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Green Roofs in Melbourne – Potential and Practice

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1. ABSTRACT

In Melbourne, green roofs are increasingly being included in the new and retrofitted buildings that claim to be ‘sustainable’ or ‘green’. This enthusiasm follows overseas experience where a variety of benefits have been recorded; these include a reduction in heating and cooling loads. This benefit is of particular importance because of the urgent need to reduce the greenhouse gas emissions associated with air conditioning. What is the potential for such savings and to what extent are some of the existing green roofs likely to achieve these benefits? This paper begins with a review of the overseas experience to reduce conditioning loads, particularly cooling, in temperate climates. Some observations on the potential and practice of green roofs in Melbourne is then presented. The results of measurements of plant canopy, soil and hard surface temperatures on two green roofs in the Melbourne Central Business District are discussed and future on-going work is outlined.

Keywords: green roofs, Melbourne, commercial buildings, potential, practice

Introduction

In Australia, commercial buildings produce 10% of the national greenhouse emissions and have a major part to play in meeting Australia’s international greenhouse obligations (Department of Climate Change and Energy Efficiency, 2010). Within the commercial sector, heating, ventilation and air-conditioning (HVAC) are the main sources of energy consumption. Figure 1 shows the commercial building energy consumption by categories. It can be seen that nearly two thirds of all energy is used for heating, cooling and ventilation of buildings. Since much of this energy is supplied by electricity, the buildings are significant contributors to greenhouse gas emissions. All technologies that offer the potential to reduce HVAC loads should be explored in order to reduce emissions.

![Figure 1 – Commercial building energy use in Australia (source: ABCSE, 2006)](image-url)
Green roofs are one of those technologies that have received media attention and endorsement in recent times in Australia. The popular ABC science program, Catalyst, for example, aired a segment on the technology in May 2010, which opened with shots of one of the green roofs (GR1), discussed later in this paper. The roof was described as “an outdoor lab providing important clues as to how our cities can cope with climate change” (ABC, 2010). An article by Ker (2010) praised the potential for green roofs, citing positive overseas research, and local academics and politicians who support the concept. Even the much-loved cartoonist for the Melbourne Age, Michael Leunig, has been inspired by the attention given to green roofs (Age, 1st May 2010). One of the key recommendations of a report entitled “Future Map: Melbourne 2030 by The Committee for Melbourne (2008) was to advocate for the incorporation of vegetative roofs into the building standards and promote the creation of ‘green roof’ credits.

Unlike Europe, the number of buildings in Australia with green roofs is still small (Williams et al., 2010). One of the reasons for the limited application of green roof systems in this country is the lack of research into their suitability for our various climates (Wilkinson et al; 2009; Williams et al., 2010). If the technology is to be promoted for its potential to reduce greenhouse gas emissions, it is critical that any recommendations are based on realistic estimations of reductions. This paper reports the first phase of a project to determine the potential for green roof technology to reduce the greenhouse gas emissions caused by heating and cooling commercial buildings in Melbourne. The methodology adopted in this first phase has been to review the overseas and Australian research which has focussed on reducing conditioning loads, to visit various green roof installations in Melbourne to assess industry and user practice, and to collect typical measurements of plant canopy, soil and hard surface temperatures on hot summer days. The findings in this phase are presented below in addition to outline of future work.

Previous Research

There are two indicators of the effectiveness of green roofs to reduce greenhouse gas emissions. The primary indicator is the direct reduction in conditioning energy achieved by the technology and the secondary indicator is the reduction in roof temperatures. Overseas research has been reviewed to determine its relevance to Melbourne in terms of the levels of energy reduction achieved and the limitations of the research. There has been considerable research conducted overseas into the impact of green roofs on building energy consumption. Wong et al. (2003), using measured site data for their model, predicted savings of 1-15% in the annual energy consumption of a five-storey commercial building in Singapore. A roof covered with shrubs was found to be most effective. Space and peak load savings for the whole building of up to 64% and 71% respectively were also predicted. Since this study was conducted in a tropical climate, the building will have different conditioning requirements to a building in Melbourne.

The cooling effect of green roof installed on a hospital roof in Italy was evaluated by Lazzarin et al. (2005). In summer, when the soil was dry, there was a 60% reduction in thermal flux on the roof due to the plants. If the soil was wet, there was a small additional passive cooling effect due to evaporation of moisture from the soil. These effects, however, were not translated into energy savings for the building. Saiz et al. (2006) predicted that the installation of a green roof on an eight-storey residential building in Madrid only had a marginal effect on total energy consumption by 1%, with 0.5% reduction in the heating season and 6% reduction in the cooling season.
Interestingly the authors predicted that a 4% reduction could be achieved with a white roof, although additional insulation would be required to compensate for the reduced solar gain. Sfakianakis et al. (2009) determined that a reduction in cooling load of about 11% was possible in a Mediterranean climate. The green roof had little impact on the heating load. However, since these findings were calculated for residential buildings, their applicability to commercial buildings is limited. Similarly, a study of the shading effect of trees has shown that the total cooling energy used in two houses could be reduced by 29% (Akkari et al., 1997). Again, since this research was for residential buildings with trees planted in the ground (not on the roof), it has limited relevance to this study. Sailor (2008) developed a physically-based model of the energy balance of a vegetated rooftop and used this to simulate the energy saving potential of green roofs on a two storey commercial building in two climates, Houston and Chicago. For a base-line green roof, electricity savings for cooling were 2% of the control building in both locations with a conventional roof. Natural gas savings (for heating) were 9% and 11% for Chicago and Houston respectively. The model was validated only using soil temperatures measured on a green roof installed on two-storey building in Florida.

All of the above research is based on computer predictions of savings. The research reporting actual measured savings in energy consumption is much more limited. One exception is the experimental field station study by Liu and Baskaran (2003), who found that the energy required for space conditioning due to the heat flow through the green roof in summer was reduced by more than 75%. The green roof was completely covered with a wild flower meadow in the first year of the study and common lawn grass in the second year. This type of green roof, known as ‘extensive’, is not common in Australia, most installations to date being ‘intensive’, which have a variety of vegetation communities.

A secondary indicator of the effectiveness of green roof technology is the ability of the vegetation to reduce roof temperatures. The overseas research has again been reviewed. Meier (1991) found that strategically placing plants on building surfaces can significantly reduce building surface temperature by up to 80%, although reductions of 25-50% was more common. Under a green roof, indoor temperatures (without cooling) were found to be at least 3-4°C lower than hot outdoor temperatures of between 25°C and 30°C (Peck and Callaghan, 1999, cited in Wong et al., 2003). Niachou et al. (2001) conducted measurements of surface and air temperatures on a planted roof. A green roof was found generally to result in lower surface temperatures; up to 10°C on uninsulated roofs. Furthermore, the authors found that room temperatures below the green roof were lower by approximately 2°C. The evaporative cooling effect of a rooftop lawn garden in Japan showed a 50% reduction in heat flux entering the rooms below the garden and a reduction in surface temperature from 60°C to 30°C during the day (Onuma et al., 2001). Wong et al. (2007) carried out ‘before’ and ‘after’ experiments on a multi-storey car park in a Singapore. A maximum difference of 18°C was observed between a vegetated and non-vegetated roof. It was noted, however, that the temperature of bare or sparsely covered dry soil can exceed the uncovered roof temperatures. In this case, temperatures of over 70°C were recorded.

Overall overseas experience indicates that green roofs appear to have the potential to reduce heating and cooling loads of any occupied space below the vegetation, although the estimated reductions vary greatly from as little as 2% to as much as 75%. In most cases, this potential has been estimated from computer models based on measured soil
and vegetation temperatures, rather than actual measurements of reduced energy consumption.

In Australia, published research on the potential and performance, actual or simulated, of green roof technology is very limited. CSIRO has used data from a test garden at The University of Melbourne’s Burnley Campus to validate a simple model based on AccuRate to predict the impact of a green roof on a building’s energy consumption (Chen and Williams, 2009). Their study predicted that cooling energy needs could be reduced by 48% and heating needs reduced by 13%. The authors state, however, that their results should be used cautiously and care should be taken in their interpretation because of the assumptions and simplifications made. Padovani et al. (2010) found that a green roof on a small community building in Melbourne had little effect on the temperatures in the main activity space. The authors concluded that this was due to significant level of insulation used in the building. Recycled shipping containers with an R-value of 7 were used for the external walls and the roof above the activity space had a thermal resistance of R3. This finding is similar to that of Castleton (2010) who concluded for the UK that that where insulation levels are high i.e. in new buildings, green roofs have no or minimal impact. In terms of the potential to implement green roof technology in Melbourne, the study Wilkinson et al. (2009) provides a valuable insight. The authors analysed the commercial building stock in Melbourne’s Central Business District (CBD) and found that there was a total of 528 existing commercial buildings, of which only 15% (or 78) were considered to be suitable for the addition of a green roof. Wilkinson et al. (2009) therefore concluded that there was only a limited potential for green roof technology in Melbourne. This means that even if the effectiveness of the technology to reduce greenhouse gas emissions is proven, the scope for its implementation in Melbourne is likely to be small on existing buildings and limited largely to new buildings.

**Green Roof Practice in Melbourne**

According to Craig (2008), there were only two notable green roofs in Melbourne, but by 2010, the authors were aware of at least eight installations. Five green roofs were visited as part of this research. Observations made at these visits provide some insight into the understanding of green roof building owners and operators. The first installation, identified here as GR1, is on a residential tower in Melbourne’s CBD. It has 1600 m² intensive roof garden above the carpark in Level 10 (Fig. 2). The car park is ventilated continuously with ambient air to avoid the build-up of car exhaust fumes. The green roof therefore has little or no impact on building HVAC energy consumption. The plants require high maintenance and need to be watered three times a week, which is done with collected rainwater stored in a 175,000 water tank. The grassed area, claimed to be the largest expanse of natural grass in the CBD, needs to be cut once a week in the growing season. The garden is located next to an indoor swimming pool and is used by residents as a recreation space. The addition of the green roof has resulted in a significant increase in the property value of the apartments. The intensive garden includes a number of trees, which required bracing to avoid damage by the high wind speed experienced at this site.
GR2 is a very prominent hotel and entertainment complex in the CBD of Melbourne and owns a green roof. A site visit, however, determined that most of the ‘grass’ was in fact artificial and that the green roof had been installed to provide a more pleasant outlook for the guests whose rooms overlooked the area. GR3 is a single storey government building located outside of Melbourne and is a past environmental award winner of the Royal Australian Institute of Architects. The green roof has been planted with indigenous grasses. However, at the time of the visit in mid-summer, these grasses had been cut right back and there was little vegetation visible (Figure 3). GR4 is another roof garden in the CBD of Melbourne above the offices of a leading property developer. Estimates of actual vegetation indicates that only 30% of the roof was covered by a green roof (Figure 4), thus significantly limiting any beneficial impact that the vegetation may have. GR5 is a newly designed intensive garden on an existing building which was mainly designed and constructed in order to showcase the benefits to the public. This green roof used up a large amount of money and resources for installation and consists of special substrates and devices for stormwater treatment and collection.

Detailed measurements were conducted on GR1 and GR4 during summer and the results are presented below.

**GR1 Data Measurements**

Measurements were conducted on the roof top during 3\textsuperscript{rd}-10\textsuperscript{th} March 2010. Air temperature and humidity at different locations were recorded for a week using HOBO-RH and temperature sensors with operating range -20°C to +70 °C and RH accuracy ±5%. Sensors were completely protected from solar radiation. The sensors were
programmed to record the data continuously at 15 s intervals. Temperatures inside the soil were also measured. Weather conditions were recorded using a weather station. Surface temperatures at different times of the day were recorded using an infrared camera. Figure 5 shows a comparison of the temperature of the soil and the temperature of the concrete during 10 am to 4 pm. Concrete surface temperature went up to 55°C at 3 pm whereas the temperature of the soil was around 20-24°C. These results are in accordance with the results of the field studies conducted in Singapore where the concrete surface temperature went up to 53°C during the afternoon (Wong et al., 2007). Figure 6 shows the comparison of soil temperature under the grass and under plants for a whole day. During the night, soil temperatures under grass and plants were same, but after 1 pm, soil temperature under the plants were lower than soil temperature under the grass, the maximum difference being around 3°C. This is expected as plants provide more cover and shade to the soil compared to grass.

Figure 5: Comparison of soil and concrete temperatures

Figure 6: Comparison of soil temperatures under grass and plants
Figure 7 shows the comparison of air temperatures. It can be seen that during the night, the ambient temperature was lower than the temperatures among plants and adjacent to grass, whereas during the day the temperatures among plants and adjacent to grass were lower than ambient temperature, the maximum difference being around 5.3°C. The temperatures among plants and adjacent to grass were quite similar, the plants being slightly cooler in the night and hotter during the late morning and late afternoon compared to grass.

![Figure 7: Comparison of air temperatures](image)

**GR4 Data Measurements**

The vegetation type at GR4 mainly consists of small plants and coniferous bushes without the any grass as shown in Figure 8. Figure 9 shows the comparison of surface temperatures during 12 pm to 4 pm. Similar to GR1 the concrete surface temperature increased up to 53°C whereas the temperatures under the soil were around 22°C. The soil temperatures under the bush and short plants were very similar, the temperatures under the bush being slightly lower than the temperatures under short plants.

![Figure 8: A view of the short plants and bush at GR4](image)
Figure 9: Comparison of surface temperatures

Figure 10 shows the comparison of air temperatures at sparsely planted bush, densely planted bush and short plants. Similar to the previous case, during the night, ambient temperature was lower compared to the temperatures at the plants. During the day, temperatures near the bush were around 6.2°C lower than the ambient temperature. However, temperatures in between the short plants were found to be higher than the ambient temperature. This could be due to the low leaf area coverage of short plants.

Figure 10: Comparison of air temperatures

**Future Work**

This paper has described the first phase of a research project to assess the greenhouse gas reduction potential of green roof technology in Melbourne. In the next phase of the research, a mathematical model based on the TRNSYS software will be developed to predict the energy savings, and associated greenhouse gas reduction, of a commercial building with a green roof located in Melbourne. The measured data will be used to
validate the model. The simulation program will then be used to predict the potential of green roof technology to reduce greenhouse gas emission on similar buildings located in the other capital cities of Australia.

Conclusions
A review of both primary and secondary indicators of the effectiveness of green roof technology in the overseas literature has shown that it has the potential to reduce energy use and associated greenhouse gas emissions from commercial buildings. However, most of the savings cited are based on predictions from computer models, and many of the locations have different climates to Melbourne. Current practice and understanding of users of green roofs in Melbourne is far from that required to benefit from the technology in terms of greenhouse gas emission reduction, indicating that much more education is required if the technology is to be promoted for this benefit.

Detailed measurement conducted on two of the green roofs showed that the air temperature at the vegetation was around 5.3-6.2°C lower than the ambient temperature. The surface temperature of the concrete rose to 55°C during the afternoon whereas the soil temperatures under the plants were around 20-24°C. These temperature differentials are similar to the findings in overseas studies. Comparison of soil temperature showed that the temperature under the plants were lower than the temperature under the grass. These results can be used to validate a mathematical model to be developed in the second phase of this project.

References


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