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# Living Walls in The City: Community Values and Expectations

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**Abstract:** There is an increasing interest in living walls in the urban environment, particularly when linked into green infrastructure for urban heat island mitigation. However, the social acceptance of such systems in Australia is largely untested. To address this knowledge gap, a survey of nineteen local government authorities and twenty living wall owners and managers was conducted. The survey participants included commercial and residential buildings. The survey was used to study living wall owners' motivations and expectations of living walls as well as the social values attached to the installed infrastructure. This study related the experiences of living wall owners to the current technical knowledge of living walls and contextualised the benefits and costs of living walls for Australian homes and buildings within the public attitudes and motivations for installing such infrastructure. The survey found that social acceptance and the aesthetic values placed on living walls and greenery more broadly represented a substantial advantage for living walls.

**Keywords:** Green infrastructure, living wall, urban heat island

## 1. Introduction

A vertical greenery system (VGS) is a type of green infrastructure (GI) used in mitigating the urban heat island (UHI) effect [1], [2]. Plants on VGSs are capable of releasing latent heat during the evapotranspiration (ET) process [3]-[6]. There are two popular types of VGSs; one is green façades (GFs), the other being living walls (LWs). Living walls (LWs) offer flexibility and attractive designs but are more complicated and costly in terms of both set-up and maintenance. The primary benefits espoused of GFs and LWs are thermally related. VGSs have been shown to lower the façade's temperature in summer while acting as an insulator in winter [7]-[9]. As a passive building structure, VGSs have been shown to be capable of reducing a building's energy consumption [10]-[12]. Previous studies into VGSs have investigated their thermal efficiency, design, vegetation, phytoremediation capability and economics value. Of late, research studies into VGSs have diversified into multidisciplinary areas including acoustics and social studies [13]. Bustami et al. [13] also found that from the 166 outdoor VGS articles reviewed, only six (4%) were on social studies. However, these six social studies into VGS all reported positive psychological benefits for users. Moreover, discriminating factors such as maintenance and high costs continue to be a challenge for professionals dealing with VGSs.

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Social studies on VGSs are relevant as the presence of VGSs and biophilic infrastructures have been associated with psychological wellbeing [14]. Three studies have shown that in the results of surveys, VGSs were not completely understood to some respondents [14]-[16]. A study on building oppressiveness in an urban environment reported that respondents preferred street trees to buildings with green façades [17].

Although the terms VGSs and LWs are used together, VGSs refer to studies incorporating either one or both GFs and LWs, while this study focuses only on LWs. This study investigates the social context of LWs in particular, to provide additional insights into why, where and how VGSs have been installed and operated in the city of Adelaide in South Australia. This study also targets owners and managers of LWs to examine the motivation and expectations of LW owners and also investigates the social values attached to LWs.

## 2. Methods

### 2.1 Study Area and Participants

A survey was undertaken in Adelaide, South Australia, which has a temperate Mediterranean climate region with an average maximum summer temperature of 34.2ºC and average summer rainfall of 64.4 mm [18]. The city has an average winter temperature of 17ºC with 222.1 mm average winter rainfall, as recorded at the inner-city weather station of Kent Town, Adelaide [19]. South Australia is subject to drought periods, however, metropolitan areas have access to reliable source of potable water. The inclusion of green infrastructure in the urban urban environment is supported in the 30-year Plan for the Greater Adelaide which is the foundation for strategic direction and policy within the state government and at the local government level.

Eighteen local government authorities in the Adelaide metropolitan region were contacted to ascertain if incentives were offered or constraints were in place relating to the installation of a VGS. Specifically, the councils were asked about any existing VGS installations in their local government area and whether council approval was required for the installation of a VGS. Finally, information was sought on whether there were any council policies covering or promoting GI and if any council grants were available to support or subsidise the installation of VGSs. Responses to these questions were able to be given by the first-line enquiry in most councils, with five instances of referral to specific departmental officers.

To source individuals, businesses and professionals who own, manage, design or install LWs, LW installations located in the Adelaide metropolitan area were identified using internet search engines, by word-of-mouth and opportunistic sightings. LWs were screened for survey suitability with potential participants invited (via telephone, personal contact or email) to participate in the survey and were provided with an explanation of the research. The research surveys were conducted face-to-face except for three participants who returned a completed survey. Survey information was transcribed to a spreadsheet for analysis that included descriptive statistics and simple calculations. Photographs of the LWs and notes from face-to-face conversations were also documented.

The primary limitation of the LW research survey was the sample size. The total number of LW in the Adelaide metropolitan area was unknown due to lack of approval requirements. Consequently, a considerable amount of time was needed to identify LW owners and managers. Although the sample size of this survey was small, it is warranted as sufficient as the results provided preliminary insights into the social value of LWs to add some context to a primarily technical study of LWs' benefits and costs. This study provided indicative data of the social values and laid a basic foundation for future research.

### 2.2 Survey Questions

The survey comprised of 41 questions of varied format, including radio button, yes/no, 5-scale Likert score, ranking and open discussion. The survey had six sections divided as follows:

- Section 1: General information. This section collected demographic data, information about ownership and responsibility, LW installation details and knowledge sources.
- Section 2: LW properties and design. This investigated the type of LW, reasons for installation, location, size of the structure, number of pots/pockets and plant species, types of plant species chosen and soil characteristics.
- Section 3: Maintenance. This section sought information on fertiliser and pesticide application, irrigation systems and water use, maintenance programs and operational issues.
- Section 4: Overall experience. This enabled those surveyed to state if their overall expectations were achieved, what recommendations they would give to other users, and what were the costs of installation and maintenance.
- Section 5: Motivation and experience. This section used a 5-scale Likert score to gauge motivation, perceived benefits, and the importance of native plants.
- Section 6: Interview style questions. This part of the survey was designed to prompt discussion on the importance of LWs to the business or individual, the motivation for installing a LW, a description of the benefits of the LW, disadvantages or unexpected events experienced, critical factors considered in the design, and overall experience.

## 3. Results

All 19 local government authorities within the Adelaide Metropolitan area responded to the survey. A total of 32 LWs were identified, 20 of which were successfully surveyed and the results are presented in this section.

### 3.1 Local Government Knowledge and Support for VGS

Of the 19 local government authorities who responded, only six were aware of VGSs in or around their area. Nine councils indicated that no planning or development approval was required to install a VGS on private property. The remaining 10 councils specified that no approval was required unless specific building regulations were breached. The City of Adelaide was the only council to have an explicit policy to promote GI, including VGSs. While some councils indicated that GI is implicitly considered in their current programmes, eight councils did not foresee the introduction of a policy promoting GI, with four indicating budget constraints and six not responding to the question.

One Council has a funded initiative to promote green infrastructure which is available to businesses and individuals to install VGSs (City of Adelaide). Two Councils indicated funds might be available through the Community Development Grants – Environment or Community/Personal grants which could be considered for VGSs (City of Burnside; City of West Torrens). The remaining sixteen Councils do not have a current grant program to promote GI in their region.

### 3.2 Survey Participants

Twenty completed LW surveys were analysed for this study. Nineteen of the LWs were installed over a nine-year period from 2009 to 2017 with one installation underway at the time of the survey (2019). The surveyed LWs covered a diverse range of locations that included cafes, hotels, retail and mixed-use buildings, local government offices, areas of recreational entertainment, private residences, the offices of product designers and landscape architects, and an educational institution. These were subsequently categorized as small business (n = 8), large business (n = 3), corporate (n = 3), hotel (n = 3), residential (n = 2) and landscape architect (n = 1).

### 3.3 Living Wall Properties, Design and Maintenance

The survey questions about the properties and design of LWs revealed that commercially available modular pots are the most common installation type (n = 13, 65%) followed by (unique) horizontal systems (n = 3, 15%). Other installation types are felt pocket pouches (n = 1), GEOWEB® (n = 1) and Fytowall® (product names) (n = 1). One respondent nominated a variety of types given their experience as a landscape architect. Respondents were asked to rank six possible reasons for choosing their LW type, with an option to provide other reasons. Table 1 provides a break down of the highest ranking reasons given by the participants, one respondent did not answer the question.

**Table 1 - Highest ranking reason for LW installation**

| Highest Ranking Reason | No. of Respondents |
|---|---|
| Ease of maintenance | 8 |
| Aesthetics | 7 |
| To introduce green to the urban environment | 2 |
| Store supplier | 1 |
| Alternative to wall cavity insulation | 1 |
| Time to green the façade | 1 |

The LWs were installed in commercial settings (n = 15), public buildings (n = 2), residential properties (n = 2) and multi-storey residential apartment building (n = 1). Five of the LWs faced north, south and east, respectively, with four facing wests, and one south-west. The number of plant species ranged from one (1) to >40. The most common plant groups selected were perennials (n = 15) and succulents/sedum (n=11). Potting mix was the most common substrate medium (n = 14).

Commercially available modular pots were the most common type of installation which is not surprising given the availability of these products at home and hardware stores. Perhaps, subconsciously the familiarity of the use of similar-looking general plastic plant pots with a soil growth medium having perceived results that offer a 'low risk' option. The LW structures ranged in size from 2.5 $m^2$ to 200 $m^2$ including four LWs having two separate structures with the same attributes within proximity, therefore considered as one LW. The number of modular pots per $m^2$ varied from 0.5 to 54, with an average of 17.5 modular pots per $m^2$ (Table 2).

The cost of LW installation varied between LW types and within LW types. The most expensive LW installation overall was AUD 400,000 while the least expensive was a horizontal system (AUD 400), mostly reflecting vast differences in size. The average cost of LW installation from this study was AUD 990 per $m^2$.

In terms of living wall maintenance, fertiliser was applied in two-third of the LWs (n = 13), whereby a variety of fertiliser types were used and with differing rates of application. Among the fertilisers used were slow-release fertiliser, liquid fertiliser and compost. The rate of application varied from annually to once every two to three weeks. Eighteen LWs (90%) were irrigated with automatic drip irrigation systems, while two LWs were watered manually. Irrigation overflow were also imparted in the system with all the LWs except for two.

**Table 2 - LW type, size and number of units/pots/pouches and plant selection**

| LW Type | LW Total Size ($m^2$) | Number of Units/Pots/Pouches | Units/Pots/Pouches Per $m^2$ | SA Native Plant Sp. | No. of Plant Groups |
|---|---|---|---|---|---|
| Fytowall | 200 | 800 | 4 | mix | 3 |
| GEOWEB ® | 200 | 1912 | 95 | yes | 2 |
| Modular pots | 5 | 90 pots | 18 | yes | 3 |
| | 6 | 60 pots | 10 | yes | 1 |
| | 7.5 | 120 pots | 16 | mix | 2 |
| | 8 | 100 pots | 12.5 | no | 3 |
| | 8.75 | 165 pots | 19 | no | 1 |
| | 9.6 | 210 pots | 22 | no | 1 |
| | 18 | 450 pots | 25 | no | 2 |
| | 24 | 282 pots | 11 | no | 3 |
| | 25 | 80 pots | 3.2 | no | 2 |
| | 28 | 480 pots | 17 | mix | 4 |
| | 30 | 17 pots | 0.5 | yes | 1 |
| | 36 | 432 pots | 12 | yes | 3 |
| | 43 | 2304 pots | 54 | mix | 1 |
| Horizontal | 3 | 6 rows | | mix | 2 |
| | 3 | 6 rows | | no | 5 |
| Horizontal (wicking bed) | 2.5 | 10 rows | | no | 3 |
| Felt pocket pouches | 6 | 72 pouches | 12 | no | 2 |

SA: South Australia

Living wall maintenance mainly involved application of fertilisers, management of irrigation system and attention of the plants. In about one-third of the LWs (n = 7), fertiliser was not applied while one respondent did not know if fertiliser was applied, and one responded did not answer the questions. Ninety percent of the LWs (n = 18) did not have pesticide applied. Eighteen LWs were irrigated with automatic drip irrigation. Two LWs were watered manually, one as required and one – at a restaurant – using left-over table water from patrons.

Two of the LWs did not have plant maintenance program or plan, while the rest had basic to comprehensive maintenance such as replacing plants as required, pruning, growth medium replacement and pest management. The reported frequency varied from as required to monthly and even once per two years. Of the nine maintenance-related issues, overwhelmingly the most common issues encountered were dead plants (n = 15) and vandalism or theft (n = 10). Interestingly, regular pruning (n = 4) and regular maintenance (n = 3) were also reported as maintenance-related issues, implying that the high degree of maintenance required by the LW itself need to be taken into consideration by future LW owners. The survey suggested that for predominantly large or commercial LWs, high maintenance costs are often involved. However, for smaller LWs, maintenance was still conducted but not quantified in financial terms.

## 3.4 Living Wall Motivation and Experience

Eleven categories were provided for respondents to scale firstly their motivation and experience of installing a LW and secondly the benefits enjoyed from the LW installation. A 5-point Likert score for each category was used. One respondent did not answer one category under motivation and experience, while seven respondents did not answer certain categories under benefits enjoyed.

Aesthetics emerged overwhelmingly as both the dominant motivation and the dominant benefit experienced by LW owners and end users. Social and environmental benefits, including biodiversity and sustainability, were also very strong in both the motivations and benefits. By comparison, energy savings and cooling benefits were relatively minor factors both in terms of motivations and realised benefits.

Only about 30% of the respondents considered the use of LWs to reduce energy as either relevant or extremely relevant, and similarly energy savings were generally not seen as a key benefit for installing a LW (77%). Two of the respondents indicated energy savings were relevant for motivation but subsequently scored the actual benefits as irrelevant (n = 1) or did not answer the questions (n = 1). Both of these LWs were north-facing, and both were large installations (corporate/large business). The two residential LWs rated energy costs as extremely relevant in terms of motivation, with one scoring the benefits as extremely relevant and the other as relevant. In these cases, the actual energy savings were not measured, but it is plausible that the west and east aspect of these two LWs may have contributed to non-trivial energy savings [20].

The three potential benefits of incentives (95%), produce (85%) and increasing the property value (85%) were ranked as (extremely) irrelevant or neutral as motivations. Given that no funding incentives by local or state governments were available, the irrelevance to LW owners and managers is understandable.

Perhaps the most important response to the motivation and experience of installing a LW was the social engagement LW owners and managers (80%) wanted to encourage within the community in terms of promoting the benefits that a LW offers and to also improve ambience on their premises. The motivation and experience scores are generally comparable to the benefits enjoyed from installing a LW, suggesting that users are generally satisfied with the performance of LWs relative to their expectations. Moreover, the benefits tend to align with the findings of previous studies in terms of aesthetics, beauty, comfort, happiness, provision of a calming environment and tranquillity [15], [21].

The use of crop-producing plants was limited to only herbs in four of the LWs surveyed, three of which indicated that the produce is of relevance to their motivation, while only one enjoyed the crops produced. While it may not be of interest for other LW owners and managers as most were interested in aesthetics, the production of valuable crops such as herbs could potentially help to offset the financial costs and/or to elevate the benefits enjoyed from the LW installation, and hence improve the cost-effectiveness of these systems.

Seven respondents indicated there were no disadvantages or unexpected events experienced by installing a LW. Other responses included complexity, coordination of the installation, a potential hazard for people who attempt to climb the LW, theft of plants and hardware, and vandalism. The most commonly cited factors considered in the LW design were location (n = 10), sunshine hours (n = 5), plant species (n = 11) and shading (n = 6). Individuals also noted budget, ease of maintenance, ease of access, engineering, weight, planning and approval requirements, aspect, development of a self-sustaining system, irrigation, exposure, thermal load, and biodiversity as important considerations.

The overall experience of having a LW installation was positive for all respondents, although one respondent did make further comment on the frustration of plants dying. Respondents were generally happy with their experience while being practical with the benefits of the system. LWs were deliberately placed in locations to attract people and encourage usage of the space. The most relevant motivations to install an LW were social related aspects and benefits enjoyed by the owners and managers. Table 3 and Table 4 show the rank assigned to the motivational factors and benefits enjoyed, respectively, based on the percentage of relevancy points given against the maximum points.

Ranking the motivation and experience of LW owners and managers in establishing a LW and the benefits enjoyed suggested that social-related aspects such as aesthetics, social engagement and community benefits of LWs were of greater importance than incentives, produce, energy savings or surface water quality. Moreover, technical thermal aspects such as energy savings and microclimate were both ranked sixth in motivation, and ninth and fifth, respectively, for benefits enjoyed. Positive feedback from patrons and the community were a large part of the success of a LW, particularly for commercial businesses.

## 4. Discussion

Except for one, no Councils surveyed in this study promoted green infrastructure through explicit policies, with the likelihood of a future policy being very low. However, in some Councils, development plans and policies were indirectly supporting green infrastructure. Previous social science studies that have examined the value of VGSs that included both LWs and GFs [22], their use in the tropics [21] and perception studies in the tropics [16] have all called for policy movements by governments to support the installation of VGSs and to promote their implementation within the community.

In this study, commercially available modular pots were the most common type of installation which is not surprising given the availability of these products at home and hardware stores, and perhaps subconsciously, the familiarity of similar-looking general plastic plant pots containing a soil growth medium having perceived results that offer a 'low risk' option. The prominence of perennial plants in the observed LWs is supported by previous LW studies [8], [23], [24]. Moreover, half of the respondents planted South Australian or Australian native plant species in their LWs. This indicated that they aspired to have a LW requiring minimal maintenance and water requirements. The number of herbs planted was quite low, indicating that crop production was not a high preference to most of the LW owners and managers who responded.

From the results, lightweight and commercially available materials were preferred as soil substrates for LWs. Since LWs are most commonly an additional structure attached to an existing building, any additional weight will add burden to the building structure. Hence lightweight materials were almost always preferred. Only two LWs combined sandy loam and soil into their LW containers, one being the wicking bed system that could hold more weight due to its design.

Social benefit is one of the multiple benefits enjoyed by green infrastructure [25]. Social acceptance and the value placed on LWs and greenery generally, represents a substantial advantage for LWs. This value has not been well investigated within the scientific literature, and the majority of previous LW research has focused on thermal aspects [13]. Arguably, the social and psychological benefits were not easily quantifiable and were rarely factored into the economic analysis [13]-[15]. In future life-cycle and cost-benefit studies, attempts may be made to quantify social and environmental benefits, including food produce from LW plants (when planted and harvested).

**Table 3 - Rank of motivation aspects for owners and managers to install living walls**

| Motivation | Number of Responses | | | | | Total Points | Max. Points | % Max. Points | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | | | |
| Aesthetics | 0 | 1 | 0 | 1 | 18 | 96 | 100 | 96 | 1 |
| Social engagement | 0 | 2 | 2 | 9 | 7 | 81 | 100 | 81 | 2 |
| Environmental benefits | 1 | 1 | 4 | 5 | 9 | 80 | 100 | 80 | 3 |
| Air quality | 0 | 6 | 4 | 6 | 4 | 68 | 100 | 68 | 4 |
| Biodiversity | 2 | 7 | 3 | 2 | 6 | 63 | 100 | 63 | 5 |
| Energy savings | 3 | 6 | 5 | 4 | 2 | 56 | 100 | 56 | 6= |
| Microclimate | 6 | 3 | 4 | 3 | 4 | 56 | 100 | 56 | 6= |
| Property value | 1 | 8 | 8 | 2 | 1 | 54 | 100 | 54 | 8 |
| Surface water quality | 4 | 8 | 4 | 2 | 1 | 45 | 95 | 47.4 | 9 |
| Produce | 11 | 5 | 1 | 1 | 2 | 38 | 100 | 38 | 10 |
| Incentives | 12 | 6 | 1 | 0 | 1 | 32 | 100 | 32 | 11 |

Response points: 1: extremely irrelevant, 2: irrelevant, 3: neutral, 4: relevant, 5: extremely relevant

**Table 4 - Rank of benefits experienced by owners and managers from the installation of living walls**

| Benefits Enjoyed | Number of Responses | | | | | Total Points | Max. Points | % Max. Points | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | | | |
| Aesthetics | 0 | 0 | 0 | 3 | 17 | 97 | 100 | 97 | 1 |
| Benefits to the community | 0 | 2 | 1 | 3 | 14 | 89 | 100 | 89 | 2 |
| Sustainability | 0 | 1 | 7 | 7 | 5 | 76 | 100 | 76 | 3 |
| Biodiversity | 0 | 2 | 7 | 6 | 5 | 74 | 100 | 74 | 4 |
| Microclimate | 3 | 3 | 4 | 4 | 5 | 62 | 95 | 65.3 | 5 |
| Air quality | 2 | 3 | 7 | 4 | 4 | 65 | 100 | 65 | 6 |
| Cooling benefits | 1 | 5 | 6 | 3 | 4 | 61 | 95 | 64.2 | 7 |
| Property value | 2 | 4 | 7 | 5 | 1 | 56 | 95 | 58.9 | 8 |
| Energy savings | 4 | 6 | 4 | 2 | 2 | 46 | 90 | 51.1 | 9 |
| Produce | 9 | 7 | 2 | 0 | 1 | 34 | 95 | 35.8 | 10 |
| Incentives | 10 | 7 | 1 | 0 | 1 | 32 | 95 | 33.7 | 11 |

Response points: 1: extremely irrelevant, 2: irrelevant, 3: neutral, 4: relevant, 5: extremely relevant

The issues associated with vandalism or theft may be expected given that the LW installations were relatively new and most were accessible to the public in cafes, hotels, retail outlets and municipal areas.

Available policies and incentives from local government authorities were among the motivations seen in previous green infrastructure practices, which have included VGSs and green roofs [26], [27]. However, only one of the LW owners/managers surveyed in this study received support or incentives from their local government authority. Despite being almost entirely self-funded, they were willing to pay for the high installation cost, averaging at AUD 990 per $m^2$, and additional maintenance costs. Moreover, despite these high costs, owners and managers typically had a positive experience with 100% affirmation that they would recommend the LW systems to someone else, indicating significant satisfaction with the value of LW systems.

The residential LW owners indicated strongly that cooling benefit from the LW installation was achieved, along with increased biodiversity. One has also emphasised on basic knowledge in planting including irrigation and plants is necessary before building a LW. Meanwhile, aesthetics were mainly the motivation and benefits enjoyed by commercial LW owners.

The survey revealed that greenery is of social value, consistent with findings from previous research [5]. The general public value the greenery but may not be aware of the cost involved, as attested by the owners and managers surveyed in this study. It may be possible to better integrate the cooling benefits of LWs with the social value of greenery, in a more coherent manner. In a dry climate such as Adelaide, unused outdoor spaces could be installed with LWs and converted into patios or courtyards, for the aesthetic and social benefits identified in this study.

## 5. Conclusion

This targeted study aimed to provide a social context for understanding the perspective of LW users. The majority of the Councils in metropolitan Adelaide do not provide incentives or standard requirements for VGS installation. However, lack of external funding did not diminish the motivation of LW owners and managers, as is empirically evident in this study. LW systems can deliver pertinent social value through their positive aesthetics and benefits to the community. This duly supports the multiple benefits of LWs, including social benefits, as a component of GI. The high social value and satisfaction suggest that the effectiveness of LW research could be improved in the future. A wider social survey could also be conducted whereby LW research in the future could be improved by integrating the general benefits into its application.

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