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INVESTIGATING THE IMPACT OF VERTICAL GREENERY SYSTEMS AS AN APPROACH TO ACHIEVE SDG 13

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ABSTRACT

Extreme weather events are occurring with greater intensity due to climate change. A common road map represented in 17 sustainable development goals, or SDGs which was accepted by the United Nations to overcome climate change through SDG 13 which is climate action in an effort to tackle climate change and its impacts instantly. Vertical greenery systems, or VGSs, can benefit both cities and buildings by lowering energy use, pollution discharged into receiving waters, and air pollution. The Authors adopted a data collection strategy to review the VGS, and their types while focusing on SDG 13 & its main targets. The Authors then adopted case study analysis through analyzing five case studies to review the types & impacts of VGS implemented in the projects, to conclude how VGS can be used as an approach to achieve SDG 13 through studying the main aspects of VGS. The Authors then adopted a data analysis strategy through conducting an online questionnaire aimed at investigating the most important aspect of VGS & its impact on targets of SDG 13, evaluating the impact of VGS on achieving each target of SDG 13, ranking the aspects of VGS according to their impact on achieving SDG 13, and lastly, arranging the targets according to its importance in achieving SDG 13 through the usage of VGS. The Authors concluded a prospected framework concerning the usage of VGS in order to achieve SDG 13.

KEYWORDS: Sustainable Development Goals, Vertical greenery systems, Green walls.

التحقيق من تأثير أنظمة المساحات الخضراء الرأسية كنهج لتحقيق الهدف 13 من أهداف التنمية المستدامة

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الملخص

تحدث الظواهر الجوية المتطرفة بكثافة أكبر بسبب تغير المناخ. خريطة طريق مشتركة تتمثل في 17 هدفًا من أهداف التنمية المستدامة، أو SDGs التي قبلتها الأمم المتحدة للتغلب على تغير المناخ من خلال الهدف 13 من أهداف التنمية المستدامة وهو العمل المناخي في محاولة لمعالجة تغير المناخ وتأثيراته على الفور. يمكن لأنظمة المساحات الخضراء العمودية، أو VGSs، أن تفيد كلاً من المدن والمباني من خلال خفض استخدام الطاقة، والتلوث الذي يتم تصريفه في المياه المتلقية، وتلوث الهواء. اعتمد المؤلفون استراتيجية جمع البيانات لمراجعة VGS وأنواعها، مع التركيز على الهدف 13 من أهداف التنمية المستدامة وغاياته الرئيسية. ثم اعتمد المؤلفون تحليل دراسة الحالة من خلال تحليل خمس دراسات حالة لمراجعة أنواع وآثار VGS المطبقة في المشاريع، لاستنتاج كيف يمكن استخدام VGS كنهج لتحقيق الهدف 13 من أهداف التنمية المستدامة من خلال دراسة الجوانب الرئيسية لـ VGS. اعتمد المؤلفون بعد ذلك استراتيجية تحليل البيانات من خلال إجراء استبيان عبر الإنترنت يهدف إلى دراسة الجانب الأكثر أهمية من VGS وتأثيره على غايات الهدف 13 من أهداف التنمية المستدامة، وقاموا

بتقييم تأثير VGS على تحقيق كل غاية من غايات الهدف 13، وترتيب جوانب VGS وفقًا لـ تأثيرها على تحقيق الهدف 13، وأخيرًا، ترتيب الغايات وفقًا لأهميتها من اجل تحقيق الهدف 13 من خلال استخدام VGS. توصل المؤلفون إلى إطار عمل محتمل فيما يتعلق باستخدام VGS لتحقيق الهدف 13 من أهداف التنمية المستدامة.

الكلمات المفتاحية: أهداف التنمية المستدامة، أنظمة المساحات الخضراء العمودية، الجدران الخضراء.

1. INTRODUCTION

Urban development raises environmental and social challenges, threatening human well-being and city sustainability. Massive urban expansion is changing the land surface by concentrating materials that produce impermeable surfaces and effectively absorb heat, which has an impact on the local temperature and hydrology of the metropolitan area [1].

Extreme weather events like heat waves, droughts, floods, and tropical cyclones are occurring more frequently and with greater intensity due to climate change. It additionally renders water management issues worse, decreasing agricultural productivity and food security, raising health risks, destroying vital infrastructure, and disrupting the delivery of essential services like energy, water and sanitation, transportation, and education [2].

Expansion of modern cities reduces green areas, especially within city centers where the urban heat island has become a significant problem [3]. Innovative ideas for urban greening are being created to address these issues in a sustainable and environmentally friendly manner [1].

In an attempt to increase greenery in cityscapes and to provide passive cooling, vertical greenery systems (VGS), an old practice of covering building façades with plants, are receiving attention from architects, engineers, building planners, and researchers [3].

New construction techniques and strategies are therefore required to increase the social and economic value of urban infrastructures while reducing their negative environmental effects. Initiatives aimed at urban greening can help achieve ecological objectives while minimizing the negative effects of urban expansion [1].

Green spaces have become the most threatened by urban growth, and the decline in these areas is a main cause of environmental and social problems with implications for human health and well-being. Vertical greenery systems have been proposed as a solution to restore the connection between the city and nature, particularly in compact and dense cities, where horizontal space is limited [4].

Governments have implemented VGS in recent decades to attain efficient, liveable, and sustainable urban planning. The demand for Vertical Green Structures (VGS) arose from the need to reduce losses of vegetation and land use. These structures can improve biodiversity, reduce noise, and offer many other ecological services. Because VGS are simple to install on existing buildings and provide a greater visual engagement between people and plants, they help to the improvement of social well-being [5].

VGSs use ecosystem services to provide a variety of advantages. The ability of the plants to deposit and absorb particulate matter as well as to absorb gaseous pollutants is how they enhance the quality of the air. Second, they improve the thermal behavior of buildings by reducing the heat island effect and lowering temperature. By causing variations in the surrounding environmental factors, such as the temperature and humidity of the air layers and the airflow close to the building skin, they provide a microclimate. In addition, they reduce noise levels, improve biodiversity for both plants and animals and provide food. Owing to their aesthetic value, they also promote well-being and the restoration of both physical and mental health [5].

From this point, the main objectives of the research can be summarized in the following:

- Studying the vertical greenery systems (VGS), terminologies, definitions, and their types, in addition to studying the Sustainable development goals with a focus on SDG 13 which is climate action, in addition to studying the main targets of SDG 13.

- Analyzing five case studies to review the types & impacts of VGS implemented in the projects, to conclude how VGS can be used as an approach to achieve SDG 13 through studying the main aspects of VGS (improve air quality, improve thermal comfort & Energy Efficiency, Noise Reduction, Heat mitigation, enhance water absorption, Increase biodiversity protection, improve carbon sequestration, increase aesthetic values, green wall policies).

- Conducting an online questionnaire aimed at investigating the most important aspect of VGS & its impact on targets of SDG 13, evaluating the impact of VGS on achieving each target of SDG 13, ranking the aspects of VGS according to their impact on achieving SDG 13, and lastly, arranging the targets of SDG 13 according to its importance in achieving SDG 13 through the usage of VGS.

- Conducting a prospected framework concerning the usage of VGS to achieve SDG 13.

2. METHODOLOGY

The methodology of this research is divided into three main phases as shown in **Fig. 1**.

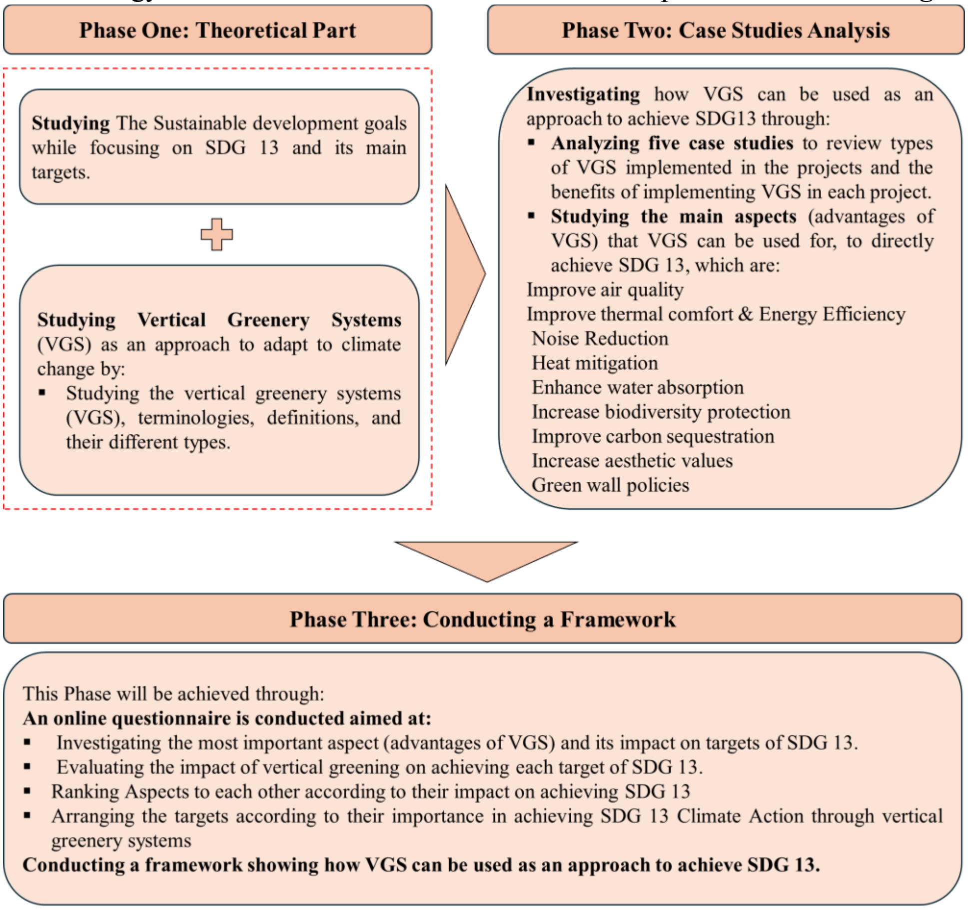

Fig. 1. The Methodology of the study

3. THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

This part is composed of reviewing two main parts the sustainable development goals while focusing on SDG 13 & its main targets and the main definitions and types of vertical greenery systems (VGS).

A common roadmap for peace and prosperity for people and the planet, both now and in the future, is provided by the 2030 Agenda for Sustainable Development, which was accepted by all United Nations Member States in 2015. The 17 Sustainable Development Goals (SDGs), which represent an urgent call to action for all nations—developed and developing—in a global partnership, are at the center of it [6]. **Fig. 2.** Shows the 17 Sustainable Development Goals according to the United Nations.

They understand that overcoming poverty and other forms of deprivation requires concerted efforts to combat climate change, protect our seas and forests, enhance health and education, and lower inequality in addition to promoting economic growth. The UN Secretary-General releases an annual SDG Progress report each year. The report is created in collaboration with the UN System and is based on data generated by national statistical systems, information gathered at the regional level, and the global indicator framework

[6]. Building on the essential principle of "leaving no one behind," the goals prioritize a comprehensive strategy for attaining sustainable development for all [7].

N.O of Sustainable Development Goal	Sustainable Development Goal Identification
SDG 1	No Poverty
SDG 2	Zero Hunger
SDG 3	Good Health and well Being
SDG 4	Quality Education
SDG 5	Gender Equality
SDG 6	Clean Water and Sanitation
SDG 7	Affordable and Clean Energy
SDG 8	Decent Work and Economic Growth
SDG 9	Industry, Innovation and Infrastructure
SDG 10	Reduced Inequalities
SDG 11	Sustainable Cities and Communities
SDG 12	Responsible Consumption and Production
SDG 13	Climate Action
SDG 14	Life Below Water
SDG 15	Life on Land
SDG 16	Peace, Justice, and Strong Institutions
SDG 17	Partnerships for the Goals

Fig. 2. The 17 Sustainable Development Goals according to the United Nations (SDGs). The Authors Adapted from [8].

Effective and efficient methods of planting trees can have a favorable impact on many of the 17 goals; planting trees can significantly increase an area's economic activity and food output. Enhancing the natural environment supports the production of food (nuts, seeds, etc.), stabilizes the soil to allow animals to graze, helps preserve water and the water table, creates jobs and income opportunities, supports climate action, and supports ecosystem restoration. It is an essential factor in managing forests sustainably, preventing desertification, preventing, and reversing land degradation, and preventing the loss of biodiversity. The majority of tree-planting organizations only assess themselves and are assessed by others based on the quantity and survival rates of the trees they have planted. It is imperative to consider the wider picture and acknowledge that certain plants could be better off being sacrificed to meet the demands of the local animal population [7].

3.1. The 13th Sustainable Development Goal (SDG13): Climate Action

The warmest period on record was the previous eight years, from 2015 to 2022 [9]. earth's atmosphere, seas, and ecosystems are experiencing extensive and unprecedented changes, according to the Intergovernmental Panel on Climate Change's (IPCC) most recent climate assessment report [10]. There is no arguing that climate change poses a serious threat to our entire civilization. Inaction will have disastrous consequences that are already apparent. Countries are capable of bringing about the reforms required to safeguard the environment via innovation, education, and adherence to our climate obligations. These modifications also present excellent chances to update our infrastructure, which will generate new employment and advance global prosperity [11]. To ensure that the Global Goals are met, everyone can contribute and utilize the following five targets to motivate action against climate change [11].

A. Target 1: Strengthen Resilience and Adaptive Capacity to Climate Related Disasters

Enhance national preparedness and ability to adjust to risks associated with climate change and natural disasters [11].

Climate change is happening rapidly than ever before, even with international accords. The WMO Atlas of Mortality and Economic Losses from Weather, Climate, and Water Extremes (1970–2019) data shows that over 11,000 documented disasters involving climate-related hazards occurred worldwide, accounting for over 2 million fatalities and US$ 3.64 trillion in losses. The report also showed that the majority of deaths were brought on by droughts, which were followed in order of severity by storms, floods, and extremely high temperatures [12].

The SDG 13 Extended Report shows that from 2015 to 2021, 98 reporting nations with local governments have disaster risk reduction strategies, up from 51 in 2015. The average percentage of local governments using these tactics increased among these nations from 51% in 2015 to 66% in 2021 [12].

B. Target 2: Integrate Climate Change Measures into Policies and Planning

Integrating climate change mitigation solutions into national planning, strategies, and policies is the goal of this target. The United Nations Environment Program (UNEP) oversees the creation of National Adaptation Plans (NAPs) in every nation on the planet. The two main goals of NAPs are to: firstly, create adaptive capacity and resilience to significantly reduce vulnerability related to climate change; and secondly integrate the adaptation into new and existing national, sectoral, and sub-national policies and programs, particularly the developmental strategies plan and budgets. NAPs operate in accordance with a continuous, transparent, participatory, and country-driven process [12].

C. Target 3: Build Knowledge and Capacity to Meet Climate Change

Enhance human and institutional capacity for climate change adaptation, mitigation, impact reduction, and early warning systems [11].

The behavior of individuals will shift as a result of education and public awareness of climate change, which will encourage them to make wise decisions. According to data from 100 countries collected by UNESCO in 2021, just 53% of national school curriculum address climate change, and most of them place a very low priority on the topic. Furthermore, according to the poll, only one-third of teachers could articulate the severity of climate change in their community or region, and less than 40% of instructors felt secure teaching about the negative effects of climate change [12].

D. Target 4: Implement The UN Framework Convention on Climate Change

Execute the developed-country parties' commitment to mobilize $100 billion collectively annually by 2020 from all sources in order to address the needs of developing nations in the context of significant mitigation actions and transparency on implementation; as soon as possible, fully implement the Green Climate Fund through its capitalization [11].

Although annual commitments of US$ 100 billion are regarded as the cornerstone of international climate funding, data indicates that this amount falls short of what is required to prevent the global catastrophe. Data from the Organization for Economic Co-operation and Development (OECD 2022) show that in 2020, rich nations collectively contributed and raised US$ 83.3 billion for climate action in developing nations, a 4% increase from 2019. This explains why developed countries' total financial contribution was US$ 16.7 billion short. According to the IPCC, a global investment upscaling to US$1.6–3.8 trillion annually would be necessary to keep warming to 1.5 C and make the transition to a low-carbon society [12].

E. Target 5: Promote Mechanisms to Raise Capacity for Planning and Management

Encourage strategies to increase the ability of least developed nations and small island developing states to effectively plan for and manage the effects of climate change, with a particular emphasis on women, youth, and marginalized communities [11].

Although the issue of climate change affects the entire world, Small Island Developing States (SIDS) and Least Developed Countries (LDCs) are especially vulnerable as a result of their geographic locations, constrained fiscal resources, and reliance on primary natural resource exports rather than greater integration into the regional economy. Approximately 12% of the world's population lives in the four countries that are classified as least developed countries (LDCs): thirty in Africa, four in the Arab States, eleven in Asia and the Pacific, and one in the Caribbean. SIDS, on the other hand, are a low-lying collection of island nations with a combined population of about 65 million [12].

Opportunities and challenges for Small Island Developing States explain that due to the fact that half of climate finance was non-concessional in 2017–2018, international development and climate financing have shown to be dispersed and inefficient.

Just 3% of public funding came from bilateral climate finance, while about 50% came from loans or non-grant channels. The research also shows that SIDS received less climate funding in 2019—from US$2.1 billion to US$1.5 billion—due to rising climate-related concerns. Additionally, the US$ 1.5 billion raised for SIDS in 2019 falls short of their needs given that their NDCs are estimated to be valued $92 billion [12].

4. VERTICAL GREENERY SYSTEMS

Urbanization and population growth have decreased the amount of green space in cities and, along with it, some of their livability. Urban heat islands (UHIs), or the increased heat created by cities, are a further consequence of urbanization. In situations where installing alternative heating or cooling system choices would be expensive and time-consuming, vertical greenery systems (VGS) have been suggested as a retrofit option for passive cooling in buildings [3].

Plants grown using structures and modular systems on a vertical profile are referred to as vertical greenery systems or VGSs. Divergent views have been expressed over the definition of the phrase "vertical greenery". Integrating leaf coverings into exterior walls; this technique is referred to as vertical greening or green façades [13]. Another definition is that vertical greenery is an alternative to roof greenery in a metropolis made up of tower blocks with a high wall-to-roof ratio and hence a big potential surface area for greening [14]. Others defined VGS as a comprehensive term for any way that plants can be grown [15, 16].

Vertical green spaces (VGSs) involve a wide range of designs and ideas, including living walls, bio-shades, vertical gardens, vertical greens, green façades, and vertical gardens [3, 4]. Furthermore, these names can be classified as living walls or green façades. Their construction system serves as the basis for the classifications [3, 4], as shown in Fig. 3.

While a living wall refers to plants grown in planter boxes that can be extended into modular systems attached to walls, a green façade often refers to climbing or cascading plants growing on or adjacent to a building surface, anchored at the bottom of the building [4], as shown in **Fig. 3**.

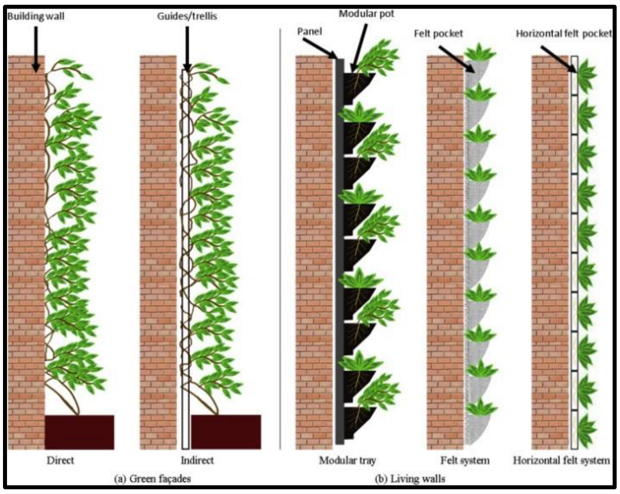

Fig. 3. Examples of various VGS types [17].

Greenery growing on or next to a building's surface is referred to as a "green façade." It can be planted on continuous guides or trellises as an indirect green façade, or as a direct green façade, also known as a conventional green façade. Both alternatives have a life expectancy of over 50 years and can be planted either directly in the ground or in planter boxes. It was demonstrated that in their first four years, climbing plants on green façades might reach heights of up to 10 meters. In comparison to living walls, a green façade is easier to construct, design, and maintain [3].

In contrast, living walls are made of plants grown in planter boxes that can be evolved into modular systems that are affixed to walls and do not require ground-level rooting space or automated watering. Popular modular panel systems include felt systems that are horizontal or vertical, trays, and more. Since the field is always evolving, this system gives the designer more alternatives. Planting in basal media or hydroponically is made possible by living walls. While felt pockets have a lower lifespan of 10 years compared to those with modular high-density polyethylene (HDPE) pots, the installation process for felt pockets is more complex than that of green façades and is appropriate for both new construction and retrofitting projects. Living walls can be found within buildings; they are sometimes known as interior living walls, and they can be specially integrated with the mechanical system of the building [3].

Two primary considerations in the urban setting account for the growing interest in VGS: (I) the scarcity of horizontal space to establish conventional green spaces, and (II) the elevated market value of the available area, which further limits the establishment of horizontal green spaces. VGSs can be used on the vast amount of wall space that is accessible in cities to enhance vegetation cover without taking up more room. Consequently, compared to other indoor plants like potted plants, indoor VGSs take up less space. Consequently, VGSs have been created as a green construction option to boost the amount of vegetation in populated regions [4].

Green walls can be found outside or inside of a building. Green walls can be found indoors and outdoors, and they can be used to filter airborne particles, add oxygen and humidity, absorb carbon dioxide, and absorb contaminants on plant surfaces. A building's exterior green walls give it thermal mass, which lowers and balances inside temperatures. The air temperature decreases as a result of leaf surface evaporation. A green wall can therefore lower the need for, cost of, and emissions of greenhouse gases from heating and air conditioning, Increased biodiversity, aesthetic appeal, and sound insulation are further advantages of green walls, especially when native plant species are used. Indoor green walls can also be integrated into a building's air circulation system. One such system is the bio wall system, which uses fans to force air through the green wall, where the plants raise the air's oxygen content and filter pollutants before circulating it throughout the building [18].

5. IMPACT OF USING VERTICAL GREEN SYSTEMS (VGS) ON SDG 13

The Authors adopted case study analysis through analyzing five case studies to review the types & impacts of VGS implemented in the projects, to conclude how VGS can be used as an approach to achieve SDG 13 through studying the main aspects of VGS.

5.1. Case Study Analysis

In this part, five main case studies will be analyzed as the following:

A. Quai Branly Museum, Paris

Inspired by the writings and thoughts of Patrick Blanc, Jacques Chirac's "green wall" at the Musée du Quai Branly was a groundbreaking initiative that stood the test of time. In terms of both surface area and the quantity of plants it contains, it is still among the biggest in the world [19]. **Table 1.** Shows the basic information of the project.

Table 1. Basic information of Quai Branly Museum, Paris [Authors based on 20].

Basic Information of the project	
Architects	Ateliers Jean Nouvel
Location	France, Paris
Area	76500 m2

The green wall, which covers one of the building's façades along the Quai Branly, is a feature of the Jean Nouvel-designed architectural environment. It became a symbol of the Jacques Chirac Museum on the Quai Branly and a mark of being of Parisian descent. For many years to come, the future green wall will symbolize the inclusive principles of the Jacques Chirac Museum du Quai Branly while also bringing colour and vitality to the city [19].

Fig. 4. Quai Branly Museum, Paris [21].

Fig. 4. Shows the living wall implemented in the project while **Table 2.** Shows the analysis of the Vertical greenery system used in the project.

Table 2. The analysis of the Vertical greenery system used in Quai Branly Museum, Paris.

VGS Analysis of the Project		
Type of VGS	Living wall [22].	
Implementing VGS	- 376 different species from throughout the globe were used in the creation of the new wall. Many of them can adapt to the climate of Western Europe because they come from mountain ranges like the Moroccan Atlas Mountains, the Drakensberg in Southern Africa, the mountains of Chili and Argentina, etc. [19]. The green wall's surface area (1,022 m²) [19]. The 730 m² covered surface area [19]. The green wall's height of 22 meters [19]. The green wall's length (47 meters) [19]. There were fifteen thousand plants seeded [19]. The green wall comprises 376 different plant species [19]. The green wall was constructed in 2004 [19].	
Benefits of implementing VGS in the project	**Heat Mitigation**	The green wall has the cooling effect of reducing heat absorption [23].
	Improve Air Quality	The green wall also filters and purifies the air, increasing interior air quality and lowering the need for artificial ventilation [23].
	Improve Thermal comfort & Energy Efficiency	Numerous natural plant species that have adapted to the climate of the area make up the green wall. This contributes to the creation of a microclimate surrounding the building, lowering the temperature and improving the comfort of both employees and guests [23].
	Enhance Water Absorption	In addition to lowering heat absorption, the drought-tolerant succulents, vines, and native plants that make up the green wall also aid in absorbing irrigation water and rainwater, enhancing percolation and water absorption around the museum. This vegetation is essential for controlling surface water runoff and encouraging a more sustainable urban water cycle [24].

B. KÖ-BOGEN II OFFICE BLOCK IN DÜSSELDORF, GERMANY

The Kö-Bogen II office complex in Düsseldorf, Germany, has been covered in 30,000 plants by Ingenhoven Architects to create hedges that, if stretched end to end, would reach five miles [25], as shown in **Fig. 5**.

Table 3. Basic information of the project [Authors based on 26].

Basic Information of the project	
Architects	ingenhoven architects
Location	Germany
Area	41370 m2

Table 3. shows the basic information of the project, while **Table 4.** Shows the analysis of the Vertical greenery system used in KOBOGEN Office Block in Germany.

Fig. 5. KOBOGEN Office Block in Germany [25].

Table 4. The analysis of the Vertical greenery system used in KOBOGEN Office Block.

<table>
<tr><th colspan="3">VGS Analysis of the Project</th></tr>
<tr><td>Type of VGS</td><td colspan="2">Green Façade [25].</td></tr>
<tr><td>Implementing VGS</td><td colspan="2">- The studio's research indicates that the two facades of the trapeze-shaped building, which face the square and garden, are completely covered in hornbeam hedges, which offer an ecological benefit comparable to eighty fully-grown deciduous trees [25].
- The largest green façade in Europe while a retail and office building in the city center was being renovated. A staggering 41,400 m² plant wall is composed of 30,000 plants, primarily grass and hornbeam hedges. One hundred and eighty mature deciduous trees would be required to cover the eight kilometers of winter-green hornbeam hedges [27].
- Considering hornbeam hedges grow locally and are relatively easy to maintain, the studio determined this was an ideal method to include a substantial amount of greenery in the office construction [25].
- For incorporating vegetation into an architectural design that goes beyond traditional "balcony plants," a thorough phyto-technological concept that is founded on a detailed site investigation is necessary [25].
-The chosen plants retain their leaves over the winter. They only need two or three trims a year, can tolerate severe winds, and grow best while facing both north and west. They are also resistant to insect infestation. Furthermore, no heating is required during the winter [25].</td></tr>
<tr><td rowspan="4">Benefits of implementing VGS in the project</td><td>Heat Mitigation</td><td>The presence of greenery enhances the microclimate of the city by reducing heat from the summer sun and storing moisture [27].</td></tr>
<tr><td>Improve Carbon Sequestration</td><td>The sizable green facade of the KÖ-BOGEN II Office Complex in Germany has over 30,000 plants that bind carbon dioxide, making it a huge carbon sink [28].</td></tr>
<tr><td>Noise Reduction</td><td>The green envelope, involving the roof, wraps three out of five sides of the building and acts as a sound buffer, damping noise [29].
Plants absorb moisture, which adds to a better acoustic environment [30].</td></tr>
<tr><td>Increase Biodiversity protection</td><td>In terms of ecological benefit, the green facade equals about 80 mature deciduous trees since it encourages biodiversity [30].</td></tr>
</table>

C. Garden House, Los Angeles, California

The exterior of Garden House in Beverly Hills, which boasts one of the biggest living walls in the country, is intended to appear from a distance like a lush hill sustaining a small community. Garden House, created by architecture company MAD, is made up of eighteen private houses that appear to emerge from the living wall, over ground-floor business units. It was completed in August 2020 [31]. **Table 5.** Shows the basic information of Garden House.

Table 5. Basic information of Garden House [32].

<table>
<tr><th colspan="2">Basic Information of the project</th></tr>
<tr><td>Architects</td><td>MAD architects</td></tr>
<tr><td>Location</td><td>Los Angelo’s, California</td></tr>
<tr><td>Area</td><td>4460 m2</td></tr>
</table>

The goal of the project is to capture the greenery of Beverly Hills, complete with native plants that can withstand drought and vines that require minimal maintenance and irrigation. However, Garden House also derives its name from another garden in the complex, a green haven in the middle of the courtyard where residents socialize out of sight of passersby [31], as shown in **Fig. 6**.

Fig. 6. Garden House, California [33].

It's a half-urban, half-natural location. This can provide an intriguing counterpoint to Beverly Hills, a neighbourhood that is frequently well-kept and ordered but has a humorous, clever newcomer [33]. **Table 6.** Shows the analysis of the Vertical greenery system used in Garden House, California.

Table 6. The analysis of the Vertical greenery system used in Garden House, California.

VGS Analysis of the Project		
Type of VGS	Living Wall [31].	
Implementing VGS	- The 4,460-square-meter complex at 8600 Wilshire Boulevard, which consists of eighteen gabled houses situated atop a three-story podium mostly covered in landscaping, is the first completed project by MAD in the United States [33]. - According to the studio, the base's exterior is covered in drought-tolerant succulents, vines, and native plants, making it the "largest living wall" in the US [33]. -The bottom part of the complex, consisting of shops and houses, is covered by a green wall that serves as a podium for eighteen gabled volumes housing only residential units [33]. -These have white glass covering and wooden frames. The apartments are grouped in a circle around a central atrium that is surrounded by flora [33].	
Benefits of implementing VGS in the project	**Improve Thermal comfort & Energy Efficiency**	Thermal comfort is prioritized in the building's design through the utilization of natural ventilation and vegetation. By collecting heat and releasing moisture into the air, the green wall creates a natural cooling effect that can assist lower the surrounding building's temperature [33].
	Enhance Water absorption	Covering the lowest part of the complex, a massive green wall, the largest living wall in the US, envelops the structure. Native plants, drought-tolerant succulents, and vines make up the green wall. They improve water absorption and percolation by absorbing irrigation water and rainwater [34].
	Increase Biodiversity protection	Insects, birds, and other small animals can find a home on the green wall, which supports local ecosystems and biodiversity. In addition, native plant species that are climate-adapted and serve as a habitat for nearby wildlife are incorporated into the building's design to promote biodiversity protection [35].
	Improve Carbon Sequestration	The green wall is made up of vines, drought-tolerant succulents, and native plants. Through photosynthesis, this greenery can take up carbon dioxide from the atmosphere, which is then stored in the soil and plant cells [33].

D. Terminal 3, Shanghai Airport, Singapore

The Changi Airport in Singapore offers an abundance of natural attractions, including living walls, topiaries, butterfly gardens, a refuge for dragonflies, a cactus garden, and a sizable park. But Terminal 3's living wall, which features over 50 varieties of 100,000 plants, is quite remarkable. [31]. **Table 7.** Shows the basic information of Terminal 3, Shanghai Airport, Singapore.

Table 7. Basic information of Terminal 3, Shanghai Airport, Singapore [36].

Basic Information of the project	
Architects	Tierra Design Pte Ltd
Location	Singapore
Area	4144 m2

The living wall in Terminal 3 brings life to the busy transportation hub. Three football fields' worth of space is taken up by the vertical garden. An advanced irrigation system that precisely provides the right amount of water and fertilizer to each plant is what keeps the garden alive [31].

Fig. 7. Terminal 3, Shanghai Airport, Singapore [36].

Fig. 7. shows the living wall in the project, while **Table 8.** shows the analysis of the Vertical greenery system used in Terminal 3, Shanghai Airport, Singapore.

Table 8. The analysis of the Vertical greenery system used in Terminal 3, Singapore.

VGS Analysis of the Project		
Type of VGS	Living Wall [31].	
Implementing VGS	-At 4,144 square meters, the green facade of Singapore Changi Airport Terminal 3 is impressive and huge. It has 25 types of climbers and around 10,000 plants. The infrastructure system is fastened to the stainless-steel cables holding the plants, and each cable can be removed if individual plants need to be replaced [36]. - The most notable aspect of the new terminal building is this 300-meter-long vertical garden, which is divided only by four water features [36].	
Benefits of implementing VGS in the project	**Increase Aesthetic values**	- At 14 meters high and 300 meters long, the green artwork is arguably the most iconic indoor landscape feature. It was intended to emphasize and soften the massive dividing wall rather than to conceal and screen it [36]. - The wall indicates an international border and divides two primary purposes; the green tapestry gives it a hospitable, living, organic form. Terminal 3's interior design was recently awarded the 2009 Honor Award from ASLA [36].
	Improve Thermal Comfort & Energy Efficiency	With occasional misting, the Changi Airport green wall also aids in controlling the terminal's interior temperature [36].
	Heat Mitigation	A variety of foliage vines and bromeliads cover this green wall serving as a natural heat insulator [37].
	Increase Biodiversity protection	This green wall which consists of a variety of foliage vines and bromeliads is encouraging biodiversity [37].
	Improve Air Quality	Engineers defined the type of stainless cables for the green wall, watering strategy, humidity management system, and other aspects to optimize the mechanical system to enhance air quality [38].

E. The Standard, Australia

The Standard; shown in **Fig. 8.** is a multi-award-winning project that rises above Brisbane's streets and is home to the largest green wall in Queensland and the largest fire-rated green wall in Australia [39]. **Table 9.** Shows the basic information of The Standard, Australia.

Table 9. Basic information of The Standard, Australia [39].

Basic Information of the project	
Architects	architecture firm Woods Bagot
Location	Australia
Area	boasts a 2,044 m2 rooftop amenity space for its residents

The Standard was created by Hutchinson Builders for Aria, a powerful and progressive real estate development firm. A single glass tower with four-cylinder shapes is topped with a recognizable crown profile. Curving the floor plate minimizes the impression of mass from the pedestrian realm, and the ground level's use of natural materials, such as brick, pays homage to the diversified nature of the West End [39]. **Table 10.** shows the analysis of the Vertical greenery system used in The Standard, Australia.

Fig. 8. The Standard, Australia [39].

Table 10. The analysis of the Vertical greenery system used in the Standard, Australia.

VGS Analysis of the Project		
Type of VGS	Living Wall [39].	
Implementing VGS	- A 410 square meter FC_Fytofelt Green Wall system from Fytogreen was employed [39]. - The appealing green wall that envelopes the lower floors of the curved façade was designed by green wall designer and Fytogreen botanist Erik van Zuilekom. With over 9,300 plants and 68 distinct species on display, this remarkable vertical garden features a tropical rainforest at its base. There are barely two centimeters of felt substrate beneath the surface [39]. - The protecting crevices of the ornamental steel columns were filled with ferns, cymbidium orchids, and native Australian orchids. Furthermore, because it may root at the nodes and spread throughout the surface, White Rabbit's Foot Fern was planted with the intention of growing new roots right into the felt covers [39].	
Benefits of implementing VGS in the project	**Increase Aesthetic values**	-It creates an iconic and distinctive constructed form by combining live green walls, architectural screening, and high-performance double glazing [39]. -Honors comprise Australia's Property Council's Innovation and Excellence Award in 2023 [39].
	Green Walls Policies	The standard policies for green walls and roofs in Australia aim to improve human health and well-being, support biodiversity, and incorporate green infrastructure into planning, design, and management techniques by encouraging the installation of green walls and roofs throughout urban environments. By highlighting the advantages of green infrastructure such as enhanced biodiversity, reduced stormwater runoff, and cooling through evapotranspiration, these regulations aim to boost the use of green roofs and vertical greening [40].
	Heat Mitigation	Vegetation is used for heat mitigation measures to lessen the impact of urban heat islands (UHIs). In order to help cool the surrounding area, vegetation can produce latent heat flux, boost evapotranspiration, and give shade [41].

6. HOW VERTICAL GREEN SYSTEMS CAN ACHIEVE SDG 13

Vertical greenery systems, or VGSs, can have many important advantages for buildings and cities alike. They can help reduce air pollution, energy consumption, and the discharge of pollutants into receiving waters.

Using VGS to effectively improve air quality, increase thermal comfort in buildings and cities, reduce undesirable noise, and create aesthetically pleasing surroundings may have several positive effects on one's health and well-being. Indoor and outdoor VGSs are equally effective at purifying the air of pollutants, especially fine particles, and volatile organic compounds (VOCs) that pose a significant risk to human health. While the effectiveness of these greening strategies may be limited to the building and nearby street canyon regions, they can enhance the function of the remaining urban green infrastructure in eliminating air pollutants [4].

In addition to reducing urban heat and enhancing building thermal comfort, VGSs also help to mitigate extreme heat events, which have been linked to higher rates of sickness and mortality, especially in impoverished areas. In addition to potentially assisting in reducing the urban heat island effect and lowering street canyon temperatures, VGSs can significantly increase cooling up to 8 to 9 °C [4].

In the previous section, the Authors adopted case study analysis through analyzing five case studies to review the types & impacts of VGS implemented in the projects, in order to conclude how VGS can be used as an approach to achieve SDG 13 through studying the main advantages of VGS. A set of concluded aspects that VGS can be used for, to directly achieve SDG 13 which is climate action have been intensively explained in the following:

A. Improve Air Quality

The World Health Organization (WHO) states that air pollution is the kind of pollution that poses the most risk in metropolitan areas. This review's numerous research demonstrates how outdoor VGS can lower air pollution, particularly particulate matter (PM), which is a major air contaminant that poses a substantial risk to human health. For instance, compared to non-green areas, green infrastructure, such as green walls, reduced PM2.5 and PM10 on average by 25% and 37%, respectively [4].

Despite the fact that different species collected varying amounts of PMs, using VGS with smaller-leaved species and leaf needles may remove PMs more effectively. PM2.5 levels are higher in environments with higher plant diversification. Similar to this, plants placed in green walls with uneven topography greatly increase PM capture [4].

Entire urban green infrastructure, including outdoor VGS, may contribute to better indoor air quality. On the other hand, indoor vegetation can support and enhance the function of outside vegetation. Indoor vertical green spaces (VGS) are regarded as a practical phytoremediation method for eliminating air pollutants including PM and volatile organic compounds (VOCs) without taking up much room [4].

B. Improve Thermal Comfort/Energy Efficiency

Elevated external temperatures lead to elevated interior temperatures, which significantly impact human comfort, health, and overall well-being [4].

By enhancing a building's thermal balance and comfort, VGS can lower cooling-related energy consumption and expenses. There is a lot of data to support the claim that bare walls frequently have warmer air than green walls. For instance, a green wall could lower indoor temperatures by up to 9 ◦C in the summer and reduce thermal amplitude and variability of the wall temperature by up to 9 ◦C. Adding green walls and roofs to buildings could lower indoor temperatures by up to 8.3 ◦C during the summer. According to research conducted in Spain, also greening a portion of a building as part of urban regeneration projects can reduce the energy used for cooling by 10-15%. Green building envelopes might reduce indoor temperatures by 5 °C and save energy by 17% to 25% when it comes to cooling [4].

The cooling impact of outdoor VGS may be enhanced and reinforced by installing interior VGS. Evapotranspiration causes the temperature around the plants to drop, which cools the surrounding air [4].

Through shadowing and evapotranspiration, the vegetation provides a cooling effect that, during warm periods, enables a decrease in air and surface temperature and a rise in relative humidity. Even during chilly weather, green facades can be advantageous because they serve as a wind and thermal barrier, boosting thermal insulation and promoting air and surface warming [42].

C. Noise Reduction

The WHO lists noise as the second leading factor in health issues, particularly when it interferes with people's ability to sleep. According to studies, VGS can lessen noise levels inside. For instance, green walls in inner-city buildings reduced traffic noise from 2.6 to 5.1 dBA. Also, through in situ and lab testing a living wall increased the foundation wall's acoustic insulation by 6 db. Additionally, they observed that small-leaved plants fared better at high frequencies, while large-leaved plants absorbed more at medium-high frequencies [4].

D. Heat Mitigation

In addition to reflecting sunlight and lowering air temperatures through transpiration, urban green cover also offers shade and passive cooling. In addition to improving comfort in metropolitan areas, this may also have positive health effects by reducing the number of heat-related diseases and deaths [18].

By improving thermal comfort and having a cooling impact, green facades considerably lessen heat stress and the rate at which the physiologically equivalent temperature causes pain. Temperature decreases of up to 8 ◦C were observed in highly urbanized places with narrow streets and tall buildings, while an average UHI mitigation of up to 5 ◦C was recorded in different climate zones [42].

E. Enhance Water Absorption

Urban streams' water quality and watershed health can be enhanced by capturing runoff, lowering peak flows, and growing green cover and soil in these areas. Enhanced absorption of water can also mitigate localized flooding [18].

F. Increase Biodiversity Protection

For birds and other creatures, urban greenery can offer crucial habitats and passageways. A healthy urban environment must have biodiversity [18].

G. Improve Carbon Sequestration

Limiting carbon emissions is essential to mitigating climate change, and carbon sequestration is vital to this effort. Although plants are the finest carbon sinks due to their capacity to absorb and store CO2, it might be difficult to locate sufficient green spaces in urban settings that are ideal for them. Because they demand less space, offer more ecosystem services than horizontal systems, and can help lessen environmental issues, green walls are a possible alternative. The urban environment and buildings' capacity to store carbon are both improved by vertical green systems [43].

H. Increase Aesthetic Values

Applying green walls can convey elements of urban design such as defining building alignments along streets, controlling building height, hiding completely unattractive blank walls, or enhancing the feeling of intimacy in small areas [44].

Green walls, also known as living walls or green facades, enhance a building's performance and integration at the city scale in addition to its aesthetic behavior. They can serve as a standalone structure, a coating for newly constructed or already-existing buildings, or as features that define and harmonies the urban environment. The incorporation of plants into the construction of buildings itself sets apart the modern application of living walls from earlier applications. The greenery solutions for buildings are adaptable systems that can be tailored to challenging shapes, sizes, or hard-to-reach regions, including windows or the window ledges of old buildings in historically significant urban areas [44].

I. Green Walls Policies

Green infrastructure is being utilized more and more globally to lessen the negative effects of densely populated places, which helps to naturalize the built environment. Green infrastructure is becoming more and more popular among policymakers as a solution to take into account in urban planning and architecture. This is because many municipalities have implemented incentive programs to encourage the development of green walls and/or roofs [45].

Programs for environmental education, construction norms and rules, performance rating mechanisms, regulatory actions, tax breaks, and financial incentives can all be used to implement incentive policies. Program and policy development is driven by a variety of factors, including the local environment, political climate, resource availability, and environmental philosophy. Furthermore, the successful deployment of green infrastructure can be greatly impacted by the existence or lack of appropriate laws and policies [45].

Six categories were used to group the primary incentives that were found: tax reductions, financing, construction permits, sustainability certification, legal obligations, and agile administrative processes [45].

Europe and North America have the highest concentration of incentive programs globally, with 71 and 40 incentive policies, respectively. Furthermore, incentive programs (121 policies) primarily highlight the promotion of green roofs. or, in certain cases, of both green walls and roofs (22 regulations). There were no unique reward programs discovered to encourage the installation of green walls [45].

Examples of these policies are the Green Roof and Wall Policy in North America: The goal of the Green Roofs for Healthy Cities 2023 Policy Guide is to give experts in the green infrastructure sector information on where to find policies and programs that will encourage the development of green roofs and walls across North America. It is intended to serve as a guide for advocates and policymakers who are interested in creating or revising programs and policies related to green roofs and walls [46].

Also, Green Roofs and Walls Policy in Sydney: This strategy aims to encourage the building of more green walls and roofs within the local government area of the City of Sydney. Increasing the quantity of walls and green roofs will have several advantages. With the help of this policy, the Council will be able to better understand and encourage the usage of green walls and roofs in Sydney's residential and commercial sectors. The Sydney green wall and roof industry sector is another target of the policy [47].

7. QUESTIONNAIRE ANALYSIS AND EVALUATION

In this phase, the impact of vertical greenery systems (VGS) has been investigated on the main targets of the sustainable development goal 13 (SDG 13) which is climate action through an online questionnaire that was distributed to a group of experts including architects and urban planners to investigate the most important aspect of VGS & its impact on targets of SDG 13, evaluate the impact of VGS on achieving each target of SDG 13, arrange the different aspects of VGS by ranking them to each other according to their importance in achieving SDG 13, and lastly, arrange the targets of SDG 13 according to the ability to achieve SDG 13 through the usage of VGS.

7.1. STIMULI

The questionnaire consists of two parts. The first part is the demographic data for the respondents in which they were asked for their specialization (architect or urban planner), and their years of experience. The second part of the questionnaire consists of multiple choice questions to determine the most effective feature for the VGS that can directly enhance achieving each target quoted by the United Nations for SDG 13 in accordance with rating the impact of VGS on each SDG target in general, other sampled questions in order to determine the relative importance for these aspects in accordance with each other for achieving the

SDG 13 as well as determine the most important target for the SDG 13 that could positively be affected through the usage of VGS.

7.2. PROCEDURES

The required data was gathered using an online questionnaire method. The form of the questionnaire consists of two parts:

- The first part asked the respondents about their specialization and their years of experience through multiple-choice questions requiring only a single answer.

- The second part asked the respondents to rate the impact of VGS on each SDG target quoted by the United Nations in general through a rating scale from 1 to 5 where 1 is the least importance and 5 is the most importance, then asking the respondents to determine the most effective aspect for the VGS that can directly enhance achieving each target for SDG 13 through multiple choice questions requiring a single answer, in addition to asking the respondents to determine the relative importance for these nine aspects in accordance with each other for achieving the SDG 13 through a multiple choice grid that requires a single answer in each column where columns represent a rating scale from 1 to 9 where 1 is the least importance and 9 is the most importance, and the rows represents the nine aspects of the VGS. And finally, asking the respondents determine the most important target for SDG 13 that could positively be affected through the usage of VGS through a multiple choice grid that requires a single answer in each column where columns represent a rating scale from 1 to 5 where 1 is the least importance and 5 is the most importance, and the rows represent the 5 main targets of the SDG 13 quoted by the United Nations.

7.3. RESULTS & DISCUSSION

The findings of the questionnaire can be discussed through the following:

The first part: is the demographic data of the respondents in which the total number of respondents that participated in filling the questionnaire is 51 respondents, **Table 11.** shows the results of participants' basic information.

Table 11. Descriptive background parameters of the Questionnaire

No. of Participants	Specialization %		Years of Experience %				
	Architect	Urban Planner	1-5 Y.	5-10 Y.	10-15 Y.	15-20 Y.	+ 20 Y.
51	90.2%	9.8%	15.7%	5.9%	41.2%	11.8%	25.5%

The second part asked the respondents to: Determine the most effective aspects for the VGS from the nine aspects which are (improve air quality, improve thermal comfort & Energy Efficiency, Noise Reduction, Heat mitigation, Enhance water absorption, Increase biodiversity protection, improve carbon sequestration, increase aesthetic values, green wall policies) can directly enhance achieving each Target for SDG 13 through multiple choice questions requiring a single answer, **Table 12.** shows the results of this part.

Table 12. The impact of the VGS aspects on each target of SDG 13

		Aspects of VGS								
		Improve Air Quality	Improve Thermal comfort & Energy Efficiency	Noise Reduction	Heat mitigation	Enhance Water Absorption	Increase Biodiversity protection	Improve Carbon Sequestration	Increase Aesthetic values	Green Walls Policies
1	Strengthen resilience and adaptive capacity to climate-related disasters	5	27	3	7	0	0	3	0	6
2	Integrate climate change measures into policies and planning	10	14	2	6	1	1	4	1	12
3	Build knowledge and capacity to meet climate change	11	10	2	5	2	0	6	3	12
4	Implement the UN framework convention on Climate change	14	7	0	9	1	5	4	2	9
5	Promote mechanisms to raise capacity for planning and management	7	6	7	5	2	4	5	3	12

Determine the impact of VGS on each Target of SDG 13 with a linear scale from 1 to 5 where 1 is the least importance and 5 is the most importance, **Table 13.** shows the results of this Part.

Table 13. The impact of VGS on each Target of SDG 13

		Level of Importance				
		1	2	3	4	5
1	**Strengthen resilience and adaptive capacity to climate-related disasters**	3	1	13	23	11
2	**Integrate climate change measures into policies and planning**	1	0	22	16	12
3	**Build knowledge and capacity to meet climate change**	0	3	14	25	9
4	**Implement the UN framework convention on Climate change**	1	3	17	20	10
5	**Promote mechanisms to raise capacity for planning and management**	2	1	14	26	8

The respondents were then asked to determine the relative importance of these nine aspects of VGS in accordance with each other for achieving the SDG 13 Climate Action through a multiple choice grid that requires a single answer in each column where columns represent a rating scale from 1 to 9 where 1 is the least importance and 9 is the most importance, and the rows represents the 9 features of the VGS which are (improve air quality, improve thermal comfort & Energy Efficiency, Noise Reduction, Heat mitigation, Enhance water absorption, Increase biodiversity protection, improve carbon sequestration, increase aesthetic values, green wall policies), **Table 14.** shows the results of this Part.

Table 14. The relative importance of the aspects impacting the achievement of SDG 13

	Level of Importance									Mean	Ranking
	1	2	3	4	5	6	7	8	9		
Improve Air Quality	6	5	1	1	2	3	6	13	14	6.33	2
Improve Thermal comfort & Energy Efficiency	3	4	2	1	1	3	6	14	17	6.88	1
Noise Reduction	8	6	10	5	2	8	8	2	2	4.27	6
Heat mitigation	1	1	4	6	6	10	13	6	4	5.96	3
Enhance Water Absorption	3	3	10	6	17	7	2	1	2	4.51	5
Increase Biodiversity protection	6	9	4	14	3	9	2	3	1	4.08	8
Improve Carbon Sequestration	1	3	11	8	7	7	10	3	1	4.94	4
Increase Aesthetic values	7	13	8	6	5	3	2	6	1	3.82	9
Green Walls Policies	16	7	1	4	8	1	2	3	9	4.2	7

Finally, the respondents were asked to determine the most important target for SDG 13 that could positively be affected by the usage of VGS through a multiple choice grid that requires a single answer in each column where columns represent a rating scale from 1 to 5 where 1 is the least importance and 5 is the most importance, and the rows represent the 5 main targets of the SDG 13 quoted by the United Nations. **Table 15**. shows the results of this Part.

Table 15. The relative importance of the impact of each Target of SDG13

Targets		Level of Importance					Mean	Ranking
		1	2	3	4	5		
1	**Strengthen resilience and adaptive capacity to climate-related disasters.**	13	4	4	8	22	3.43	2
2	**Integrate climate change measures into policies and planning.**	3	7	9	18	14	3.65	1
3	**Build knowledge and capacity to meet climate change.**	3	7	28	11	2	3.04	3
4	**Implement the UN framework convention on Climate change**	14	19	5	11	2	2.37	5
5	**Promote mechanisms to raise capacity for planning and management.**	18	14	5	3	11	2.51	4

Fig. 9. shows the prospected framework part 1 that was conducted based on the first two phases and the questionnaire, reviews the main steps to conduct framework 2. The second part of the framework shown in **Fig. 10.** comprises a set of actions regarding the three main aspects (Improve Thermal Comfort & Energy Efficiency, Improve Air Quality, and Heat Mitigation) that impact positively the achievement of SDG 13 through using VGS.

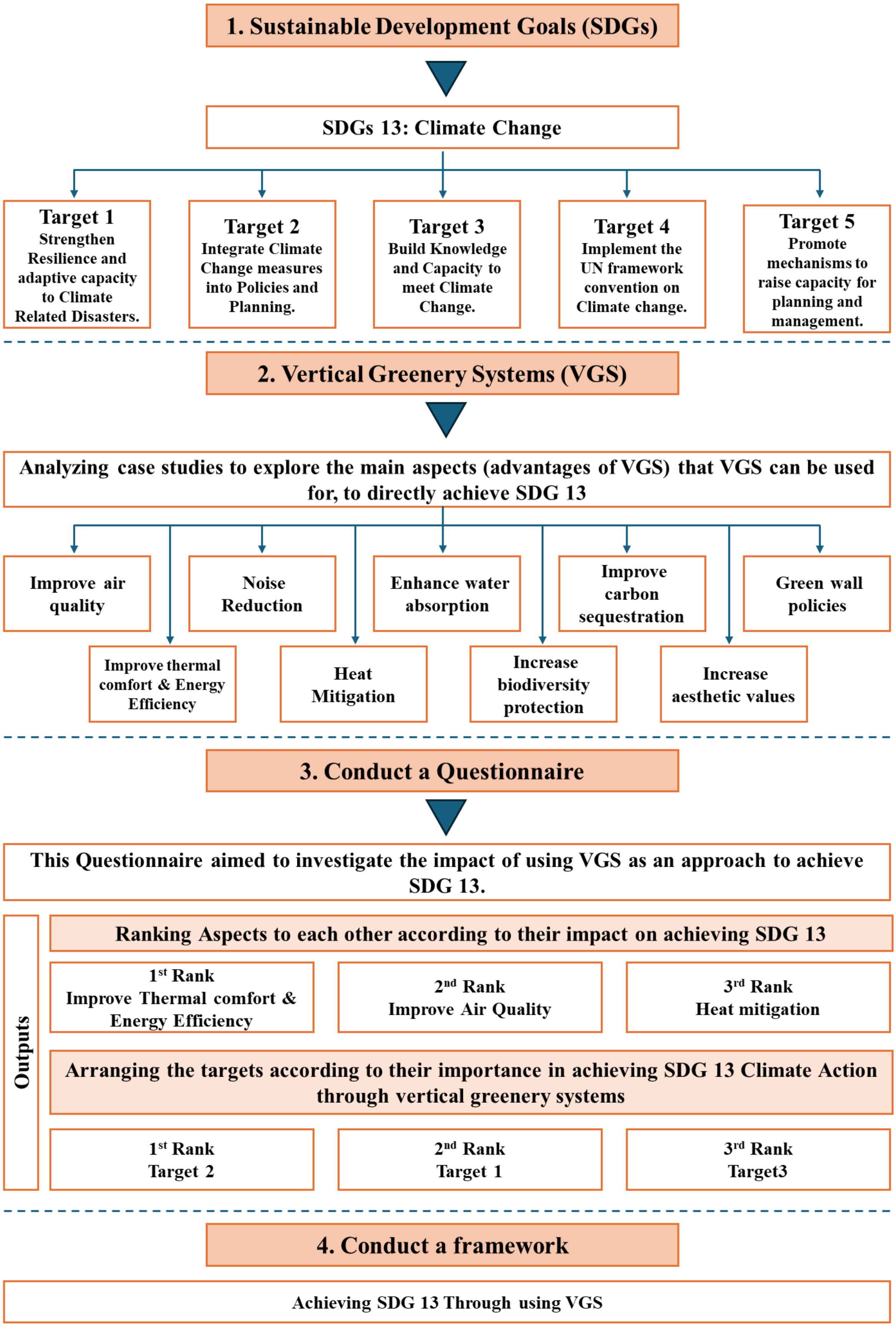

Fig. 9. The prospected framework part 1

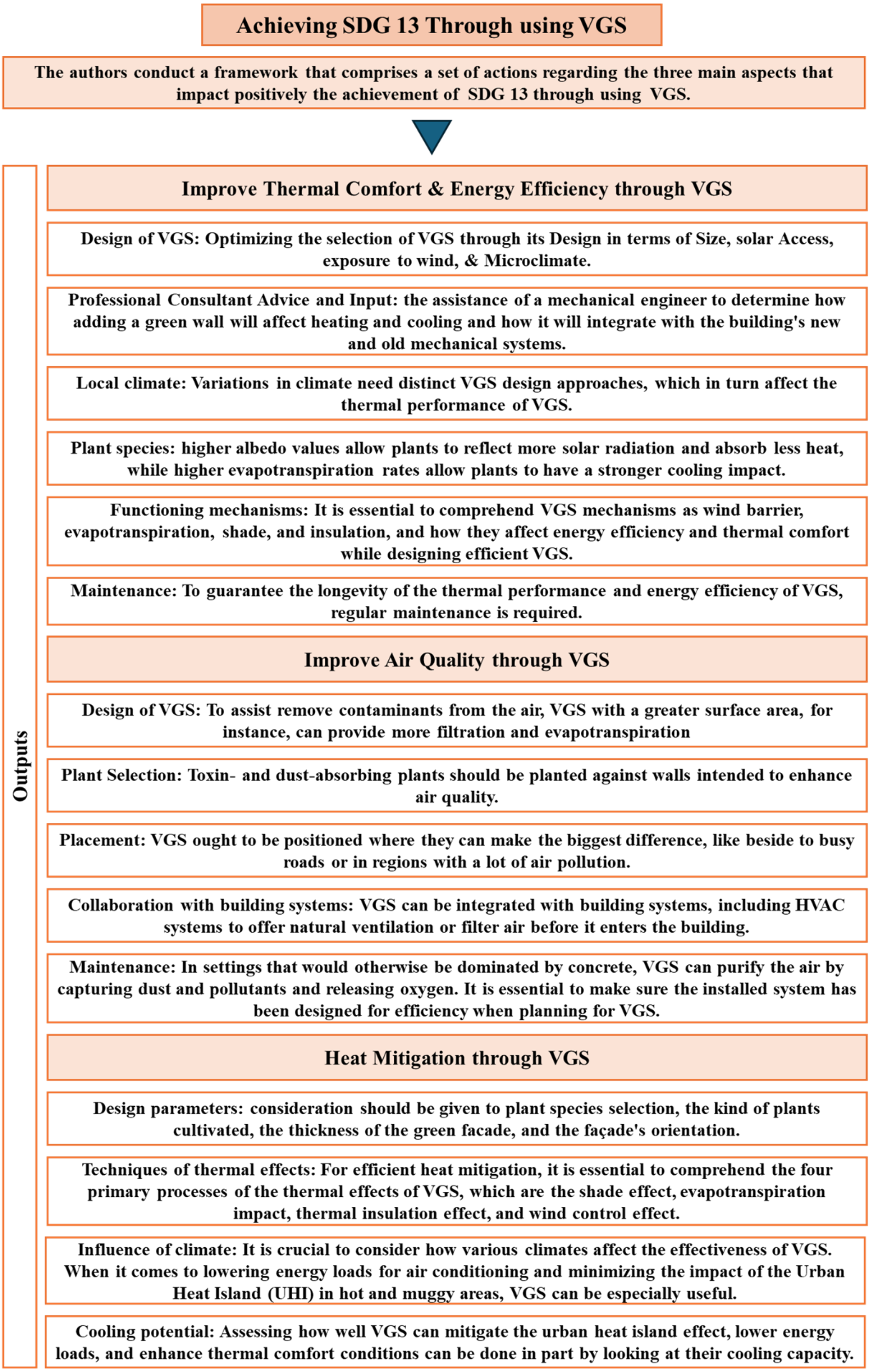

Fig. 10. The prospected framework part 2 [Authors based on 18, 48, 49, 50, 51, 52, 53].

8. CONCLUSION

Despite international agreements, climate change is occurring more quickly than it has in the past. Improving national readiness and resilience to climate change and natural disaster hazards has turned crucial.

Vertical greenery systems, or VGSs, can benefit both cities and buildings in a variety of significant ways. They can aid in lowering energy use, pollution discharged into receiving waters, and air pollution.

Our research findings provide evidence of the direct relation between VGS and achieving SDG 13 which is climate action. It also highlights the proven importance of implementing VGS in achieving SDG 13. Improve thermal comfort & Energy Efficiency, Improve Air Quality as well as Heat Mitigation are the most important features that could positively promote the achievement of SDG 13.

Target 2 of SDG 13 (Integrate climate change measures into policies and planning) is the most important target for SDG 13 that could positively be affected through the usage of VGS, then Target 1 (Strengthen resilience and adaptive capacity to climate related disasters as quoted by the UN), then Target 3 (Build knowledge and capacity to meet climate change), then Target 5 (Promote mechanisms to raise capacity for planning and management), finally Target 4 (Implement the UN framework convention on Climate change) is the lowest important target for SDG 13 that could be barely affected by using VGS.

The Authors recommend using the vertical greenery systems VGS as an approach to achieve SDG 13 with multiple considerations for architects including the Design, size, age (if retrofitting), structural capability, exposure to wind, solar access, and microclimate. In addition to, the plant selection, and the VGS placement in relation to temperature, light levels, and weather exposure are all major factors. Also, the irrigation system must be reliable. All the previous factors must be considered in terms of improving thermal comfort & energy efficiency, improving air quality, as well as heat mitigation in order to enhance achieving SDG13.

Limitations: The research findings were subjected to the sample size of the questionnaire. Variations in the sample size may affect research findings.

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