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# Thermal performance investigation of a living wall in a dry climate of Australia

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ABSTRACT

There is a paucity of information regarding contribution of living wall systems in building environments and energy performance in dry climates. In this study, thermal sensors were installed for monitoring temperature and relative humidity of a living wall, a bare wall, and surrounding microclimate and also indoor back walls. Two scenarios of warm and cold days were considered in this research during February until August 2015. During the warm day's scenario, the recorded temperatures on the bare wall surface varied from 14 to 61 °C while the recorded temperatures on the living wall were lower, from 12.50 to 46 °C. Similarly, temperature data collected from both bare and living walls during cold day's scenario ranged from 7 to 18 °C. However, the surface of the bare wall was warmer than living wall in both scenarios. The living wall did not show significant effect on the temperature of studied microclimate of 0.50 and 1.00 m, while the living wall was significantly effective on reducing the temperature of the studied back wall. In addition, the heat transfer through the living wall was less than the bare wall. The results confirmed the potential of the living wall in creating an insulation layer for the adjacent building while it showed non-significant effect on mitigating urban heat island effects in summer days. Further modelling investigations to study the effects of adding living walls to the building's skin is recommended.



## 1. Introduction

Addition of green infrastructure into the building is part of the new urban reformation to solve the current developed urban environment problems. Green roof and living wall are the examples of the green infrastructure that have been recommended widely around the world [1–3]. Similar to the available traditional roofs in the urban environment, there are a number of walls that have the potential to be covered by living walls. Living walls can potentially improve the air quality and reduce the pollution level [4], produce cooling effects or reduce temperature inside of the buildings and in surrounding environment [2], reduce building energy usage [5], and improve human health [6]. Green wall is also a way of creating beauty and improving sustainability in the urban environment. In general, green façade, green wall, living wall, building cladding and vertical garden or greenery are the terms that have been used widely for this type of technology [2,3].

There are two installation methods for these green systems. One, used for green façades, is installed for climbing plants to grow vertically without attaching to the surface of the building. The other, used for living walls, is a building envelope system where plants are actually planted and irrigated.

Researchers have been trying to quantify the environmental benefits of living wall systems through experimental and simulations. Investigation of the effects of adding green roofs and green walls to the urban environment of 9 cities around the world with different ranges of climate was investigated by Alexandri and Jones [7] who showed that they have a significant effect of reducing urban temperatures. The results of research in Japan indicated that green walls reduce the surface temperature of buildings by 10 °C when covered with vegetation [8].

A number of empirical studies have been completed, showing that through the use of green walls "ambient air temperature is

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lowered by almost 5 °C, whilst also decreasing the heat fluctuation which occurs during high summers and low winters" [9]. This enhancement of thermal performance is created by an air layer between the green wall and original wall, producing an insulated envelope for the building, helping to reduce energy costs by as much as 23%, a fact discovered in research by Feng and Hewage [10] indicating that covering buildings with vegetation saves cooling and heating consumption levels across all architect styles.

In another study by Mazzali et al. [2], three living walls were monitored in north of Italy for thermal behaviour and energy performance. The results showed the bare wall was between 10 and 20 °C warmer than the living wall and higher net positive energy was entered into the building from the bare wall compared to the studied living walls.

However, in review study by Hunter et al. [11], they concluded that temperature on the bare walls and living walls as well as temperature away from both the bare walls and living walls required more investigation with more attention to microclimate studies.

Australia has been experiencing the most of severe warm years in its history of climate data recording which began in 1910. Since year 2009, the years, 2009, 2013, 2014 and 2015 were respectively the second warmest, first warmest, fourth warmest and fifth warmest years of Australia's history [12–15]. This means more intense heatwaves, and record-breaking temperatures have been occurring from October to December in the recent years. In addition, Australia's average rainfall was below long term national average and long-term drought continued in the north east and south of the country. A strong El Niño contributed to the drier and warmer climate in recent years. Therefore, any strategies that provide a solution to ameliorate the climate change consequences have to be taken into consideration. One of the useful strategies is the addition of living walls into the urban and built environments of the Australian cities.

However, the Living wall industry in Australia is in its infancy and there are still many research gaps that needs to be addressed [8]. One of these research gaps is the potential of living wall systems in mitigating summer urban heat island (UHI) effects of Australian cities.

Adelaide has developed a 30 year plan and living walls is among those recommended technologies for future reformation of the city to become a sustainable urban environment in Australia. Hence, further research is required to investigate how well these technologies are able to be implemented into the urban and built environments of Adelaide [16]. This research aimed to find out the living wall benefits for an urban environment in Adelaide.

Reviewing of the implemented non research demonstration living walls in Adelaide showed that most of the walls are located in indoor environment with orientation of facing either north or east whereas west has the strongest sun exposure. Therefore, for this research, the living wall was installed on the west-facing wall of the Atrium in Building N at the University of South Australia's Mawson Lakes campus. The installation occurred in December 2014. The main hypothesis of this study was that the surface of the living wall is generally cooler than bare wall in summer time and warmer in cold days providing an insulation layer for the building's indoor environment. Also, the other hypothesis was that living wall would ameliorate the temperature of the surrounding environment to a more comfortable level for humans as less heat will transfer through a wall covered with a living wall than a bare wall. During the term of this study, an experimental living wall was set up and monitored with adjacent of the identical bare wall. Twelve iButton that measures temperature (° C) and relative humidity (%) sensors were installed to monitor temperature of the living wall, bare wall, the surrounding environment and also back of the both wall for a seven-month period.

## 2. Material and methods

### 2.1. Experimental design

This study was conducted at the University of South Australia, Mawson Lakes campus from December 2014 until July 2015. The study site has a hot Mediterranean climate based on the Köppen–Geiger climate classification. This generally means it has mild, wet winters and hot, dry summers. Adelaide is the driest of the five Australian state capital cities receiving approximately 550 mm per year on average. Rainfall is generally infrequent, light and unreliable throughout summer and the average precipitation in January and February is approximately 20 mm. In winter, rainfall is much more reliable with June being the wettest month of the year, with approximately 80 mm of rainfall. The average yearly relative humidity is varied from 36 to 61% during summer and winter. In summer, the maximum average temperature is 29 °C but there is considerable variation in temperature and Adelaide can usually expect around a week every year when the day time temperature is 40 °C or above [17]. It was decided to build the living wall at the existing Atrium space as it provided the required space and facilities. The building's west facing wall was chosen as it receives the greatest sun exposure. The size of the wall was 7.0 m (length) × 4.0 m (width) or 28 $m^2$ in area. A review of Australian living wall suppliers including Fytogreen, Holman and Elmich was undertaken and in this preliminary study all their respective available products with regard to their suitability for this project was considered. Following this review, the Elmich VersiWall (VGP 2060) system was selected for this study [18]. According to Elmich [18], VGP 2060 is an easy to install and low maintenance vertical greening system that allows choice of a variety of mounting, planting density and growth media options to suit different installation requirements. VGP 2060 Trays allow spacing of 200 mm and 250 mm horizontally and 150 mm and 225 mm vertically depending on plant size, planting density selected and or design requirements. VGP 2060 Trays can be easily removed from their mounts individually for plant maintenance or design change. Each VGP Tray has a water reservoir with a cover designed to allow reuse of stored water via capillary action to sustain plant growth. VGP 2060 Trays and Mounting Panels are manufactured from UV stabilised recycled polypropylene that meets requirements for international "Green Building" certification. To study the existing thermal distribution on the wall and also for comparing with the surrounding micro-climate, preliminary TR10 temperature data loggers as described by Ref. [19], were collected using thermal sensors located on the wall during the period of December 2014 to January 2015. The results showed that the wall temperature increased to maximum of 59 °C which was 18 °C warmer than the nearest weather station's (Parafield) measured temperatures for the same time of day. Also, further preliminary studies were undertaken including sun/shade studies and a 3D model of the study area generated to have ideas to assess the suitability in terms of solar light and sun/shade movement during summer and winter days.

According to the size of the selected living wall, 26% of the wall or 7.2 $m^2$ of half right side of the existing wall was allocated for installing the living wall. The design of the living wall was in line with the statistical design for covering all purposes of the study. A Latin Square statistical experimental grid with 12 × 12 rows and columns was designed for conducting this study. The design allowed consideration of nine species, two soil media, one of which was scoria as discussed by Ref. [20] and clay. The main and lateral irrigation systems were also designed using EPANET hydraulic