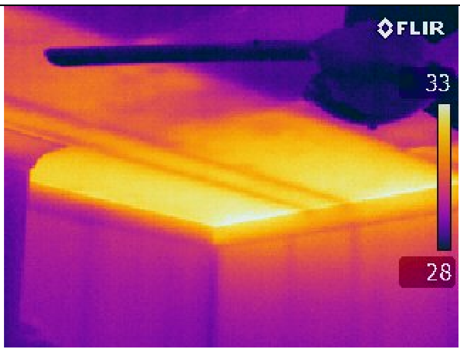
TABLE 5: COMPARISON OF MAIN LIVING ROOM TEMPERATURES IN SEQ HOUSES 2012/13

House	*Star rating*	*AC cooling thermostat*	*July 2012*			*January 2013*		
			Mean	*Min*	*Max*	*Mean*	*Min*	*Max*
Weather station data Climate 9 - Amberley			13.7	0.8	23.5	26.5	16.5	40.2
Weather station data Archerfield			15.15	4.1	23.8	26.55	17.6	37.4
InsulLiving (steel SIPs; SOG[5])	9	No heating; AC cooling = 26°C from 14/1/2013	21.15	16.85	24.06	26.80	22.72	33.00
QLD 20 (non-steel SIPS; off ground)	9	No AC or heater	19.18	14.95	22.91	24.29	19.94	29.79
QLD 4 (brick veneer / timber; SOG)	7.5	AC = 24°C	NA	NA	NA	25.81	22.1	29.6
QLD 10 (brick veneer; SOG)	7.5	AC = 24°C	NA	NA	NA	26.42	22.17	32.16
QLD 19 (straw bale; off ground)	7	No AC or heater	20.36	15.58	24.83	26.23	21.75	32.70
QLD 18 (timber; off ground)	7	No AC or heater	20.53	13.74	26.79	26.61	21.40	33.82
QLD 3 (brick veneer; SOG)	6.5	AC = 24°C	19.72	15.12	26.63	25.94	20.63	32.13
QLD 5 (brick veneer; SOG)	6	AC = 25°C	NA	NA	NA	27.35	20.22	36.7
QLD 2 (brick veneer; SOG)	5.5	AC = 24°C	22.03	16.16	27.17	28.99	24.15	36.64
QLD 8 (brick veneer; SOG)	5.5	AC = 24°C	19.67	14.62	23.65	NA	NA	NA
QLD 11 (light weight; off ground)	3.5	No AC or heater	19.28	12.17	25.19	27.04	21.69	33.18
Shaded cells relate to Jan 2012								

INSULATION QUALITY

Thermal imaging was conducted on 15 houses in SEQ and Townsville, including 2 display homes. Most of the homes built via traditional framing methods (for walls and/or roofs) displayed some problems with insulation installation that would make them non-compliant (minor to serious) with the current building regulations and impact negatively, to varying degrees, on the thermal performance of the building. The common issues relating to insulation and thermal leakage are shown in Figure 5.

[5] SOG = Slab on ground (i.e. house built on a concrete slab). Off-ground houses are built on stumps / posts.



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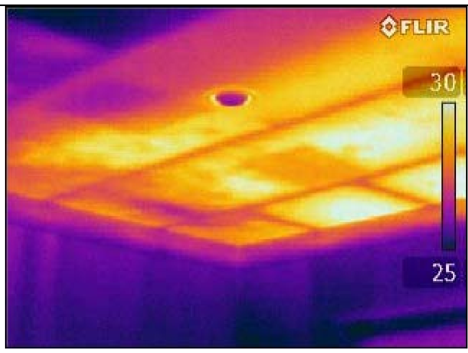

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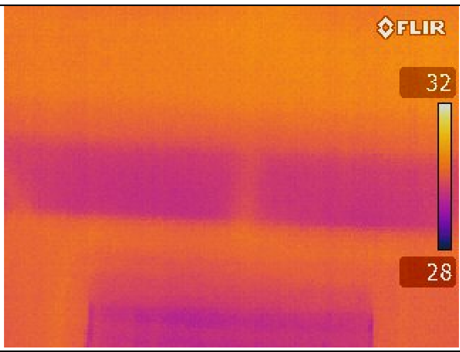

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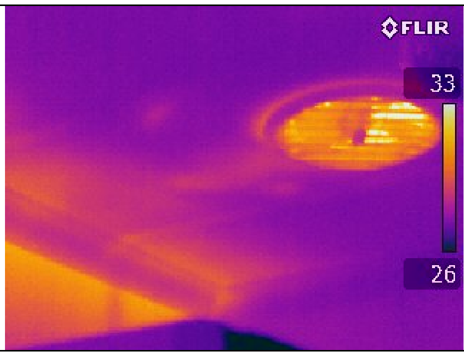

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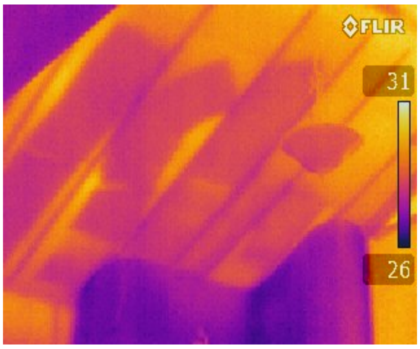

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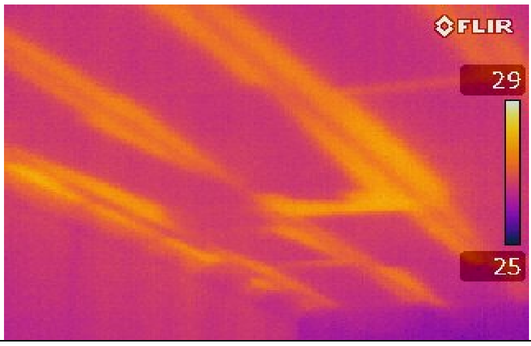

a) Poor perimeter coverage (typically 300-600mm around perimeter of internal ceilings), with particularly poor coverage in the corners of hip roof designs

b) Patchy (or absent) ceiling coverage in general

c) Entry hallways, utility rooms (e.g. bathrooms, laundry) and bulkheads often not insulated correctly (similar with garage ceilings and walls adjoining main house)

d) Poor insulation around exhaust fans (pictured), lights, roof access covers

e) Leakage around doors (pictured) and windows

f) Two of the homes revealed extensive and serious non-compliance issues that required house owners to seek restitution from the relevant builders.

FIGURE 5: INSULATION INSTALLATION CHALLENGES IN TRADITIONAL CONSTRUCTION

In contrast, thermal imaging of the InsulLiving House did not reveal large gaps in the insulation. This is to be expected, as the insulation is manufactured into the wall and roof products, eliminating the risk of poor worksite practices (during construction or maintenance) impacting negatively on thermal performance. A few minor thermal leaks were found, however, in some of the joints between roof and wall sections. This has been reported previously. The use of thermal tape and sealants in these areas should rectify this small problem.

APPENDIX A: ADAPTIVE COMFORT BAND

Taking into account research relating to adaptive comfort, acclimatization and the bioclimatic chart (de Dear and Brager, 2001; Auliciems and Szokolay, 2007) [6], summer and winter comfort bands were calculated according to the following equations:

Eq. 1 $T_n = 17.8 + 0.31 \, xT_{om}$(January) +/- 2.5°C (90% acceptability)

Eq. 2 $T_n = 17.8 = 0.31xT_{om}$(July) +/- 3.5°C (80% acceptability)

Where T_n = thermal neutrality and T_{om} = mean outdoor monthly temperature (Auliciems and Szokolay, 2007)

These adaptive comfort bands are shown in Table 6 together with the assumed room occupancy hours and heating and cooling thermostat set points applied by NatHERS. The rating scheme's summer neutral cooling temperatures are based on *effective temperature*. NatHERS also assumes a three staged approach to the achievement of comfort in summer: natural means (e.g. operating windows); mechanical ventilation (ceiling fans) and lastly the extraction or provision of heat (artificial heating / cooling). The annual adaptive comfort band is therefore taken to be 18-28°C for south east Queensland, the same range used by Tuohy et al (2001) as one approach for thermal modeling based on adaptive comfort criteria. The comfort band for Townsville is slightly higher (20 - 29°C).

TABLE 6: COMFORT BANDS AND NATHERS HEATING / COOLING SCHEDULES AND SET POINTS

	Summer Comfort		Winter Comfort	
Location	Adaptive comfort band	NatHERS Cooling thermostat setting and time schedule	Adaptive comfort band	NatHERS Heating thermostat setting and time schedule
Climate zone 9 (South-east Queensland inland / western suburbs)	22.0 – 27.9 °C	26.0°C **Living spaces** 2400-0700 - no cooling 0700-2400 - cooling **Sleeping spaces** 1600-0900 – cooling 090001600 – no cooling	18.2 – 23.2 °C	**Living spaces** 2400-0700 -no heating 0700-2400 - 20 °C **Sleeping spaces** 2400 – 0700: 15 °C 0700-0900: 18 °C 0900-1600: no heating 16:00-2400: 18 °C

[6] Auliciems A and Szokolay S (2007) "PLEA Note 3: Thermal Comfort", http://www.arct.cam.ac.uk/PLEA/Document.aspx?p=9&ix=6&pid=4&prcid=40&ppid=524 [Accessed 11/6/2011].

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