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The Green Wall Efficiency in VOC Mitigation and Indoor Environments' Improvement: A Sustainable Design Strategy in Oman

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Abstract: This research is a call for a solution that balances human well-being with environmental sustainability. At our college, we as a team observed how students and staff feel against paintings and artworks, inspiring us to propose the Green Wall as an effective solution. The primary methods to explore the effects of vertical gardens within architectural and interior design studies. By having field studies for observations and assessment of installing vertical gardens. To verify the problem, we conducted on-site measurements using some Ranger devices in a selected site with a number of field test results. And observed results confirmed the presence of high concentrations of particulate matter and VOCs in the environment, confirming the problem identified and calling for further study and mitigation which is the main part of our research work. Vertical garden offers environmental and educational value to Oman to be used in Oman's public buildings as living design elements that reflect Oman Vision 2040, particularly in supporting the goal of improving the Environmental Performance Index. By enhancing air quality and introducing greenery in educational facilities. The team proposed the use of a vertical garden as one of the measures to reduce indoor contaminants to get healthy indoor environments.

Key words: vertical garden, VOC mitigation, indoor environment, Oman, well-being, experimental study, sustainable benefits

1. Introduction

Vertical Garden is the new face of Breathing Architecture and biophilic design. There is a need to make it known throughout Oman by architects and Interior designers to establish the vertical gardens as part of the new design profile.

This research offers a comprehensive theoretical and experimental information to develop the vertical gardens solutions) for architects and interior designers with a sustainable development approach. Whether the vertical garden is part of a future eco-design or simply designed for more "aesthetic benefits "in urban environments" [1].

There is a big need for the knowledge about sustainable design principles [2] and to highlight the importance of prioritizing it for architects & interior designers [3].

The first part of the research work aims to collect useful information about the impacts and uses of the vertical gardens from different points of views of architecture and interior design [4]. In the second part of the work, an analytical methodology is followed, studying different examples and how their existence influences the users.

The last part of the research work is to study valid construction systems in the local market and the effectiveness of the living walls [5]; For this purpose, we can do a practical experiment in public building to have a strong interaction with the building users. This research is to assess how the vertical gardens will

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generate a smooth transition between the building and the natural background that allows the plant element to be included within the architectural space. As well as there is a need to assess its impact in Interior design while designers use the living walls/vertical garden to give a sustainable and innovative aspect to any interior space [6] in addition to a lot of advantages such as noise absorption and beautifying the interior space to bring the natural world into the different environments of Oman's workplaces [7].

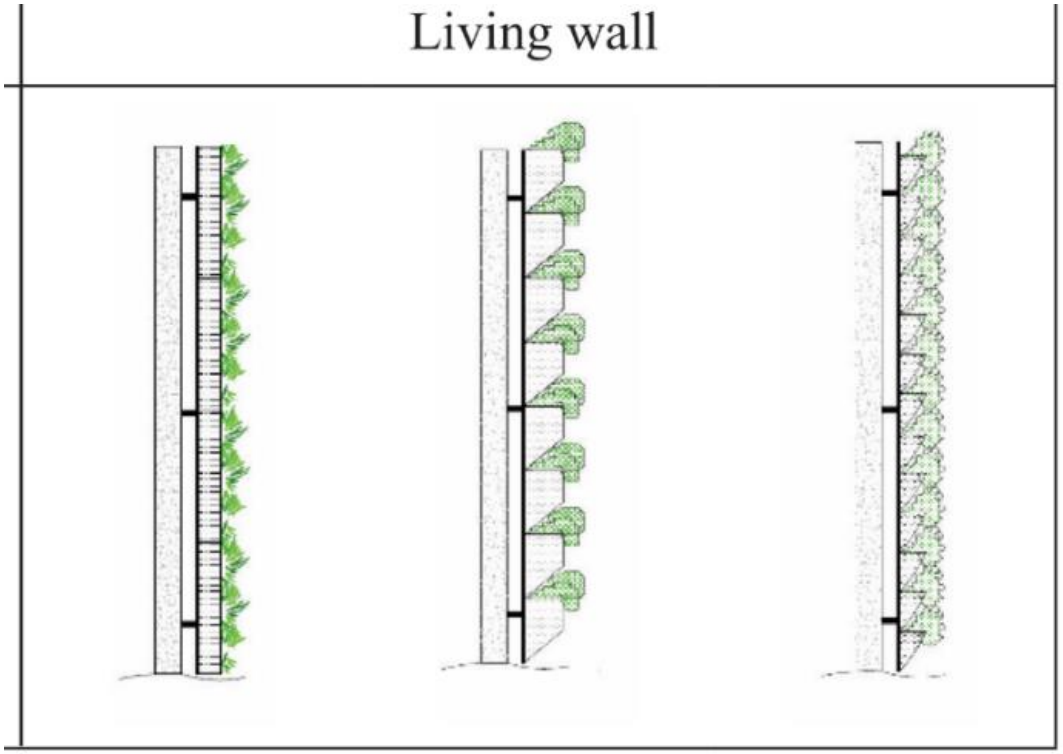

Fig. 1 Drawing of living wall [2].

As part of sustainable practices within the college environment, the research project was initiated to serve both environmental and educational purposes. The implementation of this research project was supported through external funding provided by the Ministry of Ministry of Higher Education, Research and Innovation This support enabled us to bring the project to life with high-quality materials and professional execution, aligning with national sustainability goals.

All project-related expenses were carefully documented and receipts for all purchases made throughout the implementation of the vertical Garden are available and can be provided upon request.

As an overall achieved outcomes; the research project Assesses the effectiveness of vertical gardens that leads to provide valuable insights and design solutions for the long-term viability for them. And assists faculty and students with all knowledge necessary for their (architecture-interior design) projects. In addition to presenting a number of results and corresponding recommendations.

The vertical garden, is vegetation grown on a vertical surface, either inside or outside a building. Plants are typically rooted in soil, stone, or water and supported by built-in irrigation systems. They are botanical biofilters help in creating cleaner and healthier indoor and outdoor environments, and to improve building insulation [4].

We proposed the use of a living green wall as one of the measures to reduce indoor contaminants and unwanted heat within the building. It has been proven to work effectively through past studies. For example,

[8] recognized VOC exposure's indoor health outcomes as a demand for control [9] illustrated that active green walls are able to remove over 50% of VOCs in a single air pass. These findings justify that the inclusion of green walls can be an influential component in improving air quality and building healthier indoor environments.

Assessing the Long-Term Sustainability and Effectiveness of Vertical Gardens in Oman that leads to provide valuable insights and design solutions for the long-term viability for them while enhancing aesthetics and biodiversity making vertical gardens a valuable alternative as they utilize vertical space without encroaching on ground space.

Our green wall integrates the principles of both flower turbines and kinetic energy harvesting to produce clean, low-voltage electricity — enough to power a small 1.5V battery.

The design includes miniature, flower-shaped turbines subtly embedded within or above the wall structure. These turbines respond to light airflow, either from natural wind or movement created by people passing by, ventilation systems, or even water flow from irrigation pipes.

At the same time, we incorporate kinetic power elements — for example, tiny rotating components driven by flowing water (similar to micro Archimedean screws) or gentle movement in plant leaves. These motions are converted into energy through small-scale dynamos or piezoelectric elements.

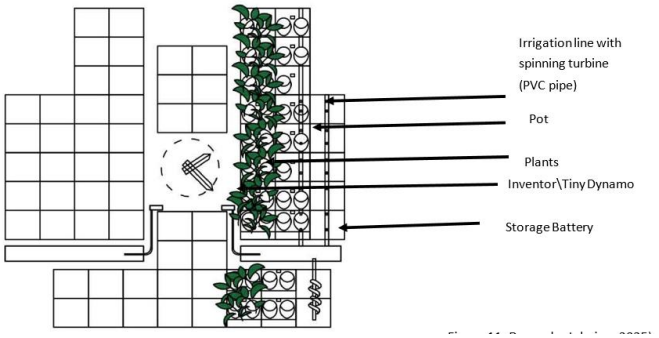

Fig. 2 Green wall design drawn by students, 2025.

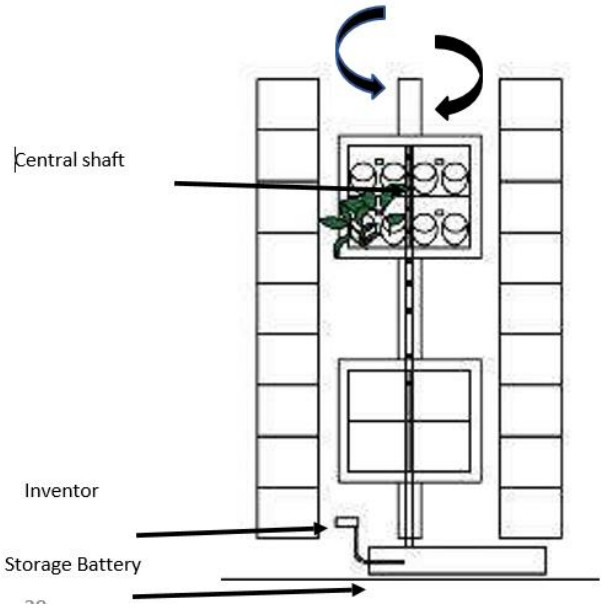

Fig. 3 Green wall design drawn by students, 2025.

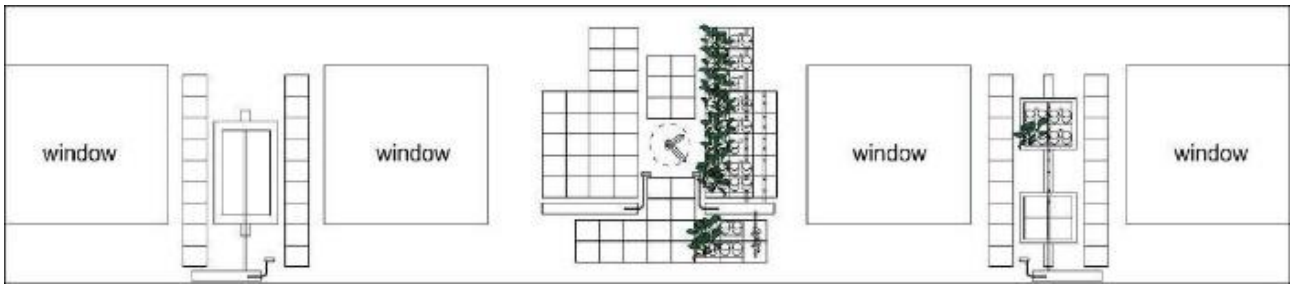

Fig. 4 Green wall design done by Students, 2025 includes Rotating Panels, Mini Dynamo Inside: Converts rotation into power. 1.5V Battery: Stores energy from rotation, Outputs: clock, LED light.

Our dynamic green wall doesn't just serve as an eco-friendly surface — it also generates power in a creative and educational way [10].

We've integrated kinetic energy harvesting into the wall's existing rotating writing panels. These double-sided panels, which students can spin to write on both sides, now do more than support learning — they act as kinetic energy sources [8].

Fig. 5 Executed green wall design done by students, 2025.

Each time a student rotates a panel, the motion drives a mini dynamo, similar to those used in hand- powered flashlights or bicycle lights. This rotational movement is converted into electricity and stored in a tiny battery or capacitor, delivering a 1.5V output — enough to power a small LED, digital clock, or environmental sensor embedded in the wall.

To enhance the concept, we may also embed small flower-shaped vertical turbines along the top of the wall, which catch wind or airflow from nearby windows or HVAC systems. These add another layer of renewable energy collection, combining wind and motion into a single system.

2. Material and Methods

2.1 Methods

2.1.1 Study Area

V O C S P R O B L E M

Volatile organic compounds (VOCs) are present in every paint and may have harmful impacts on human health, especially when people are exposed for a long period. These chemicals may be the cause of respiratory problems, organ damage, and even cancer. [8[carried out an experiment in which they measured the amount of 15 VOCs in paint factories. The results showed very high amounts of m,p-xylene, ethylbenzene, and toluene.

2.1.2 Data Used

• The overall study is based on: Mixed Methods: Combines both qualitative and quantitative approaches.

-Qualitative: Focuses on understanding concepts experiences (international & local case studies), in other words: Inductive: Starts with observations and builds up to theory & practical implementation.

-Quantitative: Focuses on numerical data analysis (surveys, experiments).

• case study: Green Walls in Educational Facilities

Harvard University Location: Cambridge, Massachusetts

Client: Harvard University Installation: 2018

Case: Interior Design

Analytical Study: Vertical Gardens at Harvard University's Smith Campus Centre.

The installation of eight substantial vertical gardens at Harvard's Smith Campus Centre exemplifies an innovative integration of sustainability, architectural enhancement, and social functionality within a historic academic setting. These nearly 20-foot living walls serve multiple roles, fundamentally altering the spatial dynamics by transforming an otherwise ordinary indoor walkway into a vibrant communal environment that promotes social interaction among students and visitors.

• Local Case Study in Oman: Higher College of Technology Eco house, Muscat, Green Wall in Educational Facilities. Dominantly bougainvillea — suitable for hot, dry climate.

Growth Conditions: Thrives well under full sun; some lower parts show stress due to lack of light/water.

Sustainability: Bougainvillea is drought-tolerant and widely adapted to Muscat's climate.

Fig. 6 Green wall in Smith Campus Centre at Harvard University [10].

Fig. 7 Eco house green wall, photos taken by researchers, 2025.

2.2 Environmental Measurements

The study began by analysing space temperature data using sensors (July 2025), which showed that the chosen space (Multipurpose Hall) overheats significantly — up to 10°C more than (September 2025). Field research was conducted from July to November 2025 to identify and document the eco impact for vertical garden, which is helpful to be mapped for future study.

The green wall supports the college's sustainability efforts by promoting energy efficiency, reducing the carbon footprint, and encouraging the use of eco-friendly practices. It demonstrates a commitment to green infrastructure and long-term environmental responsibility.

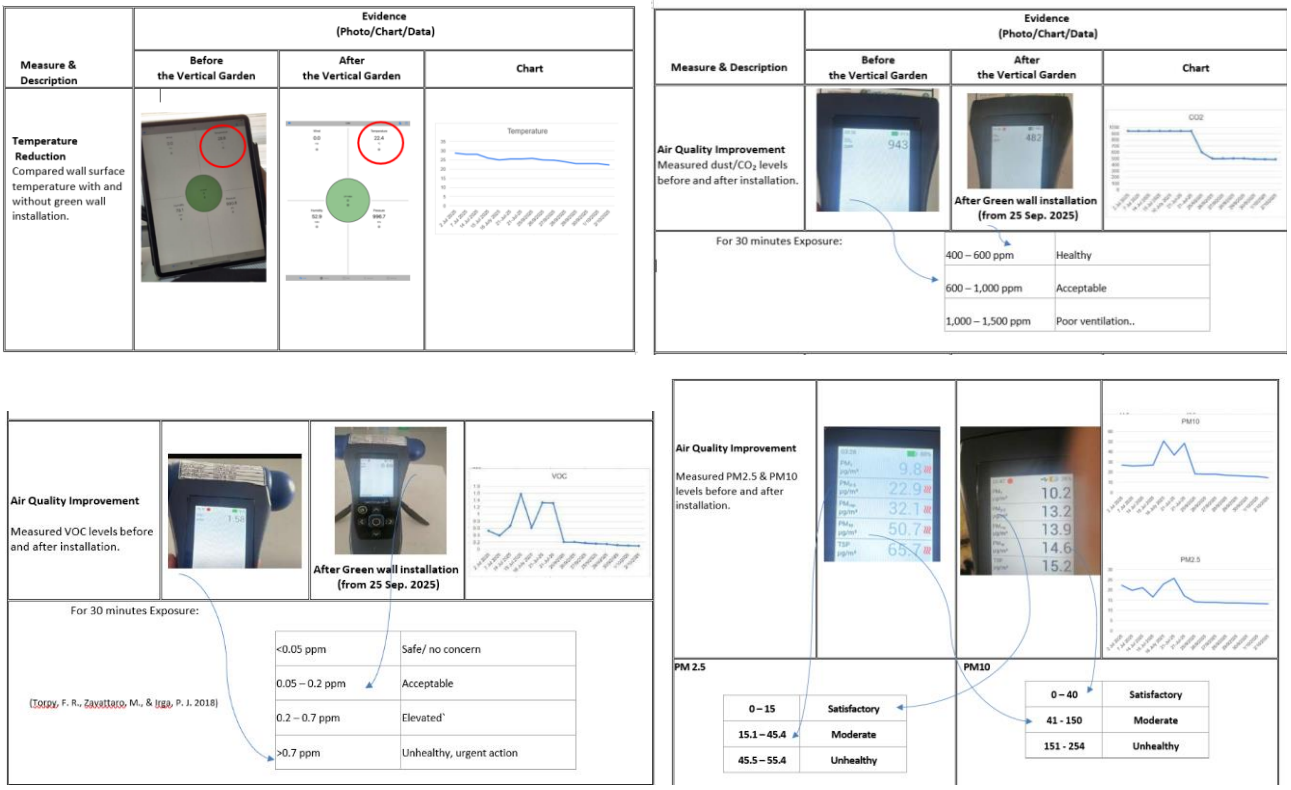

Fig. 8 All environmental measurements & charts are done by team, 2025.

2.3 Objectives

- To discover new knowledge and to keep up with the latest trends of the vertical gardens in the field.
- To solve a national problem regarding the energy preservation and to reduce the environmental impacts which is related to Oman vision 2040.
- To enhance the quality of teaching and learning by involving the students\users in research and practical implementation.
- Design considerations (Site selection and reasoning)

The green wall was installed in a well selected location within the college (Multi-purpose hall) to maximize both its visual and functional impact. The selected site ensures high visibility to students and campus users, increasing awareness and engagement. It also benefits from adequate natural light and facing the southern direction, which is essential for healthy plant growth. Additionally, the location was chosen to enhance the aesthetic appeal of the space and to demonstrate the integration of sustainable design in educational settings.

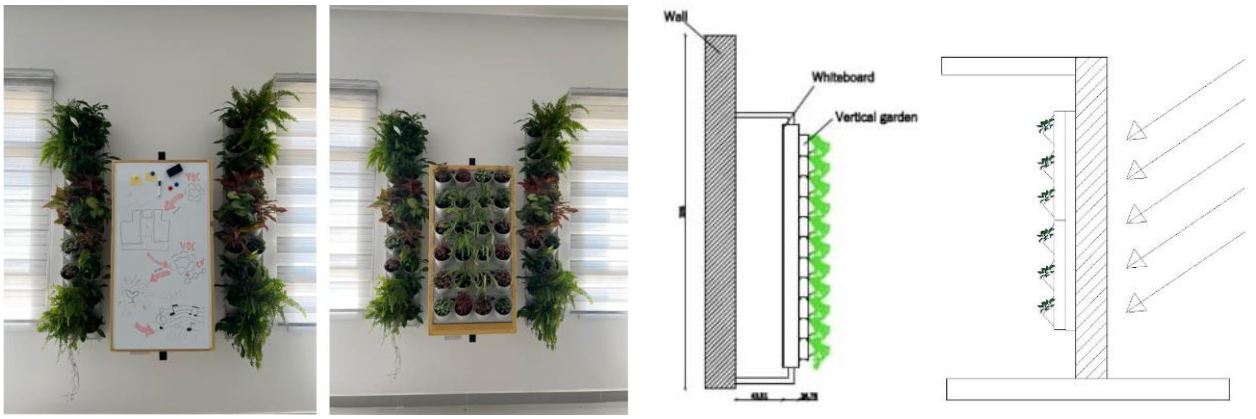

Fig. 9 Rotating components assembly after execution done by research team, 2025.

2.4 Questionnaire

Questionnaires, have been used in research to assess public understanding and satisfaction on vertical gardens.

A five-point questionnaire was created to assess SCD multipurpose users' opinions of vertical garden in their campus.

The survey was conducted between September 2025 and November 2025, with no restrictions on gender or age. Out of 100 multipurpose users approached. Data were analysed:

Participants generally agreed that vertical gardens enhance the interior space aesthetics. These findings are supported by Introducing plants into indoor spaces has been shown to improve productivity and reduce stress — participants reacted 12% faster on tasks and had lower blood pressure. Since people spend about 90% of their time indoors, enhancing indoor environments is essential. Plants also help reduce noise by absorbing, scattering, and reflecting sound, depending on room structure and sound frequency.

3. Results and Discussion

3.1 Results

A summary of the outcomes and recommendations emerged from the research project, besides all that is related to applying the outputs or how to be a content of research in further advanced stages.

To maximize the ecological and economic viability of green wall installations, proposed design solutions serve as recommendations for designers. These solutions involve using life cycle assessment, integrating AI and smart technology for maintenance optimization, selecting appropriate plant species, and utilizing sustainable materials in system structures. With these recommendations, designers emphasize the points to be considered when integrating systems into the interior space. A comprehensive understanding of existing green wall systems available in the market has been achieved through the examination of 11 green wall types, with real-world examples provided to illustrate their applications.

Users can select the most suitable system based on their specific requirements and constraints after examining their advantages and disadvantages.

Green facades are the most affordable type of vertical gardens. They are considered to be simple solutions created of support systems such as wires or trellis systems for climbers and vines, which not only support plants but also enable the use of climbers without adhesive pads. They create an air gap between a wall and vegetation, which protects a facade from severe weather conditions.

Walls and facades directly covered by such plants are also categorised.

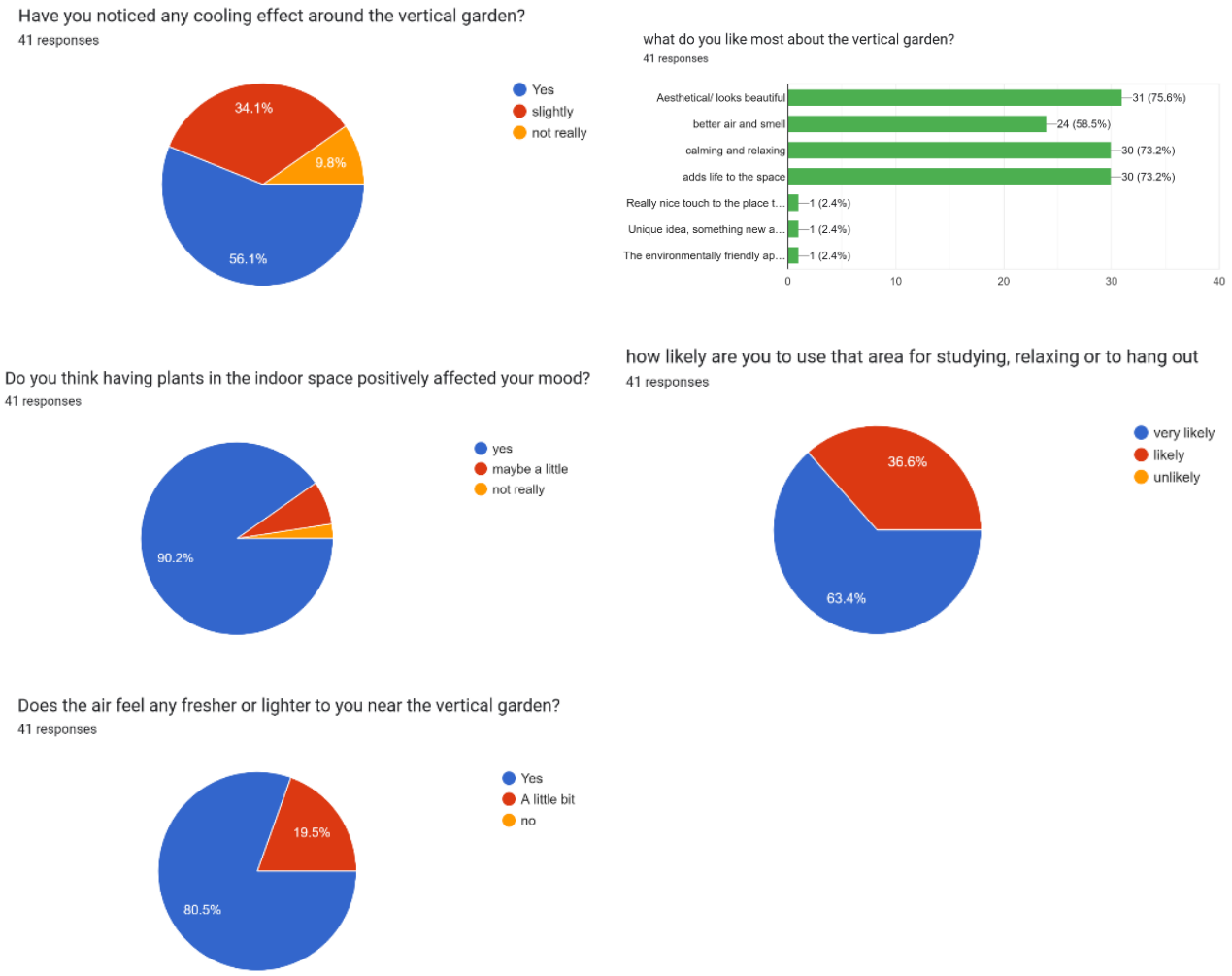

Fig. 10 A five-point questionnaire was created by research team, 2025 to assess multipurpose users' opinions of vertical garden in their campus.

Due to limited space for greenery in the built areas, alternatives like vertical gardens are being explored. Though still a new concept with limited research and policy support, living walls show great potential in addressing positive impact and improving the inside outside environments. The students propose using existing structures (SCD campus) to implement them.

Multi-Criteria findings to identify the best site for replanting activities.

3.2 Discussions

Vertical gardens offer a solution by transforming unused vertical structures into green surfaces, improving biodiversity and connecting green networks. They help reducing urban heat islands (UHI) by increasing albedo, reducing surface temperatures, and lowering the need for air conditioning, which in turn cuts harmful emissions. Research shows green walls can significantly reduce wall and air temperatures across different days and enhance energy efficiency, with cooling demand reductions of up to 66%. They also serve as passive insulation, improve humidity, absorb pollutants. Besides environmental benefits, vertical gardens enhance aesthetics, increase property values.

In addition, vertical gardens support national objectives by promoting awareness of sustainable design, encouraging innovation in energy-efficient solutions, and involving students in research and hands-on implementation. This not only advances environmental goals but also enriches the educational process by connecting learners directly with real-world applications in green architecture and green design.

As a result, we need to promote awareness about the vertical garden. This reflects a growing appreciation for decorative greenery.

Respondents favoured aesthetic uses over food production, people showed strong concern for environmental and social quality, valuing relaxation, beauty, and psychological benefits.

These findings echo global research linking small-scale vertical gardens with urban sustainability, improved air quality, and climate benefits. While aesthetic and biodiversity values were appreciated, technical concerns, and integration into different interior spaces — were also highlighted.

Recommendations:

Encouraging College campus users to handle basic maintenance tasks can reduce long-term upkeep concerns.

Understanding installation types and plant preferences will help in designing suitable guidelines and prototypes.

Municipal authorities should integrate vertical gardens into broader urban green policies and host public events to raise awareness and promote community involvement in green initiatives.

For further researches:

Integrating AI and smart technology can enhance the maintenance and lifespan of green walls. AI, combined with sensors, monitors plant health, soil moisture, and nutrients in real time, enabling early detection of plant issues and targeted care.

3.3 Validation of the Findings

We aim to link our research findings with relevant study Hawana Research to enhance the value of both works and strengthen the overall impact of our Research. In Hawana research there is a monitoring for the polluted areas inside hospitals & public buildings … so the green wall is an eco-solution.

4. Conclusions

- Vertical Garden requires no ground space.
- Air purification & dust reduction.
- Possibility to apply vegetation in hydroponic cultivation.
- Quick to install.
- Aesthetics due to covering the rigid\plain concrete structures.
- Well-being\Therapeutic effect.

Increasing the interactive features — such as rotating elements, educational displays, or energy feedback screens — to engage audiences more effectively.

References

[1] Rahman Tafahomi, David Nkurunziza, Regis Dusingizumuremyi, Gatoni Gwladys Benineza, and Reihaneh Nadi (2024). The assessment of residents' perception of possible benefits and challenges of home vertical gardens in Kigali, Rwanda, MDPI.

[2] Miriam Zaťovičová, and Martina Majorošová (2023). The use of vertical gardens as a network of urban navigation elements with a positive impact on biodiversity and microclimate in a dense urban environment, *Slovac Journal of Civil Engineering*.

[3] Oemar Idoe, and Pham Van Luong (2022). Implementation guideline green walls and green roofs: Urban ecosystem-based adaptation to climate change in Viet Nam, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

[4] Özgür Burhan Timur, and Elif Karaca (2013). Vertical gardens, available online at: http://www.researchgate.net.

[5] Hanna Golasz-Szolomicka, and Jerzy Szolomicki (2019). Vertical gardens — Modern form of green building technology, *Materials Science and Engineering*, *Forest Ecology and Management* 154 (2001): 409-430, available online at: http://www.collegesidekick.com.

[6] Ana Maria Tavares Martins, and Ines Daniel de Campos,

From the horizontal garden to the vertical garden: An architectural and environmental perspective of the "green" element, *Building Technology (International Conference)*, 2018.

[7] Zophruvelu Venuh, and Sabina Raut, Green wall for healthy and sustainable urban society: A review, *Green Wall for Healthy and Sustainable Urban Society: A Review*, 2022.

[8] Ghobakhloo, E., Rahimzadeh, H., Farhang Dehghan, S., Rostami, R., Jafari, A. J., Mansouri, N., and Omidi, F. (2023). Exposure to volatile organic compounds in paint production plants: Levels and potential human health risks, *Toxics* 11 (2) 173, doi: https://doi.org/10.3390/toxics11020173.

[9] Torpy, F. R., Zavattaro, M., and Irga, P. J. (2018). Testing the single-pass VOC removal efficiency of an active green wall using methyl ethyl ketone (MEK), *Air Quality, Atmosphere & Health* 11 (2) 163-170, doi: https://doi.org/10.1007/s11869-017-0518-4.

[10] Elif Sude Okul (2024). Design solutions for green walls in interior spaces, *Politecnico di Torino*.