SUSTAINABLE WANAKA: APPLIED BUILDING RESEARCH

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ABSTRACT

Sustainable Wanaka is a charitable trust involved in all aspects of sustainability in the Wanaka region. Over the last 16 months Sustainable Wanaka has been conducting several practical research projects on sustainable housing options that are appropriate for the Southern Lakes climate. This is important since most sustainable housing research in New Zealand is focused on the main urban centres (e.g. Beacon's NOW Homes, EECA solar research). This region has a climate unique in New Zealand and a high rate of development.

Since July 2006 Sustainable Wanaka has organised sustainable building features to be incorporated into both new build and existing dwellings. The buildings have been intermittently monitored to assess the effect of the changes.

This paper will present the results of Sustainable Wanaka's research, particularly the research conducted on existing dwellings. It will evaluate the effectiveness of the chosen energy efficiency and sustainability measures and their appropriateness for the Southern Lakes climate.

KEYWORDS:

Energy; efficiency; Wanaka; houses; monitoring

INTRODUCTION

Energy, whether it is produced by burning wood or gas or generating hydro or coal-fired electricity, has an environmental impact which can be reduced through efficient management of the end use. Buildings in New Zealand current account for 22% of energy use in New Zealand and 57% of the country's electricity is used in buildings (Department of Building and Housing, 2006)

Temperatures in New Zealand buildings are generally below the generally accepted benchmark level for health of 18°C. A study of a sample of New Zealand houses in 2006 found that 40% of the homes were 'below average' or 'cold' (Isaacs et al. 2006).

The most common heating fuel in New Zealand is wood (Isaacs et al. 2006) the burning of which, especially when burnt in inefficient appliances, sometimes results in poor local air quality (as in Arrowtown and Clyde). New Zealand's household energy demand is increasing by 1.5% a year; this is a doubling of demand by 2053 (McChesney et al, 2006). Electricity, when used as heating energy, can contribute to peak demands which put a strain on New Zealand's national electricity supply.

The cost of energy to households has risen in real terms by 16% since 1995 (McChesney et al, 2006). This, coupled with high land value in the Southern Lakes region, is making the provision for affordable housing increasingly difficult.

Energy efficient buildings can help slow the increase in domestic energy demand. They are also cheaper to run, and they are likely to be more comfortable as it is easier to maintain adequate internal temperatures.

Sustainable Wanaka's research aims to improve local knowledge on appropriate mechanisms for achieving energy efficiency and comfort in the Southern Lakes region. The focus of this paper is on the results of a retrofit of existing properties in Wanaka, Otago.

RENTAL PROPERTIES RETROFIT

This research project in 2006/2007 involved the analysis and retrofit of three 1960's houses in Wanaka.

The houses were in a poor state of repair and had little or no insulation, resulting in a damp and cold internal environment. The tenants of the two worst houses experienced persistent, reoccurring health problems over the winter of 2006.

Sustainable Wanaka was contracted by the properties' managers to make recommendations for retrofitting the houses. The contract included an analysis which involved a Post Occupancy Evaluation (POE) of the houses, and an energy analysis in ALF3. Temperature-sensing data loggers were installed in houses to measure pre-retrofit conditions. Over July and August 2006 the temperature and relative humidity of the living rooms and bedrooms were recorded. The retrofit was completed in January 2007 and the houses were monitored over the winter of 2007 to gauge the impact of the measures on the internal temperature and relative humidity. A second POE was conducted to assess whether there has been a change in the comfort and health of the tenants.

Context

Energy efficiency enables buildings to be heated to higher temperatures for the same cost OR to the same temperature for less cost.

The World Health Organisation (WHO) recommends a minimum air temperature of 18°C for there to be no health risk to the occupants. A building that is colder than 16°C over long periods may develop problems such as condensation, damp and mold growth which leads to an unhealthy environment. Research by Wellington School of Medicine states that the frequency that a person is exposed to temperatures below 16°C has a greater effect on health than the average temperature (Howden-Chapman, 2007) (i.e., the average temperature could be above 16°C but the occupants could still be frequently exposed to temperatures below 16°C).

Energy efficiency can also reduce household expenditure on heating fuel. This is particularly important for low income households, which in the UK are classified as living in fuel poverty if more than 10% of the total household income is spent on heating (Baker, 2006)

If energy efficiency measures result in reduced fuel usage then they also result in environmental benefits such as reduced carbon emissions and improved local air quality.

House #1

House #1 was built in 1967. It is a single story house built of concrete block construction with a floor area of 63 m^2. It comprises an open plan living/dining/kitchen area, and 3 bedrooms and a bathroom linked by a hallway. It is strapped and lined internally and the roof is clad in corrugated steel. The floor is suspended timber on concrete pile foundations. The timber framed windows are single glazed and have recently been draught-stripped. The building is orientated northwest but is substantially shaded for most of the day by pine trees on a nearby section.

Summary of work undertaken

The property managers installed 'Ultra' ceiling batts in the ceiling of one house in July 2006 after they were alerted to the cold conditions in the house by the tenants.

In August 2006 a Post Occupancy Evaluation and ALF3 analysis was undertaken at House #1 by Sustainable Wanaka. The measures that would result in the greatest benefit for the least cost were recommended based on payback periods calculated by ALF3.

The energy assessment conducted by Sustainable Wanaka found that an inefficient heat system and poorly insulated building envelope were the biggest contributing factors in the poor internal environment of the houses. The choice of replacement heating system was based on the following criteria: appliance running cost, appliance cost, fuel availability, appliance familiarity, net carbon emissions, appliance efficiency and heat out-put. The chosen solution was to replace the existing in-built wood burners with efficient free-standing models.

A mould analysis was commissioned from Biodet Services Ltd in Auckland. While no *Stachybotrys* (black mould; fungus linked to rashes, breathing problems and chronic chest infections) was found, one fungal species that is associated with respiratory tract allergies was present (*Cladosporium*).

The retrofit was carried out in January 2007.

Data logging equipment measured the internal temperature at the property for 2 weeks in August 2006. The internal temperature has been measured for 2 weeks in August 2007 and the comparative results are summarised in this paper.

<u>Building work completed</u>

Insulation:

- R5.0 ceiling insulation installed in the ceiling (July 2006)
- Linings in living room removed, 50mm EPS polystyrene fitted (R2.2 wall batts fitted where insulation would come into contact with cabling), new gib board lining.
- Attic space dried out with dehumidifiers and any leaks or air gaps repaired to avoid damage to the new insulation.
- Polythene laid over the ground underneath the house and around the footings.
- Foil faced insulation blanket fitted to underside of joists.
- Door to living space reinstated.

Heating and ventilation:

- Heat transfer system installed to transfer heat from the living room to two of the bedrooms.
- Fan heater fitted in bathroom.
- Existing in-built fireplace removed and lined over. New, high efficiency enclosed wood burner installed on inside wall of living room.
- Extract vent fitted in kitchen.

Cost of retrofit: $11,515.58

<u>Summary of Post Occupancy Evaluation August 2006/ August 2007</u>

The tenants have been considerably healthier this winter. During the winter of 2006, the tenants were sick frequently, and suffered particularly from respiratory infections. The tenant had attributed this to an allergic reaction to the mould, which prompted the mould analysis. The tenant's young daughter has not had a cough this year; last year she had a chronic cough for 8 months. The throat infections the tenant suffered last year have not reoccurred.

The living room was previously the only conditioned room, heated exclusively by the in-built wood burner. The wood burner, while relatively new, was inefficient and faulty. The tenant reported that the extra insulation installed in the ceiling in July 2006 had made a difference to the internal temperature but that she still found it cold. The tenant had attempted to remove the mould on a daily basis. All bedrooms were suffering from damp, mould and excessive condensation due partly to insufficient heating and partly to the building's inability to retain heat. The tenant ventilated the bedrooms daily but did not heat them for economic reasons.

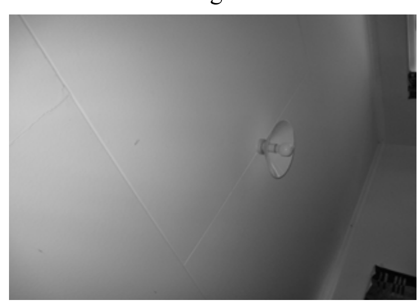
The tenant says that the new wood burner makes "a remarkable difference" (though in reality it is the combination of the new wood burner and the insulation that has made a difference). She says she "can't explain how much better it [the house] is" this year.

The main bedroom is much warmer this year, despite the fact that the walls in this room are still uninsulated. Unfortunately it is not possible to quantify the affect of the heat transfer system versus the underfloor insulation. The mould in the bedrooms and living room has not reoccurred. There is still reoccurring mould in the bathroom, which will need to be addressed in the next stage of the retrofit. The trees to the north opposite House #1 need to pruned or thinned as they shade the winter sun.

Inbuilt fireplace at House #1, before retrofit

The new woodburner was installed on the inside wall on the living room

Condensation on bedroom ceiling before retrofit



The tenant has observed no condensation on the ceiling since the retrofit, although condensation (and sometimes ice!) still forms on the windows in the bedroom.

Energy Consumption

The ALF3 analysis completed last year estimated that the retrofit measures (building envelope only) would save 2302 kWh per year[1], which is a saving of 53%. However, this assumes heating to acceptable levels before and after the retrofit. In cases where an increase in temperature is the priority, these savings will not realised but the 'take-back' will be in improved comfort.

1 Assuming heating to achieve 16 °C for 6 hours a day (ALF3 default)

The tenant at House #1 estimates she has spent approximately $600 on fire wood this winter (8 m^3 which she has not used all of) which is comparable to last year (approx. 7 m^3). Her electricity bills have remained constant over the period.

Temperature assessment

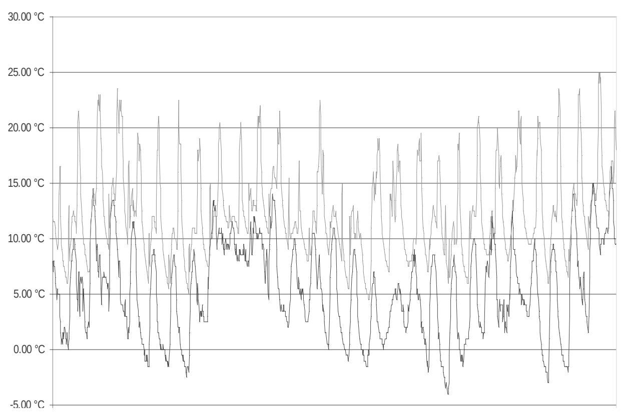
The graphs show the difference in thermal performance between winter 2006 and winter 2007 (note that the tenant was away for one week of monitoring in 2007, which can clearly be identified on the graph). It should be noted that the temperature monitoring was conducted after the ceiling batts were upgraded by the property managers in July 2006. Anecdotes from the tenant suggest that the internal temperature was lower before the ceiling insulation was fitted (as would be expected).

The winter 2007 data shows an average living room temperature of 17.5°C compared to an average living room temperature of 12.3°C for the same period (and comparable average external temperature) for 2006.

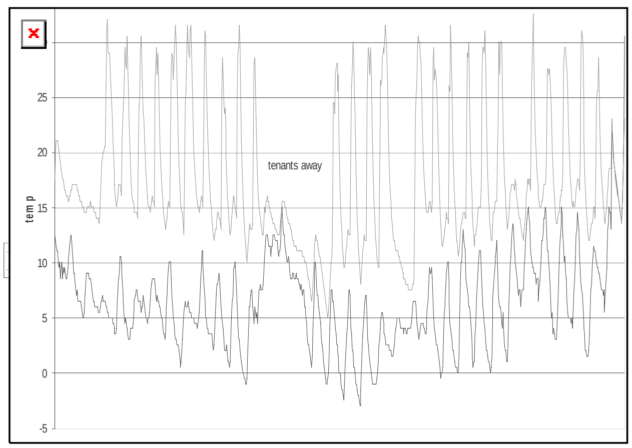
The winter 2007 data shows an average bedroom temperature of 14.0°C compared to an average living room temperature of 9.1°C for the same period (and comparable average external temperature) for 2006.

External temp: dark grey

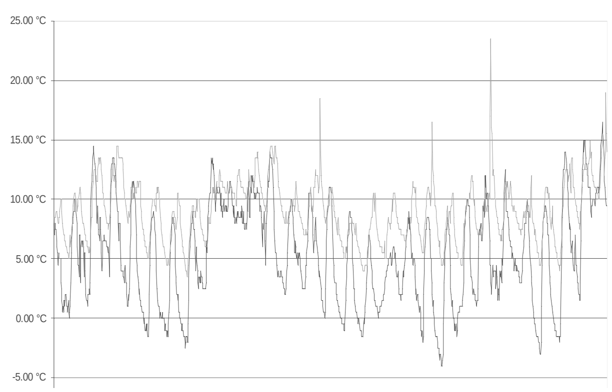
Living room temp (light grey) Jul – Aug 2006



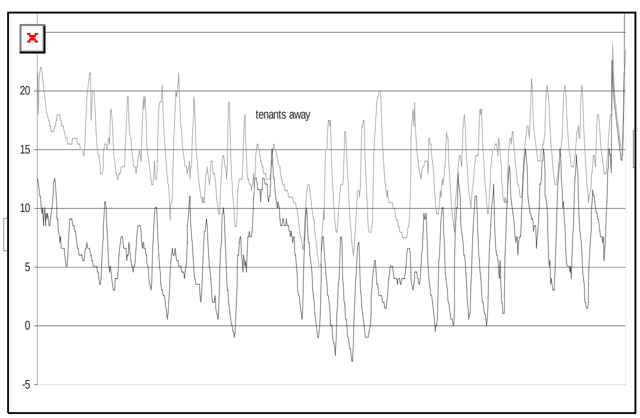
Living room temp (light grey) Jul – Aug 2007



Bedroom temp (light grey) Jul – Aug 2006



Bedroom temp (light grey) Jul – Aug 2007



Second stage retrofit and other options considered

For the next stage of the retrofit, all remaining uninsulated walls will be insulated and relined (this would have been part of the original retrofit if it had not been for budgetary constraints). The owners of the section to the North of House #1 will be approached to discuss pruning of the pine trees on their property.

Double glazing or retrofitted secondary glazing was considered for all the houses. It was rejected on the grounds of a cost-benefit analysis using ALF3. It should be noted that the R-values of the insulation fitted in both houses are the bare minimum which was due to an overstretched budget and not due to choice. This author would recommend the highest R-value available under normal circumstances.

House #2

House #2 was built pre-1967: there is no record of the date of construction. It is a single story house built of timber frame construction with a floor area of 87 m^2. The building is clad externally with stucco on mesh or rendered cement board and corrugated steel roofing and the floor is suspended timber joists on concrete pile foundations. The windows are timber framed and single glazed. The building is orientated on a Southwest – Northeast axis and comprises a large living/dining/kitchen area, 3 bedrooms, a bathroom, separate WC and laundry. The living room was heated by an inbuilt wood burner.

The house suffers from damp, condensation on the glazing, walls and ceilings and reoccurring mould on window frames, ceilings, walls and furniture. There is extensive mould growth on the ground under the house.

<u>Summary of work undertaken</u>
In August 2006 a Post Occupancy Evaluation and ALF analysis was undertaken for House #2. The measures that would result in the greatest benefit for the least cost were recommended based on payback periods calculated by ALF3. A mould analysis was commissioned from Biodet Services Ltd in Auckland.

Similar problems were identified at House #2 as House #1, despite the difference in the construction and management of the two houses, and resulted in a similar solution.

The retrofit was carried out in January 2007.

Data logging equipment measured the internal temperature at the property for 2 weeks in August 2006. The internal temperature was measured for 2 weeks in August 2007 and the comparative results are summarised in this paper.

<u>Building work completed</u>
Insulation:

- Linings in living room removed, 50mm EPS polystyrene[2] fitted (R2.2 wall batts fitted where insulation would come into contact with cabling), new gib board lining. Whole building dried out using industrial heaters.
- Attic space dried out and any leaks or air gaps repaired.
- Polythene laid over the ground underneath the house and around the footings.
- Foil faced insulation blanket fitted to underside of joists.

Heating and ventilation:

- Heat transfer system installed to transfer heat from the living room to main bedroom and hallway (adjacent to two back bedrooms)

[2] The EPS polystyrene was donated by a local business which had left over product after completion of a new building. All possible means were adopted to reduce the cost so that the budget could be stretched further. The authors acknowledges that this is not necessary or possible in all retrofit projects.

- Clothes dryer extract fitted through external wall in the laundry.
- Fan heater fitted in bathroom.
- Existing in-built fireplace removed and lined over. New, high efficiency enclosed wood burner installed on inside wall of living room.
- Extract vent in kitchen.

Glazing:
- Thermally lined curtains to living room windows
- Draught stripping

Cost of retrofit: $9,599.73

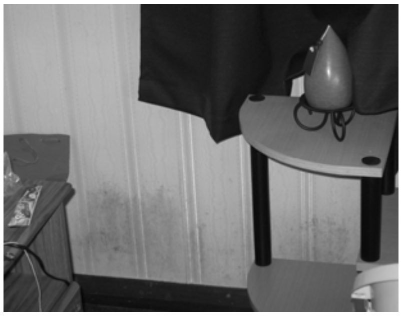
<u>Summary of Post Occupancy Evaluation August 2006/ August 2007</u>
Extensive mould, damp and condensation in both heated and unheated rooms were causing discomfort and although not proven, allegedly illness in the tenants during the winter of 2006. The tenants at House #2 have not had a repeat of their poor health in winter of 2007. The tenant says her daughter has not has a cold all winter and she recalls that last year she herself was “in and out of hospital” and suffered from a chest infection for the whole winter.

New thermal curtains have been hung in the living room. The tenant says she closes them at dusk and that they “make a big difference”.

Proir to the retrofit, the tenant had shown little pride in the house which was generally in a poor state of cleanliness and repair. The tenant now expresses pride in her living room and has made furniture and picture frames for the room. She has plans for decorating the rest of the house when the work is completed.

There is still signs of mould around the house although it is not clear whether these are old stains or new growth. The tenant believes that the mould is “no worse”.

Damp in one of the bedrooms before the retrofit at House #2



The damp appears to be no worse than a year ago. Attempts to remove the stains have been unsuccessful. The wall linings will be removed in stage 2

The inbuilt fireplace at House #2 before the retrofit

The freestanding woodburner was installed on the inside wall of the living room

<u>Energy Consumption</u>

The ALF3 analysis completed last year estimated that the retrofit measures (building envelope only) would save **3090 kWh per year**, which is a saving of 45%. Again in this case, the majority of this saving would be in take-back.

The tenant estimates that this year they will use approximately 6 m^3 of firewood, compared to 16 m^3 the year before last. Last year they used electric heaters, having decided that the inbuilt wood burner was too expensive to run. This year she has not had to use the electric heater.

The tenant believes that the new fire has made a huge difference compared to the old fireplace. She stopped using the heat transfer system in August 2007 after her electricity bill was usually high in July (mostly attributable to a faulty hot water cylinder). However at the time of the August 2007 she says that its not needed because the external temperature has been generally warmer as heat reaches the bedrooms without it. It appears the tenant was running the heat transfer systems all the time (i.e. including when there was no heat to transfer or rooms were not occupied). The thermostat should be checked to ensure that it working properly. This experience highlights the importance of proper instruction on house management for tenants. These instructions may have to be repeated several times to entrench new habits.

<u>Temperature assessment</u>

No temperature monitoring was undertaken in August 2006. Internal temperatures were recorded for House #2 in September and October 2006 and monitoring will take place for the same period this year for comparison. The temperature at House #2 was recorded during August 2007 so that a comparison can be made with August 2008 on completion of the second stage of the retrofit.

For the next stage of the retrofit all remaining uninsulated walls to be insulated and relined and thermally lined curtains with pelmets will be fitted in the spare bedroom.

<u>Recommendations of other research in New Zealand</u>

A 5 year research project by the University of Otago examined the effectiveness of retrofit options for two state houses in Dunedin. Their results lead to a recommended hierarchy of retrofit options (in order of preference, greatest benefit for cost first):

greatest benefit ↑

Insulate ceiling (if uninsulated)
Install wood burner
Upgrade ceiling insulation (if previously insulated)
Fit foil to underfloor
[or] Fit polystyrene to underfloor
Install heat pump
Improve airtightness (draughtstopping)
Insulate walls (batts and reline)
[or] add gib-backed polystyrene
Fit thermally lined curtains with pelmets
[or] retrofit double glazing

Sustainable Wanaka's research came to similar conclusions and on the basis of that research Sustainable Wanaka adopted all of the above measures (except the heat pump, a heat transfer system was installed to distribute heat throughout the house instead), choosing foil instead of polystyrene for the underfloor and batts and relining for the walls instead of gib-backed polystyrene. Thermally lined curtains were installed at House #2 and will be installed at House #1 (where necessary) in the second stage.

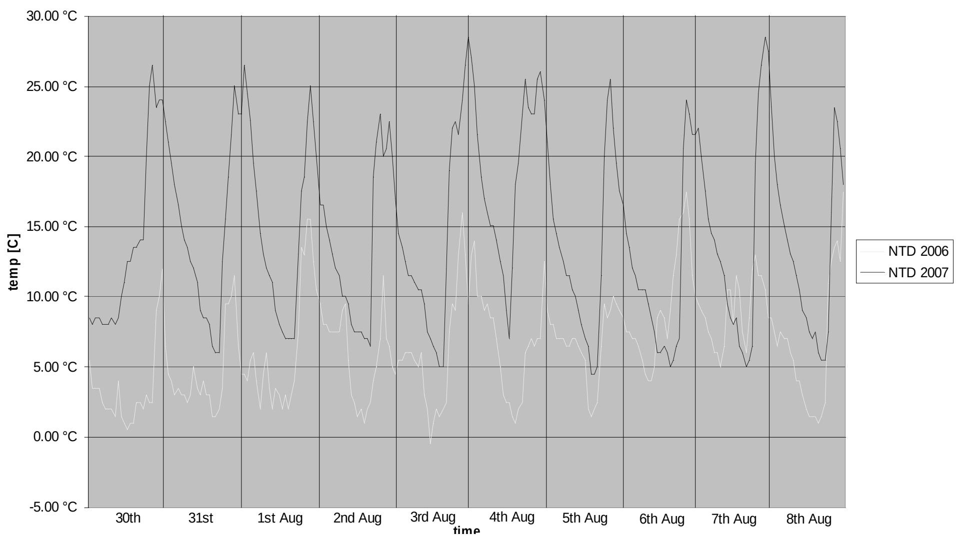
Summary

The effect on the internal temperatures at House #1 is significant because the average temperature is now above the recommended threshold for health of 16°C (Boardman, 2005). The winter 2007 data shows an average living room temperature of 17.5°C compared to an average living room temperature of 12.3°C for the same period (and a comparable average external temperature) for 2006. Comparisons of the net temperature differences (ΔT: indoor temperature minus outdoor temperature) for 10 days in August show significant difference between 2006 and 2007 (see below). The temperature histograms below show the number of occurrences of the range of temperature values at House #1. In 2006 the modal temperature values were between 10 and 12 degrees. In 2007 the modal temperature values were between 14°C and 16°C with significantly more counts above 18°C than for the previous year.

The post occupancy evaluations show not only an increase in perceived comfort but also a tangible improvement in occupant health. This is anecdotal evidence from occupants only, but if necessary a doctor's paper on the number of GP visits for winter 2006 compared with winter 2007 could confirm this.[3]

Savings in the cost of space heating occurred at House #2 (not noticeably at House #1) and data later in the year should also confirm that these properties were warmer than last year.

House #1
Comparison of net temperature differences for 30th July to 8th August for 2006 and 2007



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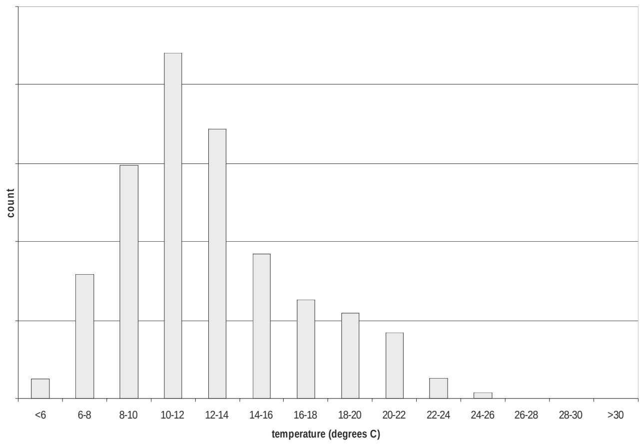
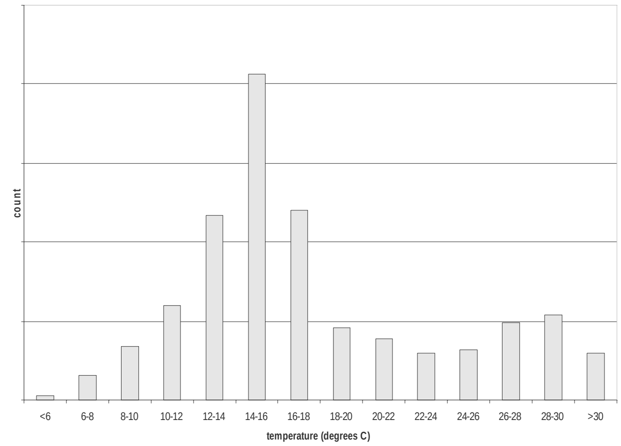
House #1

Frequency of temperatures Jul – Aug 2006



Frequency of temperatures Jul – Aug 2007



CONCLUSION

The results of the monitoring show either an improvement in comfort and health or a combination of improved comfort and energy savings. It was anticipated that there would be considerable take-back, close to 100%. That energy savings have occurred in House #2 is a bonus. The post occupancy evaluation provided a useful record of the tenants' comfort in the houses before the retrofit. Comparison with their experience in winter 2007 has shown positive changes.

This paper illustrates the kind of improvements that can be expected for a relatively small cost (approximately $10,000 was spent in each case): the internal temperature still drops regularly below 16°C but the improvement is evident. Achieving a uniform temperature in the houses will prove difficult due to the lack of any thermal mass in either house.

The energy assessment conducted by Sustainable Wanaka found that an inefficient heat system and poorly insulated building envelope were the biggest contributing factors in the poor internal environment of the houses. The University of Otago research, while far more thorough and controlled, came to similar recommendations for retrofitting which suggests that the retrofit hierarchy above could potentially be applied to retrofits in other regions.

The energy assessment resulted in the recommendation to install wood-burners was based on the demographics of the tenants in question and may not be appropriate in all cases.

The experience at House #2 illustrates two things. Firstly the retrofit evidently had a positive psychological affect on the tenant which resulted in improved perceived comfort, actual improved health, and pride and ownership of the rental property. Secondly, the mis-operation of the heat transfer system and the knee-jerk reaction of not using it highlights the importance of continued instruction on household management; educating tenants may take two or more sessions to realise results.

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