Use of roof space ventilation to address summertime overheating in New Zealand houses

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Abstract

Previous research in New Zealand houses has indicated that recent increases in insulation and double glazing requirements may have led to increased problems with summertime overheating. Monitoring of a typical New Zealand house (standard three-bedroom, lightweight timber frame construction) in the Auckland region has shown that the roof space achieves extremely high temperatures in summertime and even mid-season. The roof space therefore is a heat source that has the potential to impact significantly on overall internal temperatures.

Although the principle of ventilating the roof space to outside is well established in the northern hemisphere, traditional best practice in house design in the New Zealand climate does not recommend it. However, this advice is based on older construction standards, which included single glazing and lower levels of insulation than are currently required. This paper reports on the results of a project to test the impact of passive ventilation of the roof space in a New Zealand house built to current standards, with the intention of improving comfort levels within the living spaces. The ventilation system tested consists of air vents inset into the soffits on both the north and south sides of the house, with a ridge vent along the length of the house.

The house has been monitored across summer, autumn and winter conditions, recording internal air temperature and relative humidity throughout the living spaces and roof space of the house. Results indicate that the passive ventilation is an effective measure to reduce summertime temperatures in the roof space, with subsequent impact on the temperatures experienced in the living spaces of the house. Wintertime temperatures appear to be relatively unchanged. The project demonstrates that there is a case to be made for the adoption of passive ventilation of roof spaces to improve the thermal performance of homes in New Zealand.

Keywords: ventilation, temperature, over heating, cooling, energy

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1. Introduction

There has been substantial research demonstrating that New Zealand houses are not well heated, and many spend significant periods of time below the minimum range of indoor air temperature of 16^{o}C recommended by the World Health Organisation. This has been shown to contribute to poor health outcomes (Howden-Chapman, 2005), and has prompted a greater emphasis on higher standards of insulation in new homes, including an extensive programme of retrofit improvements in existing homes (McChesney, Cox-Smith & Amitrano. 2008). Other measures designed to improve comfort levels and reduce energy costs have also been investigated, including glazing types (Tait, Birchmore & Davies, 2011) and various retrofit options (Page, 2009; Smith, Isaacs, Burgess & Cox-Smith, 2012). Several of these studies have identified that while these measures have been effective in raising the very low minimum temperatures, maximum temperatures have also increased beyond the WHO recommended upper limit of 24 ^{o}C, creating summertime overheating in many homes.

At the same time, there has been a drive to improve the heating options in New Zealand homes, to move away from traditional wood and gas fuelled heaters that contribute to air pollution and greenhouse gas emissions. Instead, homeowners have been encouraged to install electric heat pumps, with Government subsidies provided from 2009-2012 to reduce the purchase and installation costs to homeowners. There has been rapid uptake of the technology, with heat pumps installed in approximately 21% of New Zealand houses in 2009, compared with only 4% in 2005 (Burrough, 2010). This technology has introduced the possibility of cooling into homes where previously such an option did not exist. French et al. (2009) found that in the Auckland region, heat pumps were used for cooling in 81% of homes where heat pumps were installed. An increased number of heat pumps will clearly lead to peaks in summertime energy loads which were not present in the past. Given that this coincides with the time of year where the hydro lakes in New Zealand are at their lowest levels (Knight, 2009), there is an increased likelihood that electricity to support this cooling will be supplied from gas or coal fired sources.

2. Ventilated roof space scenario

As previously documented (Tait et al, 2011; Birchmore, Davies & Tait, 2012), Unitec Institute of Technology makes use of houses built by carpentry and plumbing and gasfitting students on the Unitec campus to test the performance of building materials and techniques in a full scale situation. In this project, one of the standard houses was used to explore the impacts of a low cost and low-tech modification to this common house type, specifically to address the problem of summertime overheating. The changes to the building were intended to be uncomplicated and suitable for retrofit to existing homes as well as incorporation into new-build homes.

Previous findings indicated that extremely high temperatures were reached in the roof space of the house, as shown in Figure 1. The temperatures in the living spaces were also high, but there was a time lag between the roof space peak temperatures and the internal peak temperatures. It was hypothesised that the high roof space temperatures are acting as a radiant heat source for the living spaces, and thus impact significantly on the overall internal space temperature. If this is the case then reduction of these temperature extremes in the roof space would reduce the instances of uncomfortably high internal temperatures in the living spaces.

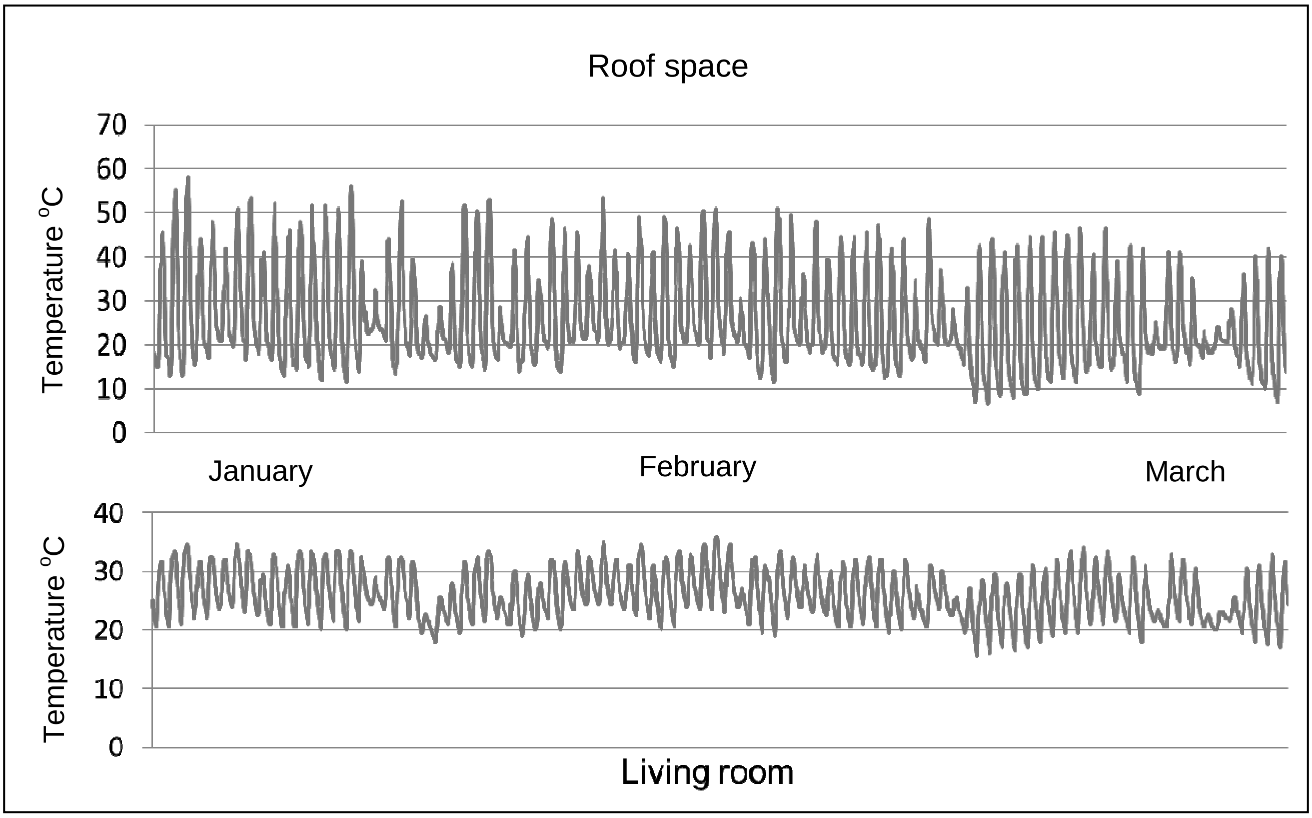

Figure 1 Comparison of roof space and living room temperatures in unventilated case

Using the buoyancy principle, the house was modified to allow passive ventilation to the roof space, with no modification of the rest of the house as previously monitored. Holes of 40mm diameter were drilled at intervals along the soffits on both sides of the building, resulting in 108 holes in total. The standard roof ridge was replaced with a proprietary ridge ventilation system. Figure 2 shows the modifications made to the house. The intention of the modification was to allow buoyant hot air to exit the roof space at the ridge, drawing in cool air at the soffits, creating a continuous air flow that increases as the temperature increases. As is evident from the photographs, the system used is low impact both visually and technologically.

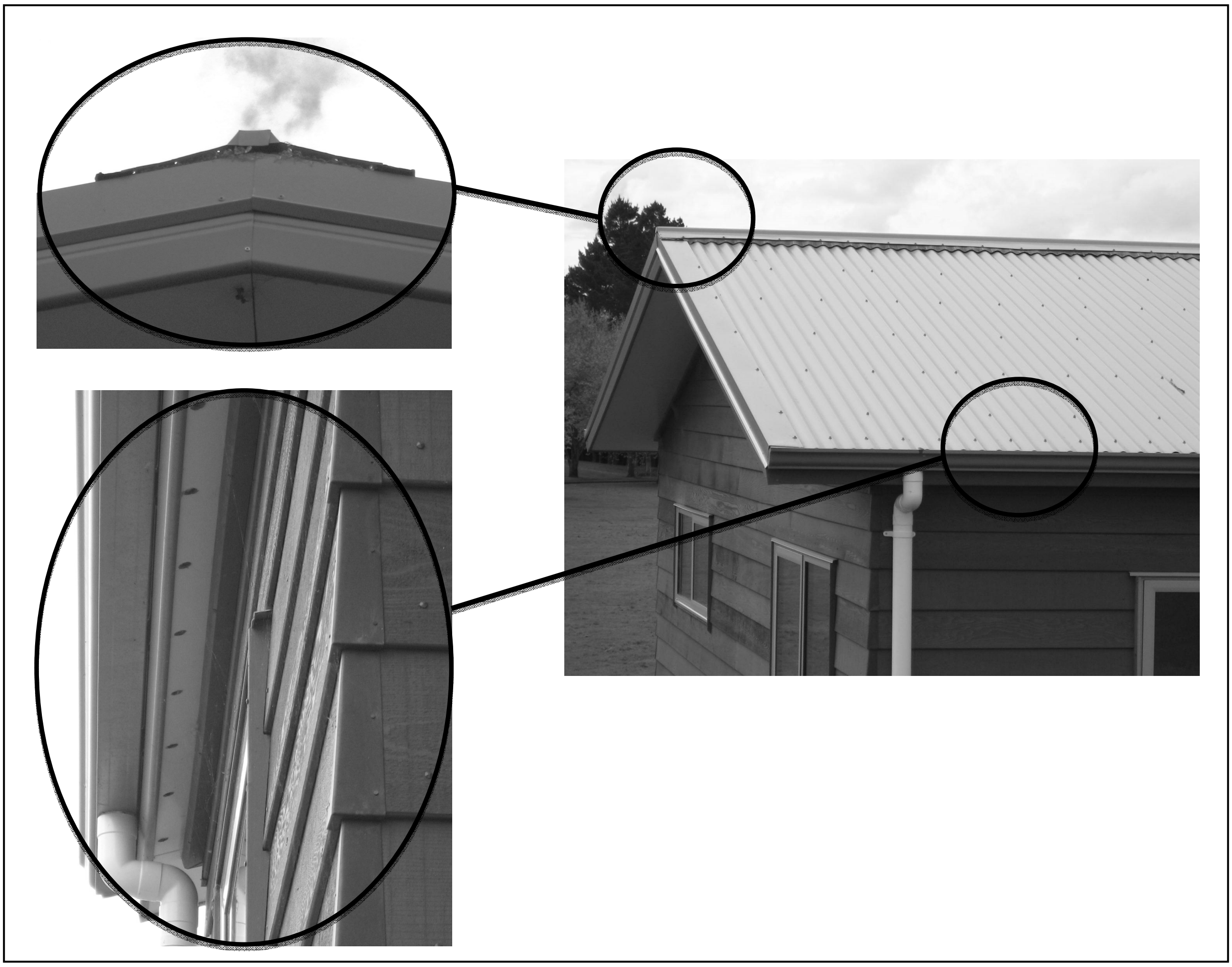

Figure 2 Modifications to house for passive ventilation

3. Methodology

Sensors were set up in various locations inside the house to sample the internal air temperature and relative humidity at hourly intervals. Sensors used are Lascar EL-USB-2 Humidity & Temperature USB data loggers. These measure and store relative humidity and temperature readings over 0%RH to 100%RH and -35°C to +80°C measurement ranges. Sensors were suspended in the living space at a height of 1500m above ground level, and located to avoid direct solar radiation. A sensor was also centrally located in the roof space. Weather data is collected on site.

The unmodified house was monitored between December 2010 and August 2011. The roof modifications were then made and the monitoring continued from December 2011 until September 2012. While not constituting a full year of data in either case, this period covered the full summer and winter seasons and was considered sufficient to meet the aims of the study.

4. Findings

In order to analyse the impact of the ventilated roof, the weather data was examined to identify days in both periods that were as similar as possible in three measures: external air temperature, global solar radiation and wind speed. The temperatures inside the roof space and living space in each case were compared. In addition, mean temperatures across selected days and periods were examined, as were peak temperature data.

The data analysis focuses on the peak summer period of February – March to demonstrate the effect of the modification on maximum summertime temperatures, and the peak winter period of July – August to identify that the modification does not negatively impact winter temperatures.

4.1 Summer time measurements

The data were first examined by comparing the performance of the house on days when weather conditions were similar in 2011 and 2012. While there were of course no identical matches, a number of days were reviewed which could be considered close. Figure 3 shows the weather data for one of these comparisons, representing February 28, 2011 and February 11, 2012. Solar radiation and air temperature reach slightly higher peaks in the 2011 case. Wind speeds are also slightly higher, and overall this could be expected to result in similar internal temperatures between the two cases. Figure 4 then presents the comparison of the external, roof space and living room temperatures in the 2011 (no roof ventilation) and 2012 (ventilated roof) scenarios.

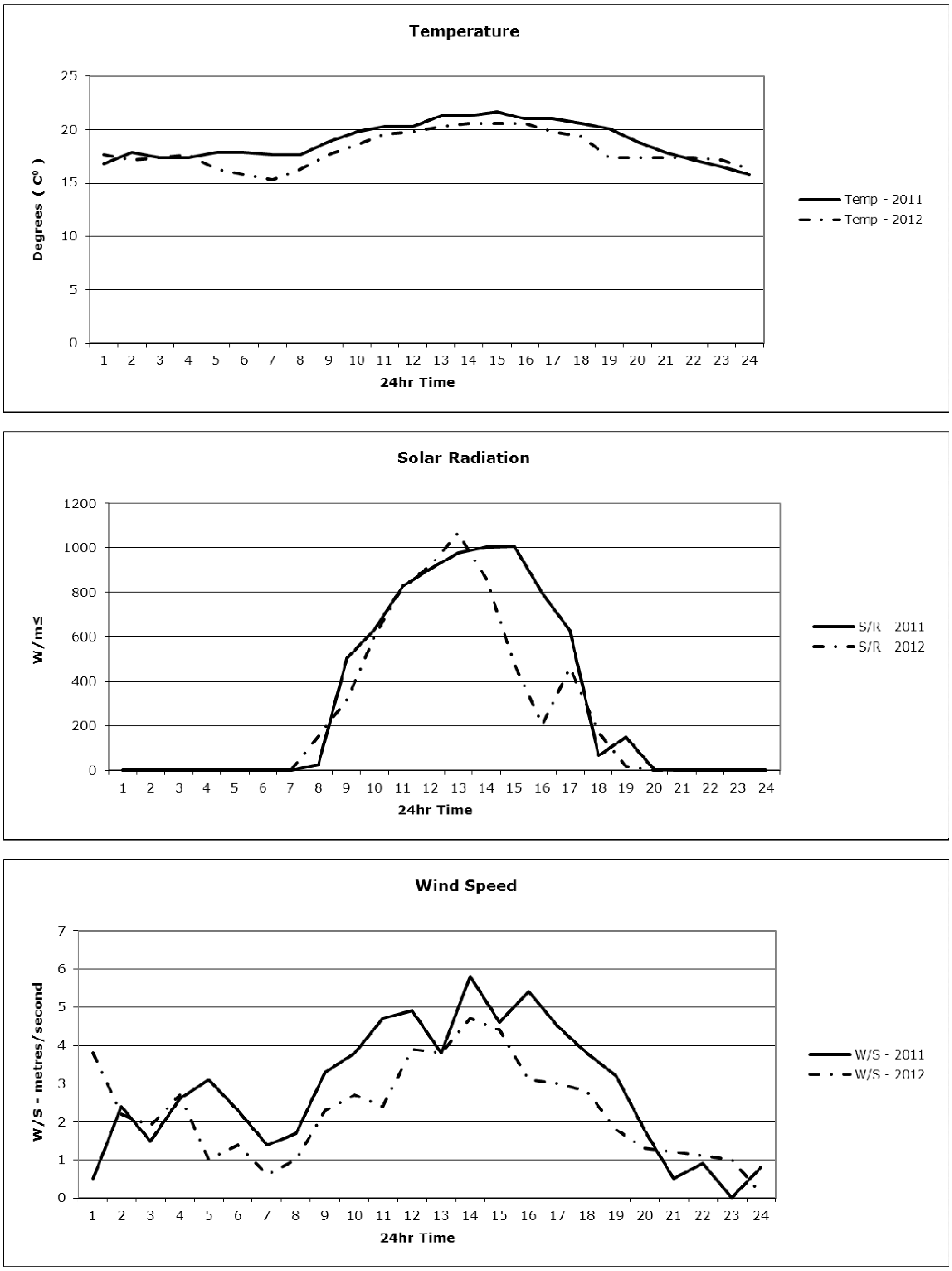

Figure 3 Weather data comparison example – summertime

As is evident in Figure 4, the variation in temperature for the internal sensors, although slightly greater than that seen in the comparison of external temperatures, is still very small. However, this small difference persists across the summer season, and the ventilated roof case can be seen to reduce temperatures overall by 1-2 degrees.

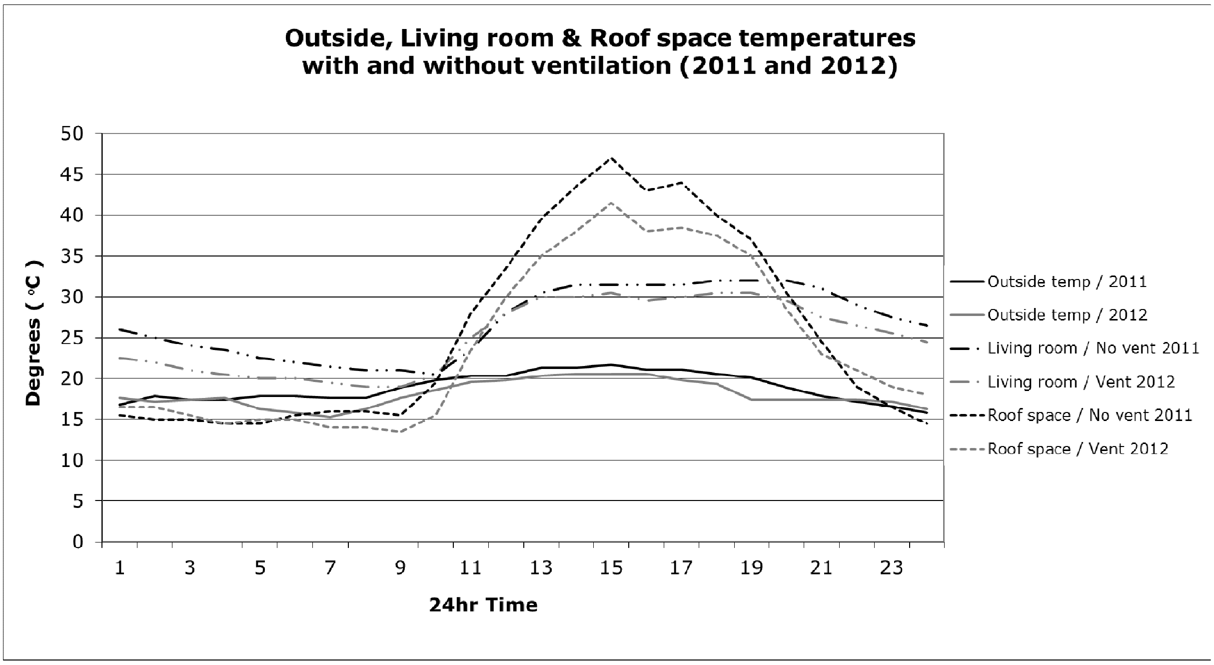

Figure 4 Temperature comparison for example summer day

The temperature difference becomes more distinct when averages over the period are viewed, as shown in Figure 5. The average external temperature in February 2012 was 1.4 degrees less than over the same month in 2012. The average internal temperature following the ventilation modifications was 2.4 degrees less. Similarly in March, the external average was 0.6 degrees lower in 2012, whereas the internal average was 1.6 degrees lower.

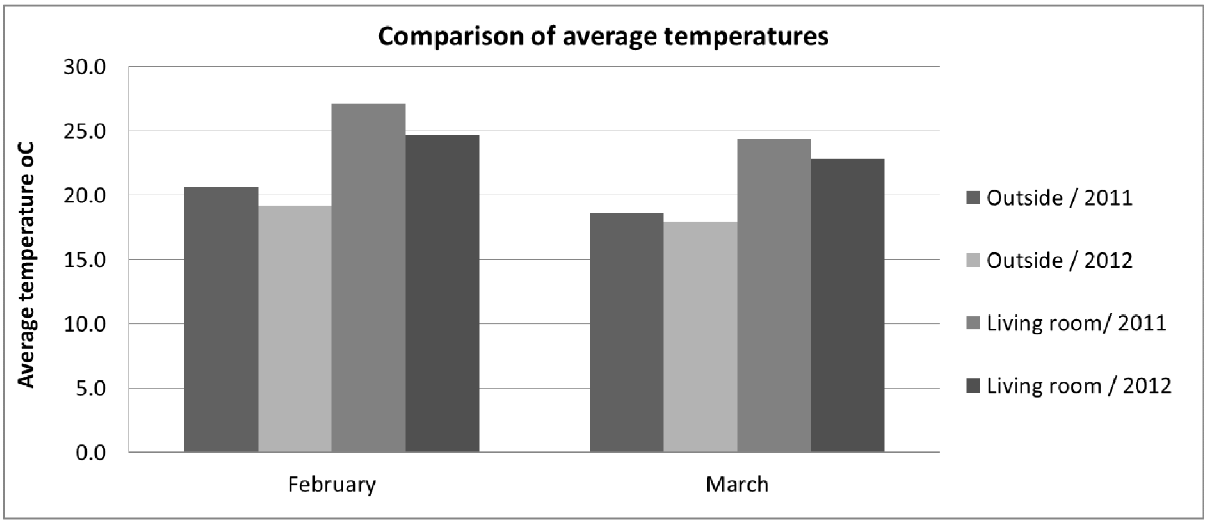

Figure 5 Average temperatures for summer months

Although the overall average temperatures appear reduced by the roof ventilation, a more substantial difference is visible when peak temperatures are examined, see Figure 6. The average daily maximum outside temperature in February 2012 was 22.5^{o}C, 1.4 degrees higher than in 2011. The maximum interior temperature however was 2.9 degrees lower in 2012. In March the temperatures overall were not as high and the difference in maximum external temperatures went from 1.5 degrees difference externally to a 2.1 degree difference in maximum internal temperature with the roof ventilation in place.

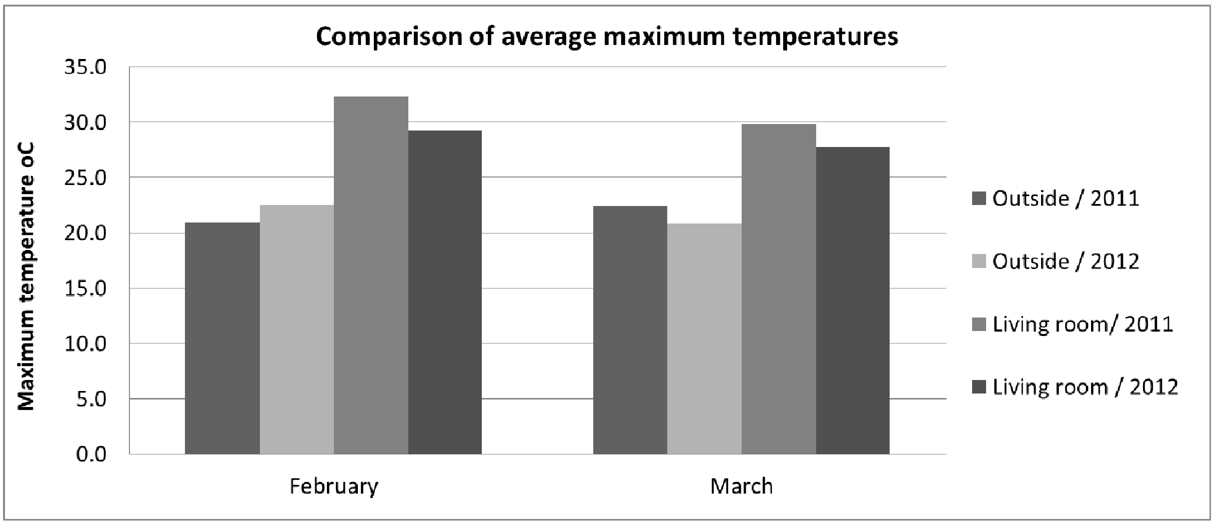

Figure 6 Average daily maximum temperatures for summer months

These results show that a small but consistent reduction in the summertime temperatures has been achieved through installation of the roof ventilation system. The improvement to maximum temperatures to a greater extent than to temperatures overall is consistent with the buoyancy-driven system, as higher temperatures will create greater air movement.

4.2 Winter time measurements

A key objective in addressing overheating concerns was that any reduction in high temperatures was not to be achieved at the expense of winter time cooling. To check whether this was the case, similar analysis was conducted on the average temperatures in the roof space and living room during the coldest winter months of July and August.

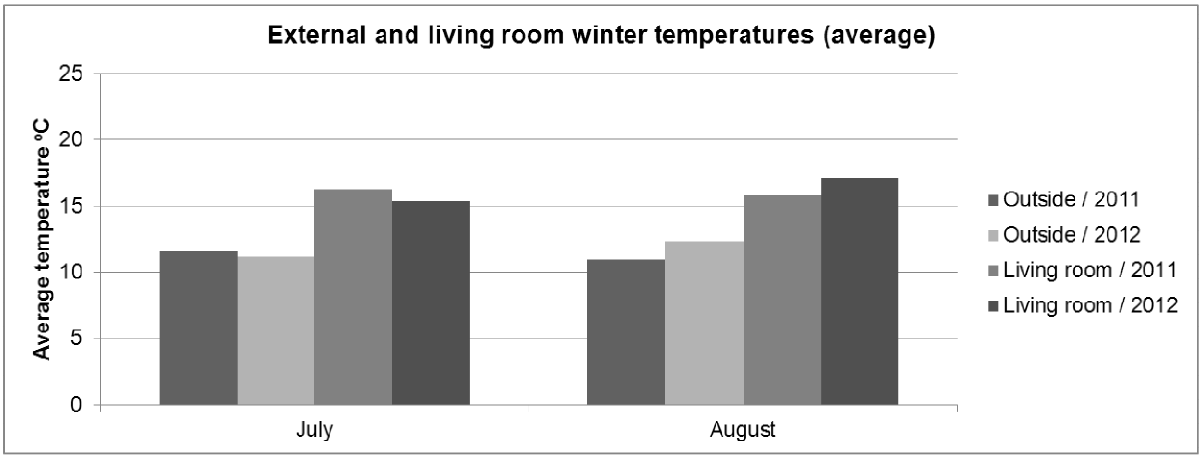

Figure 7 Average temperatures for winter months

Figure 7 shows the comparison of external average temperatures with temperatures in the living room, for each of the winter months. The relationship between internal and external temperatures is uniform across the winter measurements. The temperature difference in outside temperatures between July 2011 and July 2012 was 0.4 degrees. This was matched with a difference in internal temperatures of 0.5 degrees. A similar comparison is evident for August temperatures, where the outside temperature difference between years was 1.4 degrees, while for internal temperatures the difference was 1.3 degrees.

Again this result is consistent with expectations for the buoyancy-driven system. When temperatures are low, air movement is much reduced, and therefore there is no additional heat loss within the roof space.

5. Conclusions

A passive ventilation system such as the one reported here is a low-cost addition to a new-build house or a simple retrofit to an existing house. It is visually unobtrusive and technologically low impact. The results presented here demonstrate that this minor alteration can reduce the peak overheating in the living spaces of a house, without adding to the cooling of the space on cooler days. While the reduction of temperatures by 1-2 degrees may appear to be a trivial change when maximum temperatures are reaching above 30 degrees, the reduction in energy use for cooling across the housing stock will have a significant impact on peak loads. Even when viewed within a single house, the payback period for such a modest outlay will be relatively quick. The system has no impact on the need for heating of the house, as the most significant effect is on peak temperatures and there is less or no effect on temperatures within or below the WHO recommended range of 16-24^{o}C.

In the case studied, the inlet openings in the soffits were of a minimum size to allow air movement. Future work will include experimentation with the size of inlet openings to see if they increase ventilation rates and improve temperatures further, and to investigate the effect of ventilating via the gable ends instead or as well as the ridge vent.

Acknowledgements

This project forms part of a “Whole of House” research centre that is currently being established at Unitec Institute of Technology in Auckland, New Zealand, and has been supported by the Unitec Internal Research Fund. Materials for the project were contributed by Viking Roofspec, Auckland, New Zealand.

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