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The Green Building Envelope towards Sustainability in Official Schools, Egypt

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ABSTRACT

Water saving is a problem that faces most developing countries. In Egypt, School gardens are becoming more challenging over the years and the playgrounds are becoming poorer, School façades are typical and boring. In addition, we find severe waste of water in toilets, hand washing basins, and others. Vertical green can improve the environment in urban areas; it can improve the environmental performance of buildings and the economic performance through reducing heating and cooling costs. On social perspective, green walls may have a positive impact on both physical and mental health. The research seeks to create an educational vertical garden, Suggesting new educational uses to boost interaction and creativity. In this way, space will become an instrument of new knowledge and highlight importance of sustainable development. The research paper concludes by proposing green vertical wall for the school building blocks.

Keywords: green building envelope, sustainability, Official schools, Egypt.

1. Introduction

The provision of basic education schools in Egypt is one of the pressing issues facing the Egyptian government. The government has designed a substantial number of schools around the country. One problem is that schools of typical design have been built in varying climatic regions of the country, fig (1).The majority of pupils and teachers suffer from thermal and visual discomfort during much of the academic year inside the classrooms .The climate in Egypt is influenced by several factors including its geographical location, topography, general system of atmospheric pressure and the water surfaces surrounding it.

Playgrounds are a rarity, fig (2). The quality of school facilities has clear effects on the daily performance of both the teachers and the students who use them.

One also finds in public schools wasting large quantities of water in bathrooms and hand washing basins without benefiting from it, fig.(3). Meanwhile, the per capita share of water has dropped dramatically to less than 1000 m3/capita, which is classified as "Water poverty limit". It is projected that the value decreases to 500 m3/capita in the year 2025 (Abdel-Wahaab, 2003), fig.(4)

Green wall technologies provide a wide range of options for designers who are interested in using the building envelope to accomplish multiple objectives. Green walls can be incorporated in a modern architecture, to build a future sustainable urban living (Chong, (Chloe), 2021). Green walls provide aesthetic variation in an environment in which children carry out their daily activities, improve exterior air quality, reduce urban heat island effect, improve energy efficiency, protect building structure, improve indoor air quality, reduce noise (Sheweka and Mohamed, 2012).

The research aims to study the possibilities for applying soft landscape for public school façades in Egypt. The ideas of vertical greening "Greenscaping School" proposal are: Raising environment awareness educating young people, Empowerment of local community, Innovative design solutions, Use of eco-friendly materials, and Aiming towards sustainable future.

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The research deals with the advantages of green facades, their different types and requirements, how to reuse water for watering plants in vertical walls, a study of some international experiences for planting school facades, and finally a design proposal for planting facades of a public school.

Fig. 1: Public school façade in Egypt(Researchers)

Fig. 2: Public school playground in Egypt(Researchers)

Fig. 3: Depletion of water and extravagance in its consumption (Researchers)

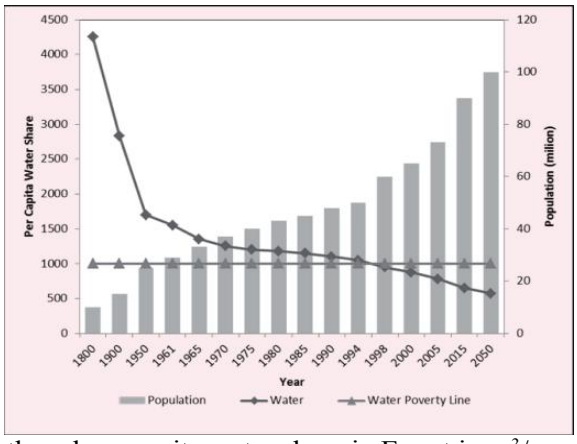


Fig. 4: Population growth and per capita water share in Egypt in m^3/year (Abdel-Wahaab, 2003)

2. Green facades systems (GRS)

Plants growing vertically on buildings are known as living walls, green walls, vertical gardens, or bio-walls. They can be located on the outside or inside of a building. A green wall is one of the green architecture techniques that reduces interior temperature, noise, air pollution, the urban heat island effect, and stormwater runoff to decrease the effects of global warming and improve public health, fig.(5). Vertical gardens may also improve interior air quality, building aesthetics, human comfort, and biodiversity, which is why they're becoming more popular as sustainable building design components, Table (1), (Hopkins and Goodwin, 2011).

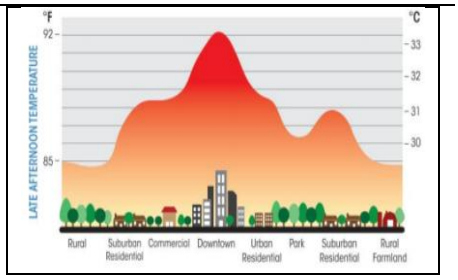
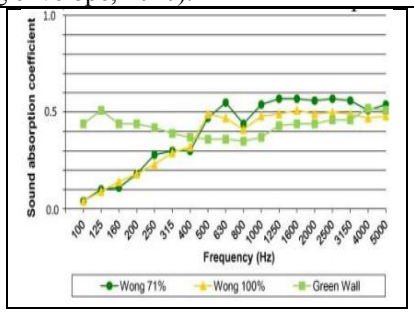
Fig. 5A: CIB Bank

Fig. 5B: Carrefour Training Center

Fig. 5C: Vodafone

Fig. 5: Randomly selected buildings showing the applications in Egypt (source- researcher)

Table 1: Green facades and living walls have several advantages.

Environmental benefits	**Increasing building energy efficiency** Green facades may block up to 50% of solar radiation, allowing buildings to become more energy efficient and reducing the urban heat island effect (Green building envelope, 2020), absorb stormwater, resulting in lower carbon emissions, fig.(6). It acts as a protective barrier, providing improved sun protection and reducing the impact of external loads and cooling requirements.  **Fig. 6:** Profile of the urban heat island (UHI) impact (Caplow *et al.,* 2008).
	Air Pollution Reduction Toxin concentrations are substantially lower in the region surrounding a living wall (Timur and Karaca, 2013), Air quality is improved by living walls (Loh, 2008), VGS can help cities breathe cleaner air, especially if their overall amount of vegetation is limited owing to a shortage of planting area (Hop and Hiemstra, 2012). Green facades have been shown to lower local air pollution by 10% to 20%. The amount of decrease is determined by the building height to street width ratio (Green building envelope, 2020).
	Soundproofing The use of living walls has been demonstrated to lower noise levels (Loh, 2008), Acoustical insulation that is significantly superior to bare wall insulation (up to 30 dB) (Haggag, 2010) , Outside noise and vibration are reduced (up to 40 dB) (Timur and Karaca, 2013), The sound insulation offered by the green wall is primarily determined by factors such as the depth of the growth soil, the type of plants, the materials used for the structural components of the living wall system, and the air layer between the plants and the wall ,fig.(7)  **Fig. 7:** The sound absorption coefficient values of the ordinary wall and the vertical garden were compared (Wong *et al.,* 2010).
Community and social benefits	In a city setting, aesthetic value is important. Improve people's physical and mental wellbeing. Enhance the public realm. Give a structure its own personality (Hui and Zhao, 2013). Reduce stress, improve patient recuperation, and increase disease resistance (Sheweka and Magdy, 2011). Positive influence on reducing crime (lower levels of fear, fewer incivilities, and less violent behavior) (Jialin, 2013) Positive impact on residents' well-being (Magliocco and Perini, 2015)
Economics benefits	As a result, the use of a vertical garden can lessen environmental effects on building facades, lowering energy usage (Fritz, 1990-1991). Increase the value of real estate, particularly if additional outdoor living area is created (Hop and Hiemstra, 2012).Increase real estate value by up to 20% (Green over Gray, 2018). Increase the value of residential and commercial properties by 7% to 15% (Jialin, 2013). The projected cost efficiency of green walls is clearly influenced by the size of the unit value (Veisten *et al.,* 2012). Economically viable with a 16-year payback time (Haggag, 2015)
in a sustainable context	Vertical garden technology's contribution to existing and new buildings enhances environmental, economic, and social aspects by addressing concerns such as sustainability, energy conservation, air quality, water efficiency, and acoustics, as well as promoting human health, happiness, and contentment (Abel, 2010).

3. Main types of green vertical garden

Green walls refer to any systems that allow a vertical surface (e.g., facades, walls, blind walls, partition walls, etc.) to be greened with a variety of plant species, including all methods for growing plants on, up, or within a building's wall (Manso and J. Castro-Gomes, 2015),fig. (8).

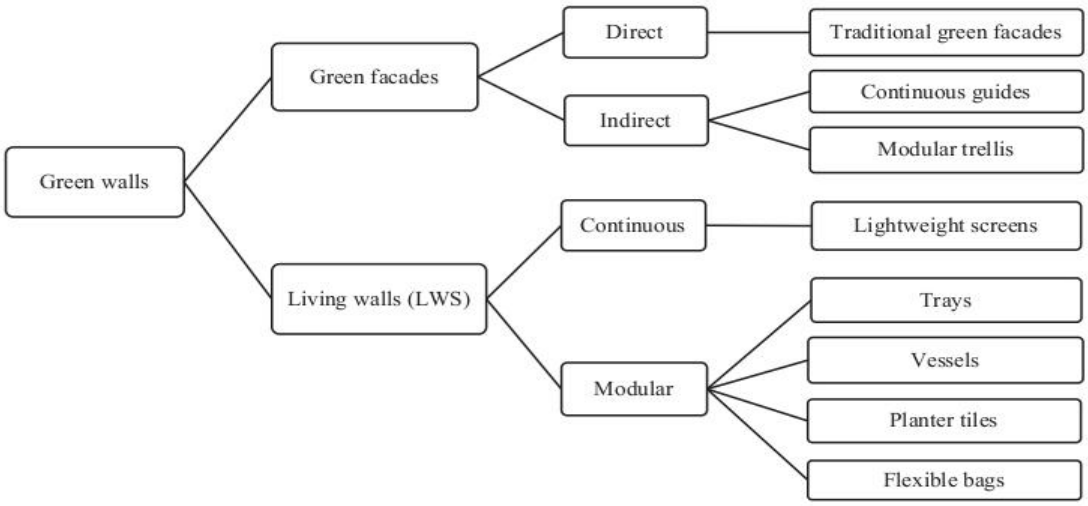
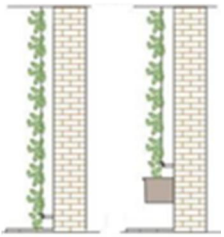
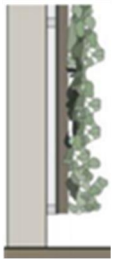


Fig. 8: Green walls are classified based on their construction features.

Green facades and living walls are the two primary types of green walls (Manso and Castro-Gomes, 2015), fig. (9). There is a clear contrast between green facades, where climbing plants often grow along the wall covering it, and the most modern conceptions of living walls, which incorporate materials and technology to sustain a broader range of plants and create a uniform growth along the surface. Each green wall system has its unique set of features, with benefits and drawbacks based on aesthetic potential, cost, and maintenance requirements, Table (2)

Table 2: Comparison of green wall systems advantages and disadvantages.

System	Category	Sub-category	Advantages	Disadvantages	figures
Green facades	Direct greening	Traditional green facades	-There are no materials involved (support, growing media, irrigation) -Low environmental impact -Low price	-Selective plant availability/climate adaptation -Spontaneous vegetative growth - Surface coverage is slow. -Scattered growth on the surface -Deterioration of the surface/plant separation -Maintenance issues	 **Fig. 9A:** Direct green facade
	Indirect greening	Continuous guides	-Advice on how to grow vegetables -Low water use	-Climate adaptation and plant choices are limited. -Coverage of the surface is slow. -Scattered growth on the surface -Some materials have a high environmental impact	 **Fig. 9B:** indirect green facade

		Modular trellis	-Support that is light in weight -Instructions on how to grow vegetables -rrigation/drainage that is controlled -Easy to put up and take apart for maintenance -Plant replacement	-Limited plant selection/climate adaptation -Some materials have a high environmental impact -High installation costs	 **Fig. 9C:** Cable and Wire -Rope Net Systems.
Living walls	Continuous systems	Felt pockets vertical gardens	-Flexible and lightweight -Increased diversity of plants/aesthetic possibilities -Uniform distribution of water and nutrients	-Difficult implementation -High water and nutrient consumption -Regular maintenance -Limited root development area -Expensive installation	 **Fig. 9D:**Continuous living wall system
	Modular systems	Trays	-Easy to dismantle for maintenance -More plant variety/aesthetic possibilities - Irrigation/drainage control	-Difficult to deploy -Heavier solutions -Surface shapes are limited to the size of trays. -Some materials have a high environmental impact. -Expensive installation	 **Fig. 9E:**Trays
		Planter tiles	-More plant variety/potential for aesthetics -Modules with an appealing design	-Difficult installation -Limited root development space -Surface shapes are limited to the size of tiles -Expensive installation	 **Fig. 9F:**Planter tiles
		Flexible bags	-Can be used on slanted surfaces -More plant variety/potential for aesthetics	-Difficult to implement -Heavier solutions due to increasing media/limited to maximum weight of building -Expensive installation	 **Fig. 9G:**Flexible bags

Source: (Manso and Castro-Gomes, 2015)

The most appropriate system is determined by the building's features (e.g., orientation, accessibility, and height) as well as the climatic conditions (e.g., sun, shade and wind exposure, rainfall). This is why it's critical to comprehend their compositional distinctions as well as their key features, Table (3)

Table 3: The following is a list of the components that make up a green wall system. Source: Momtaz, 2018)

System requirements	Green facades	Continuous LWS	Modular LWS
Support	Stainless steel, galvanized steel, wood, plastic, glass fiber cables, ropes, nets, and trellis	Geotextile felts	Galvanized steel, stainless steel, lightweight and/or flexible polymers, and ceramics are some of the materials used.
Growing media	Substrate-filled containers or ground soil	-	Organic and/or inorganic substances make up the substrate combination.
Vegetation	Plants that climb (evergreen or deciduous)	Perennials, shrubs, and grasses	Succulent plants, shrubs, grasses, perennials
Drainage	Vessels with inferior holes	-	Lateral and inferior holes
Irrigation	Drip line inside vessels	Drip line on the top of the wall	Drip line on top of each module

4. Implementing green walls in schools

The kid learns about his external world through his senses (the perceptual level), followed by (the associative level), which refers to the youngster's capacity to recall and retrieve mental pictures. Then there's (the degree of connections), which entails problem-solving abilities and the ability to think critically. The value of employing the senses in teaching has been agreed upon by thinkers, fig. (10).

Modern education attempts to use the senses to convey knowledge to children and to guide their behavior by: Sense of sight: recognizing and distinguishing between various forms, colors, sizes, and manufacturing materials, as well as perceiving their characteristics. Tactile: Differentiate between rough and smooth items, as well as round and oblong shapes. Sense of smell: the ability to discriminate between various scents. Hearing: the ability to discriminate between distinct sounds, each of which has its own significance for the kid.

Fig. 10: A living wall may be used as an interactive space in primary schools to teach students about nature and food chains (Leaving a legacy of biophilic and biodiverse spaces)

5. The educational benefits of VGS

Vertical Green Surfaces (VGSs) have been established at schools all around the world, and there are several instances. "Green roofs and walls are the ideal tools for teaching about the environment" (Leaving a legacy of biophilic and biodiverse spaces). The next generation has to know about today's environmental issues and how we're dealing with them (Sheweka and Magdy, 2011). They go on to say that VGS can give limitless teaching possibilities and can be utilized as instruments for ecological monitoring, plant and vegetable growth, and determining the building's protection. Additionally, the visual effect of VGSs has the potential to make a lasting impression on viewers and increase awareness about the need of environmental preservation (Radi´c *et al.,* 2011).

Green roofs and VGS may contribute to the sustainability of a school's design, as well as be utilized as 3D teaching texts on sustainability, according to Brkovi´c in her work on actions that schools can take toward environmental sustainability (Brkovi´c, and Parnell, 2017).

A study by McCullough *et al.* (2018) explained how an indoor living wall was incorporated into a classroom learning setting and provided a curriculum to go along with it. Living walls "have the ability to encourage critical thinking through a mix of project-based learning techniques and environmental education," according to the same research. Students can interact with indoor nature through project-based curricular models, which have the ability to stimulate real-world thinking in the disciplines of science, technology, engineering, art, and mathematics. A study by McCullough *et al.* (2018) the authors have created a curriculum that includes the use of an indoor living wall system in a classroom setting, as well as project-based learning modules that interact with the wall.

6. International case studies

1- The Escola Drassanes (a vertical urban vegetable garden)

The aim: It connects the relevance of human-nature relationships with the quality of life and environmental quality in cities, fig. (11).

Explanation: It was created by hanging vegetable baskets on the school playground's walls, resulting in a mix of different levels: a vegetable garden in the lower part that allows cultivation and harvesting; aromatic and culinary plants in the middle; and an upper area with plants that attract animal species, fostering biodiversity.

Importance: to make better use of vertical urban areas, particularly along the sides of busy highways, to build more green walls that assist to decrease chemical pollution, offset CO2 emissions, promote biodiversity, and enhance aesthetics.

2- Busby Primary school, Scotland. Vertical Garden

The aim: Students benefit from nature-based education in terms of learning, growth, and behavior, and this initiative incorporates healthy eating themes, fig. (12).

Explanation: Birds, amphibians, reptiles, and invertebrates have benefited from the walls, which also help to climate adaption through urban cooling.

Importance: It will also assist to enhance the quality of life in the local region by raising awareness among students about the need of environmental protection from a young age.

3. Lourdes School,Madrid, Spain,Vertical garden with Plastic bottles. Plastic boxes.

The aim: to teach environmental principles in schools at a reasonable cost, fig. (13).

Explanation: They made it out of packing items like plastic cartons and bottles.

Importance: The students were able to begin thinking about manufacturing processes and become aware of the requirements (on a small scale) that were required as a result of this intervention. On the other side, kids will be aware of their own ability to create, cultivate, and maintain a garden

Fig. 11: The Escola Drassanes school [The Escola Drassanes school takes charge of a vertical urban vegetable garden https://www.barcelona.cat/en/noticia/my-new-post-768_20679

Fig.12: Busby Primary school, Scotland [Busby Primary pupils create edible vertical garden https://www.greenspacescotland.org.uk/news/busby-primary-pupils-create-edible-vertical-garden]

Fig.13: Lourdes School, Madrid, Spain[https://basurama.org/en/projects/vertical-garden-in-a-school/]

7. Lessons learned from International case studies

- The installation's sustainability is contingent on a volunteer supervisor who will guarantee that students maintain the green wall on a regular basis.
- Schools may experiment with growing edible plant types, expanding the green wall concept to include the possibility of "vertical" agriculture.
- The ability to construct barriers out of basic things such as plastic bottles, ropes, and other items.
- Not necessary covering the entire vertical walls, but selecting a design that is appropriate for the children, their height, and the plants' purpose.
- Plants with a variety of forms, colors, and scents are used.

8. Suggested proposal for implementing green envelope in Official schools in Egypt

Throughout this research, a vertical greenscaping design for one of Egypt's public schools is developed to provide a comprehensive perspective and case study on vertical greening systems. The study's major objective is to employ a green wall system in a public school to create an interactive learning environment where kids may learn how to live a sustainable life in their community utilizing current teaching techniques.

The danger of damage to a building's façade is low because Green Wall systems only require a few simple repairs. Plants will not damage the façade if they are chosen correctly, and systems may be utilized on existing structures with confidence.

Using the school's site (survey-site visit-questionnaire), fig.(14) The following issues were identified: the school is located on a busy main street, which exposes the classrooms to a high level of noise pollution, a lack of plant components in open areas, monotonous and unappealing school facades, and an excessive quantity of water utilized in the restrooms.

Fig.14A: layout .(Google earth)

Fig.14B: Back entrance (researches)

Fig.14 C: school playground (researches)

Fig. 13: Abd El-Aziz Al Saud Experimental Language School

Green Walls will be installed first on the east-facing walls of the Abd El-Aziz Al Saud Experimental Language School. The following is School proposal's vertical greening ideas :

- Educating youngsters about the environment and instilling a sense of environmental awareness in them.
- Empowerment of the local population.
- Design solutions that are unique.
- Environmentally friendly items are utilized.
- Collaboration between several professions.
- Trying to build a long-term, sustainable future.

The idea was to create a one-of-a-kind atmosphere that would foster sociability, participation, and hands-on learning. As a result, space will become a tool for new knowledge, highlighting the need of long-term progress.

9. Design Considerations

There are many factors to bear in mind when building the vertical garden and green wall, Table (4).

Table 4: design Considerations for Vertical Garden (source- researcher)

Architectural Considerations	-Vertical garden types -Location of façade - Green wall is compatible with building design - Aesthetic and urban design - Native plant material which adaptable to local weather conditions - Determining a plant's hardiness - Facade surface area and Plant material selection
Construction Considerations	- Green wall is compatible with the type of construction - Protection to building structure - Availability of drainage system and water proofing - Irrigation availability and Utilizing grey water technology
Economic Considerations	- Irrigation installation costs - Installation of the system components, plants and plant materials - Maintenance expenses and Materials cost
Environmental Considerations	- Reduced energy use & temp. control - Noise reduction via insulation - Improved indoor air quality - Adapting to climate change - Integrate - landscape & biodiversity - Reduce urban heat Island - Improved public health and wellbeing - planting bed/ soil preparation

10. Design suggestions

While vertical gardens have numerous advantages, they also have several disadvantages, including additional weights on structures, costs, damages, unnecessary care, allergies, and insects.

Green wall systems need a lot of care. Monthly fertilizer and daily or weekly watering are required depending on the environment and the type of plant.

Itching, sneezing, runny nose, and other symptoms are common with plant pollen allergies. Because certain people are sensitive to specific types of plants, designers must consider the negative impacts of plants throughout the plant selection process (Alperen *et al.,* 2018).

11. Reusing Grey Water in the Garden:

Where there is a high demand for outdoor water, fig (15) demonstrates how grey water may be re-used in cost-effective ways to replace fresh water in toilets or irrigate fields.

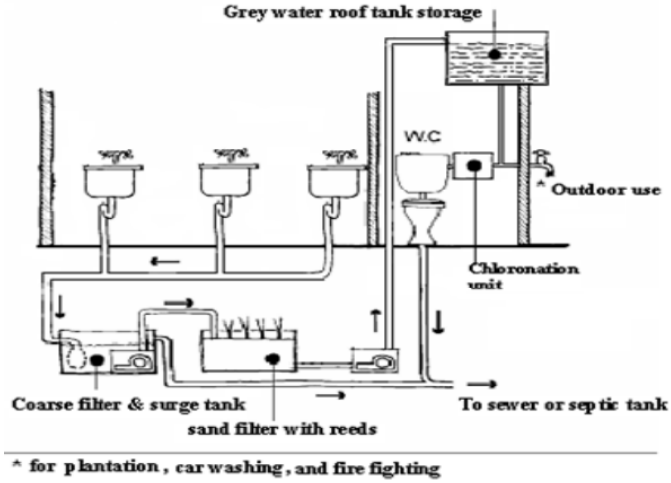


Fig. 15: grey water may be reused in cost-effective ways to replace fresh water in toilets or to irrigate fields (Mohamed and Ali, 2012)

12. Types of plants that are not recommended to be grown in school facades

Plants come in a variety of shapes and colors, and they are thought to be an important way to broaden a child's experience by allowing him to pick leaves, smell them, or touch seeds, and he may even eat some of them, so it was extremely dangerous to plant some plants that had certain characteristics (The Best and Worst Plants for the Classroom, 2017), such as**:**

1- The child's excretion of a milky material that might be harmful or cause illnesses.
2- Thorny plants that inflict injury when grasped or walked on.
3- Plants with delicate fruits that dirty the clothing of small children.
4- Plants those are poisonous.
5- Plants that are narcotic and can cause to addiction.
6- Plants that make it difficult to move.
7-Plants that attract insects and bees.
8- Plants with noxious smells
9- Stay away from flowering plants with a lot of pollen.
10- Stay away from plants that irritate the skin.

Organic fertilizers should not be used since they contain many fungus and parasites that might damage children if they fall on them.

Proposed Image Design, fig. (16)

Fig. 16 A: Exiting Façade of Abdel Aziz Al Soud Experimental school [researches].

Fig. 16 B: proposed green vertical green wall for the building blocks [researches]..

12. Evaluation

Aspects of achieving sustainability in the proposed solution, Table (5).

Table 5: Social, Ecological and Economic Impacts of the green envelope (source- researcher)

Psychological Impact	-It is represented in the community participation in the internal spaces. -Meeting the social needs of students at the level of the site, where there is a clear decline in the availability of external places and there is no familiarity between the building and the student in schools due to the lack of green space
Aesthetic Impact	The visual appearance achieves sustainability, but it needs to be developed to motivate children to love school and participate in the development of the school environment and the educational process
Health Impact	The presence of green elements on buildings achieves sustainability, which aattains the integration of green elements with the building
Job Opportunities	Opening up areas for diversity of job opportunities

Conclusion	From the above, the design became integrated for the facility by linking all aspects related to the building and making the design useful in several aspects.	
	Reduction of Urban Heat Island Effect	The green walls achieved thermal insulation, which helped to cool the high temperature
	Improvement of Air quality	The green wall improves air quality
	Improvement of Energy Efficiency	Windows and glass have a significant impact on the energy consumed and building temperatures, despite the need for natural daylight that enters through the windows, but the thermal impact must be reduced. Thus, the introduction of the green wall plays a major role in energy conservation
	Noise Reduction	-The green wall absorbs light, which helps to improve the learning environment -Noise control more effectively by absorbing sounds.
	Urban Agriculture	Increasing the culture of agriculture and integrating it with buildings
Conclusion	The green wall is one of the most important strategies for indirect cooling and helped isolate heat and noise in the school building.	
	Storm Water management	-Finding a system for collecting rainwater and using it in a thoughtful manner -Effective water management by reducing losses from water leakage -The use of a number of technologies such as automatic control and control by sensors or devices that deliver a specific amount of water and then close it helps to rationalize consumption. -Usage of gray water directly for irrigation.
	Bio-filtration of Indoor Quality	-Poor air quality has a significant impact on the health of users. -The green wall improves temperatures, which improves indoor air quality
	Other Economic impacts (increase the value of the building)	Involving students in curricular and extracurricular activities and events has increased the demand for the school building
Conclusion	Materials that are less weight can be used for agriculture have been developed to significantly reduce the temperature of the building and are able to trap water and absorb a large part of the rainwater to reduce the effects of pollution	

Conclusion

-Sustainability is defined as reducing the burden on non-renewable resources in order to pass them on to future generations. In order to assure the continuance of change-transformation-development, a sustainable city is one in which social-economic-ecological methods become compatible with the city. Green school envelope is one of the practical examples of sustainable city ideas.

-Implementing green walls in schools help to improve the quality of life in cities by insulating noise and lowering the urban heat island effect. They improve children's aesthetic perception by having a favorable psychological influence on them and increase the demand for the school building.

-Vertical gardens can help with energy efficiency and water efficiency if greywater is used for watering. A sustainable city concept relies on economic contribution as a cornerstone. As a result, the economic benefit of a vertical garden technique becomes more important.

-To be healthy, a sophisticated living wall system will always need a certain level of expert understanding and care. In our own arid desert region, the adoption of climate-appropriate flora, highly efficient watering systems, and a provision for the proper air moisture content should all be addressed, and are practical considerations for living walls.

Recommendations

The study recommends that the green wall be introduced as a solution to preserve the ecosystem and achieve long-term sustainability, that a culture of vertical farming be incorporated into the design, and that future studies on the economic feasibility study for operation and maintenance be conducted.

Further future research

Encourage architects to use nature into their designs in order to generate new sorts of ideas and conceptions.

Acronyms

GFS	Green facades systems
LWS	Living Wall System
UHI	Urban Heat Island
VGS	Vertical Green Surface

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