IHL018

Submission of Case Studies for

Final Submission

For

Sustainability Cities Challenge 2024

On

Hillview Community Club

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1. Introduction

1.1 Site Analysis

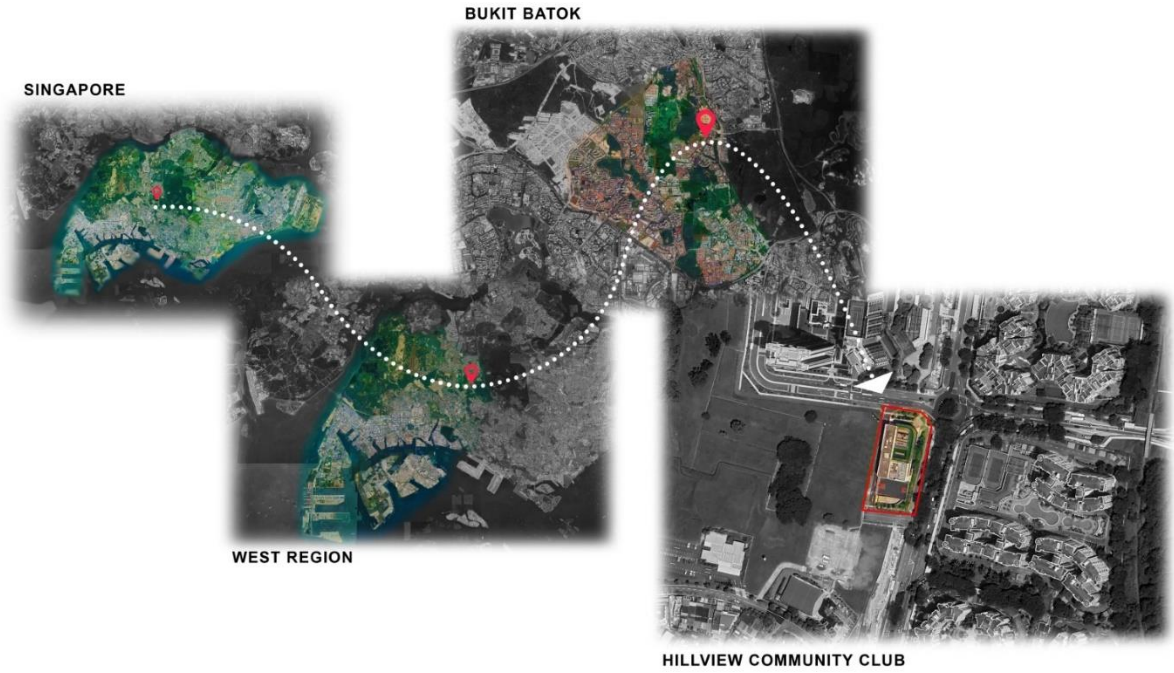


Figure 1 Site Analysis

Hillview Community Club is situated in the West Region of Singapore, specifically within the Bukit Batok planning zone. As a vital community hub, Hillview CC serves as a focal point for residents in the surrounding area, offering a diverse range of facilities and services aimed at promoting social interaction, wellness, and community engagement. This site analysis aims to comprehensively assess the physical attributes and functional aspects of Hillview Community Club, exploring its impact on the macro levels within the local community, the bioclimatic analysis of the site, and personal experience on-site.

1.11 Macro Analysis

The macro-level analysis will examine the broader urban context surrounding Hillview Community Club. This includes its connectivity to transportation networks, proximity to residential and commercial zones, and its role within the larger urban framework of Bukit Batok. Insights gained from this analysis will illuminate the club's influence on the neighborhood's social dynamics, accessibility, and overall urban development.

Figure 2 URA Site Plan

Figure 3 URA Site Plan Legend

In conducting a macro analysis of the Urban Redevelopment Authority's (URA) planning for the spaces surrounding Hillview Community Club, several notable aspects emerge. Firstly, there is a significant presence of existing residential spaces in the vicinity, indicating a dense residential population within the immediate neighborhood. Additionally, there are plans for further construction, suggesting ongoing urban development and potential population growth in the area.

The coexistence of both existing and planned residential spaces underscores the importance of Hillview Community Club as a central social and recreational hub for the surrounding residents. As the population continues to grow, the club's role in facilitating community engagement and providing essential amenities becomes increasingly crucial. Moreover, the proximity of residential spaces to the community club enhances its accessibility and fosters a sense of belonging among residents.

Furthermore, the abundance of greenery nearby is a notable feature of the area's planning. Including green spaces enhances the neighborhood's aesthetic appeal and contributes to environmental sustainability and quality of life for residents. These green spaces provide opportunities for leisure activities, promote biodiversity, and mitigate the urban heat island effect.

In analyzing these aspects, it becomes evident that the URA's planning for the spaces around Hillview Community Club prioritizes creating a vibrant and sustainable urban environment. By integrating residential developments with ample greenery and community facilities like the club, the planning aims to foster a harmonious and livable neighborhood.

One transformative design renovation opportunity for Hillview Community Club lies in the integration of sustainable and multipurpose spaces that adapt to the evolving needs of its diverse user base. By reimagining the club's layout and amenities, we can create a dynamic ecosystem that not only fosters community engagement but also serves as a model of environmental stewardship and innovation.

One ambitious concept is the creation of a **solar-powered rooftop garden** and **extended green wall** to allow the community club to have more integration with the greenery in the surroundings. These sustainable additions contribute to promoting biodiversity, reducing heat absorption, and improving air quality. Nevertheless, abundant **solar energy** in Singapore can also be harnessed at a suitable location in the Community Club to improve energy efficiency.

1.1.2 Bioclimatic Analysis:

The climatic analysis will assess how the site responds to Singapore's tropical climate. This includes considerations of natural ventilation and sun path to the site. Understanding these climatic factors is crucial for optimizing the club's environmental performance and ensuring the well-being of its users.

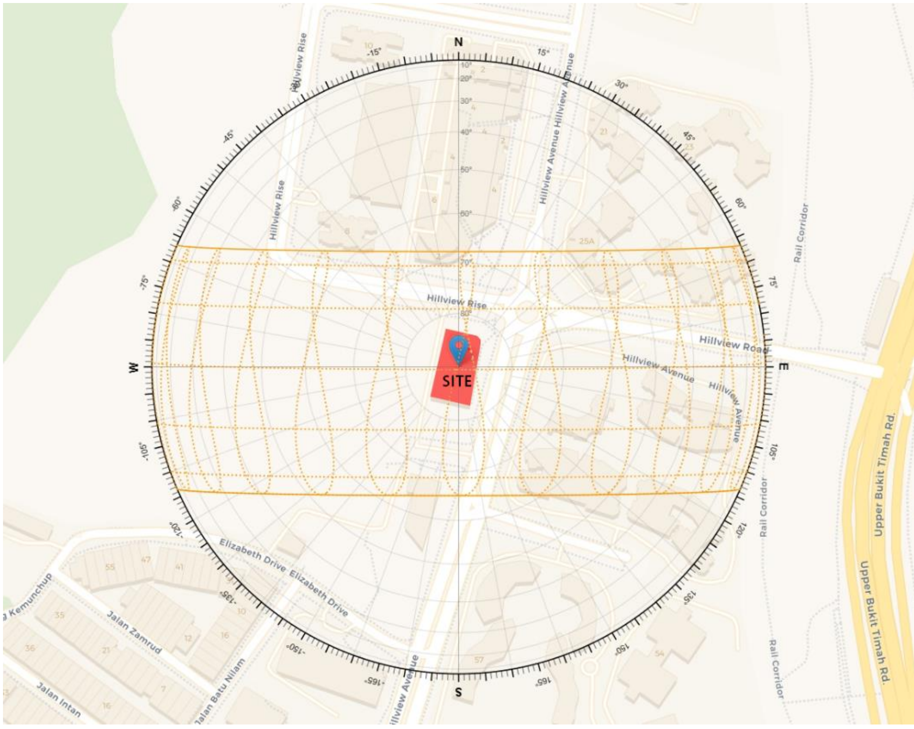


Figure 4 Sun Path Diagram

In Singapore, located near the equator, the sun's path follows a relatively consistent pattern year-round, with the sun reaching its zenith (highest point) near the equinoxes and having a slightly lower path during the solstices. This means that solar panels installed on a site in Singapore can receive substantial sunlight throughout the year, optimizing energy production.

The analysis of the site's solar exposure reveals a highly favourable condition for solar panel integration, as the current site experiences no shading from surrounding buildings throughout the year and remains fully exposed to the sun. This unobstructed solar exposure is particularly advantageous for maximizing the efficiency and output of solar energy systems.

The absence of shading from nearby buildings ensures consistent sunlight exposure on the site, enabling solar panels to capture optimal levels of solar radiation from sunrise to sunset. This continuous exposure minimizes any potential interruptions in energy generation, resulting in higher overall productivity and performance of solar panels installed on the site.

After we have observed the surroundings of the Hillview CC, the eastern side of the Hillview CC remains unblocked with the Bukit Timah Natural Reserve at a long distance apart. The western side and the southern part may have new developments coming up in future.

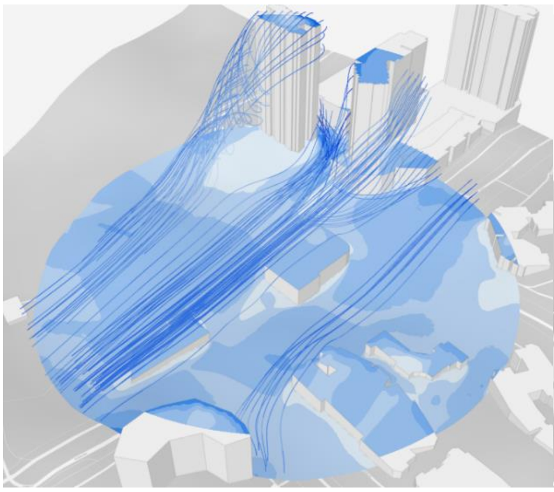
Figure 5 The Future Development around the CC

Despite the future construction of two new residential buildings on the west and south-west sides of the Hillview Community Club, the site's solar exposure remains promising due to the design features of these upcoming structures. The proposed blocks, towering between 26 to 27 storeys in height, are positioned in a way that ensures the Hillview Community Club will not be fully overshadowed during the afternoon hours. This indicates that while there may be some partial shading in the afternoon, particularly on the western and southwestern sides of the club, the overall impact on solar exposure is manageable.

The morning and noon sunlight will continue to reach the Hillview Community Club effectively, given the orientation and height of the neighbouring residential buildings. This means that crucial periods of sunlight required for solar energy generation, especially during peak hours, will still be available to the site. The unobstructed morning and noon sunlight contributes significantly to the overall solar potential of the site, allowing for efficient energy capture and utilization.

The strategic positioning and height of the new residential buildings play a key role in preserving adequate solar exposure for the Hillview Community Club. By allowing sunlight to penetrate the site during critical times of the day, such as morning and noon, the impact of the adjacent developments on solar access is minimized. This consideration is crucial for optimizing the performance of any solar energy systems that may be integrated into the club's infrastructure.

Furthermore, while there may be partial shading in the afternoon due to the presence of the new residential blocks, advanced solar panel technologies, such as those with higher tolerance to diffuse or indirect sunlight, can help mitigate potential efficiency losses during these periods. Additionally, careful design and placement of solar panels on the club's rooftops or other suitable locations can further optimize solar energy generation despite the surrounding developments.



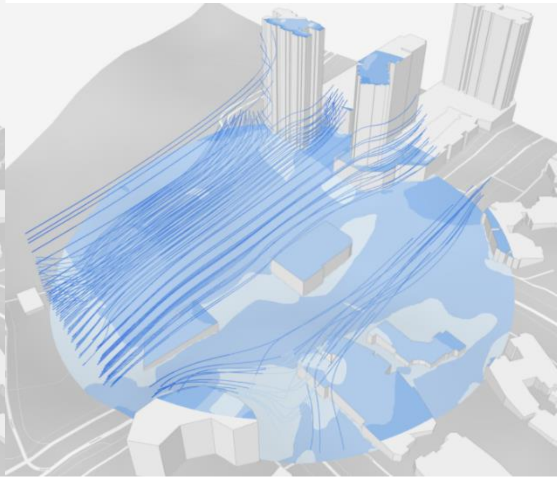


Figure 6 F South Prevailing Wind to Site

Figure 7 North-North-East Prevailing Wind to Site

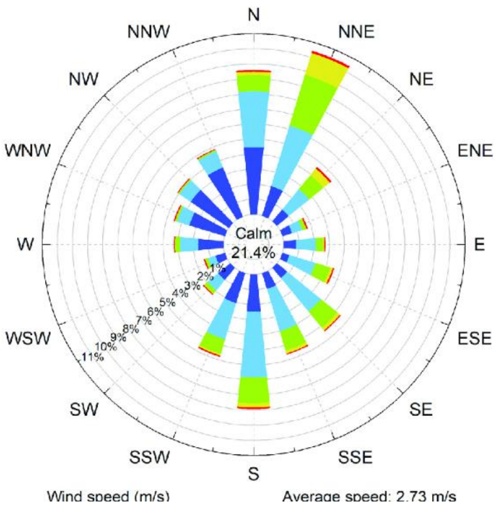


Figure 8 Wind Rose Diagram of Singapore

The site analysis indicates that the Hillview Community Club benefits from unobstructed wind flow, except for potential intensified wind channelling caused by the nearby HillV2 residential building block. Understanding the wind dynamics and its impact on the site's microclimate is crucial for optimizing environmental comfort and promoting sustainable design principles.

The absence of significant blockages allows for natural ventilation and air movement across the Hillview Community Club site, enhancing overall comfort and reducing the reliance on mechanical cooling systems. This natural ventilation is particularly beneficial in Singapore's tropical climate, where air circulation can help mitigate heat buildup and improve indoor air quality.

However, the presence of the HillV2 residential building block adjacent to the site introduces a unique dynamic. Tall buildings like HillV2 have the potential to channel and accelerate wind, creating localized wind patterns that may affect airflow around the community club. This intensified wind flow could result in stronger breezes or gusts within specific areas of the site.

To leverage this wind channelling effect positively, the design of the Hillview Community Club can incorporate features that harness and optimize natural ventilation. Strategic placement of openings, such as windows, doors, or vents, can capitalize on the directed wind flow to enhance cross-ventilation and cooling efficiency within the club's spaces.

Furthermore, landscape design elements, such as vegetation and greenery, can be strategically positioned to act as natural windbreaks or buffers against strong winds channeled by the HillV2 building. This integrated approach to site planning not only enhances environmental sustainability but also contributes to creating a comfortable and enjoyable outdoor environment for club users.

2. Background of Hillview Community Club

Hillview Community Club is situated at 1 Hillview Rise, Singapore 667970, within the historic Princess Elizabeth Estate in the Bukit Batok area. Known for its vibrant community spirit, the club serves as a key social and educational hub, fostering activities that promote lifelong learning and community engagement.

Currently, the building incorporates several sustainable features, such as a water harvesting system and green spaces within its premises, reflecting an ongoing commitment to environmental stewardship. As part of our proposal, we aim to build on these existing conditions by introducing additional sustainable practices to enhance the club’s green footprint and further support Singapore’s vision of a ‘City in Nature.’

This proposal outlines our strategies to upgrade the building’s sustainability, ensuring it not only continues to meet the needs of its community but also sets a benchmark for eco-friendly design and operation.

2.1 Personal Site Observation:

Based on personal experience and observations on-site, several opportunities for improvements can be identified at the Hillview Community Club:

2.1.1 Optimization of Solar Energy Use

- Current Situation: The club has untapped solar energy potential, with no existing solar panels or systems in place, leading to missed opportunities in energy savings and carbon footprint reduction.

- Proposed Solution: By installing solar panels on rooftops and carpark structures, we can harness this abundant solar energy. This initiative will reduce operational costs, decrease environmental impact, and serve as a visible commitment to sustainability, encouraging the community to adopt renewable energy practices.

2.1.2 Enhancement of Exterior Greenery

- Current Situation: The exterior walls of Hillview Community Club are currently bare, missing opportunities for natural shading, thermal insulation, and biodiversity.

- Proposed Solution: We propose the installation of additional vertical green walls and trellises with climbing plants on select exterior surfaces. This addition will not only beautify the structure but also offer ecological benefits such as temperature regulation, reduced heat gain, and improved air quality, creating a visually appealing and environmentally friendly atmosphere.

2.1.3 Enhancing Community Engagement Outdoors

- Current Situation: There is a noticeable lack of community engagement in outdoor spaces at the club.

- Proposed Solution: The introduction of the “Growing With Us” community farming area is designed to revitalize these outdoor areas. This space will not only provide a green refuge but also serve as a dynamic educational platform, promoting active community involvement and environmental responsibility through hands-on sustainable practices.

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3. Additional Reference Source (Green Mark Status)

- Building Details: Building Type: Commercial
- Building Main Function: Office
- Building Size: Medium
- Total Gross Floor Area (GFA): 3,868 square meters
- Occupancy Capacity: 2,800 occupants
- Air Conditioning (AC) Area: 72% of GFA
- Chiller Type: Water Cooled Chilled Water Plant
- Year of Completion (TOP/CSC): 2017
- Green Mark Award: Gold (2017)
- Green Mark Version: New Building for Non-Residential Buildings (version 4.1)

Energy Performance: Energy

- Usage Intensity (EUI):
  - 2020: 117 (2nd Quartile/ Energy Ranking)
  - 2021: 132 (2nd Quartile/ Energy Ranking)
  - 2022: 152 (2nd Quartile/ Energy Ranking)

EUI is expressed as energy per square foot per year. It's calculated by dividing the total energy consumed by the building in one year (measured in kBtu or GJ) by the total gross floor area of the building (measured in square feet or square meters).

EUI Trend of Commercial Buildings Between 2008 to 2020, the annual electricity consumption of 631 commercial buildings (GFA ≥5,000 m2) has increased by 12%, compared to the corresponding GFA growth at 50%. The average EUI in 2020 has lowered by 25% since 2008. National Building Energy Benchmarks [EUI (kWh/m2. yr)] In 2020, a total of 498 commercial buildings (GFA ≥5,000 m2) were benchmarked.

Newly constructed or retrofitted buildings, buildings on district cooling systems (DCS) were omitted from the benchmarks, and developments with electricity consumption or shared centralised air-conditioning systems that could not be segregated due to the lack of sub-metering were aggregated. To facilitate the benchmarking exercise, the buildings have been categorised by type and size. For the purpose of benchmarking, EUI can be used as an index to compare the building's annual energy performance against similar building types. EUI is the combined result of energy efficiency and consumption behaviour/pattern of the building.

Table 1: National Building Energy Benchmarks for Commercial Buildings (2020)

Building Type	Size*	No. of Buildings (in 2020)	Average EUI (kWh/m².yr)	EUI of Top 10%	EUI Ranges (kWh/m².yr)			
					Top Quartile (1% - 25%)	2nd Quartile (26% - 50%)	3rd Quartile (51% - 75%)	Bottom Quartile (76% - 100%)
Office Buildings	Large	151	≤185	≤90	≤124	124 - 163	163 - 211	>211
	Medium	121	≤217	≤75	≤110	110 - 142	142 - 225	>225
Hotels	All	89	≤218	≤160	≤187	187 - 219	219 - 270	>270
Retail Buildings	Large	63	≤312	≤124	≤190	190 - 390	390 - 460	>460
	Medium	43	≤326	≤136	≤216	216 - 294	294 - 434	>434
Mixed Developments	All	31	≤224	≤133	≤170	170 - 199	199 - 289	>289

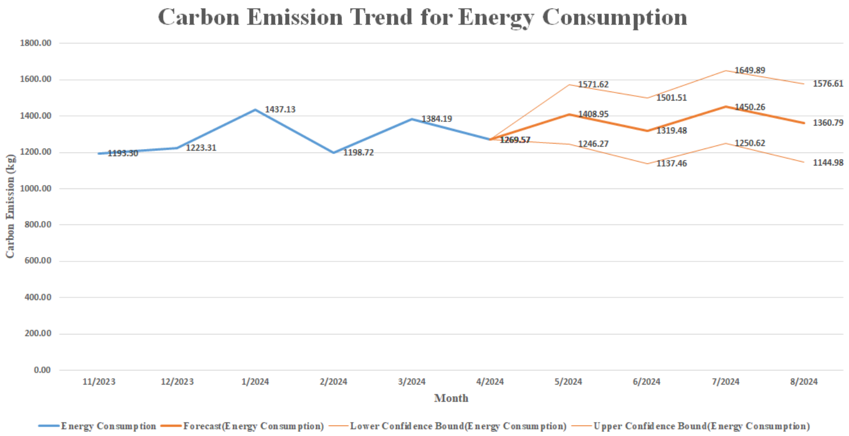
*All: Hotels and Mixed Developments of GFA ≥5,000 m²;
*Large: Office Buildings and Retail Buildings of GFA ≥15,000 m²;
*Medium: Office Buildings and Retail Buildings of GFA ≤5,000 m² and <15,000 m².

Figure 9 Green Mark Reference Table

Calculation of Carbon Emissions

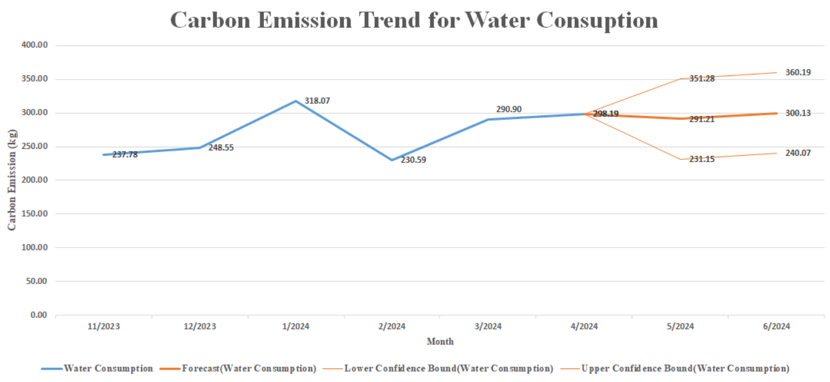
Electricity Consumption Emissions:

Month	Consumption (kWh)	Emissions (kg CO2)
Nov-23	2,863	1,193.30
Dec-23	2,935	1,223.31
Jan-24	3,448	1,437.13
Feb-24	2,876	1,198.72
Mar-24	3,321	1,384.19
Apr-24	3,046	1,269.57
Total		7,706.22



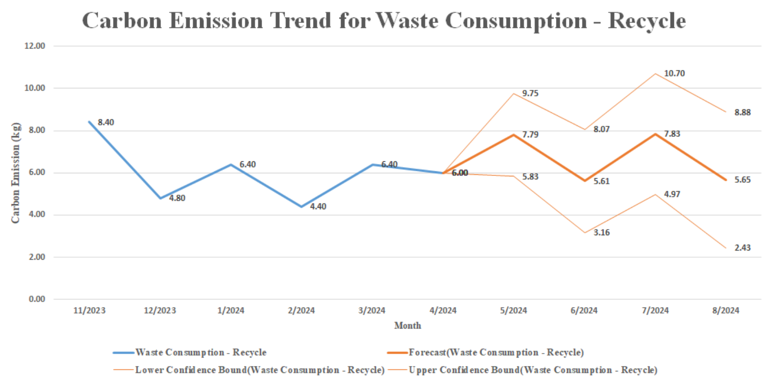
Water Consumption Emissions:

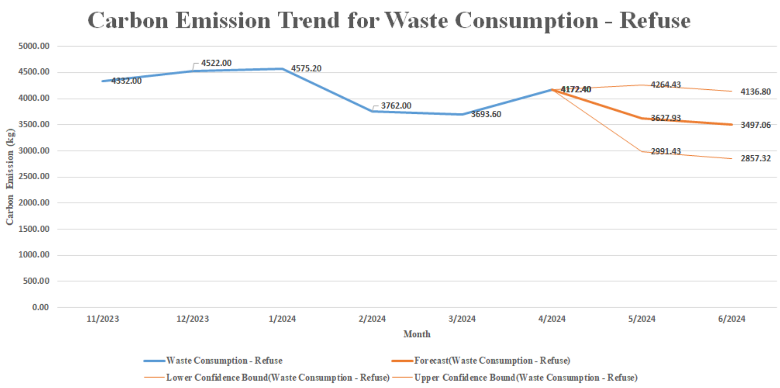
Month	Consumption (cu m)	Emissions (kg CO2)
Nov-23	566.14	237.78
Dec-23	591.79	248.55
Jan-24	757.32	318.07
Feb-24	549.03	230.59
Mar-24	692.61	290.90
Apr-24	709.98	298.19
Total		1,624.09



Waste Consumption Emissions:

Month	Refuse (kg)	Recycle (kg)	Emissions (kg CO2)
Nov-23	5,700	210	4,340.4
Dec-23	5,950	120	4,526.8
Jan-24	6,020	160	4,581.6
Feb-24	4,950	110	3,766.4
Mar-24	4,860	160	3,700
Apr-24	5,490	150	4,178.4
Total			25,093.6





Overall Total Emissions: 34,423.90 kg CO2

Analysis of Consumption and Wastage Patterns

The largest source of emissions is from waste consumption, particularly general waste, accounting for 25,093.6 kg CO2 over six months.

Table: Calculation of Carbon Emissions by Type

Carbon Emission Trend (kg)						
Month	**11/2023**	**12/2023**	**1/2024**	**2/2024**	**3/2024**	**4/2024**
Energy Consumption	1193.30	1223.31	1437.13	1198.72	1384.19	1269.57
Water Consumption	237.78	248.55	318.07	230.59	290.90	298.19
Waste Consumption - Refuse	4332.00	4522.00	4575.20	3762.00	3693.60	4172.40
Waste Consumption - Recycle	8.40	4.80	6.40	4.40	6.40	6.00
Total carbon emission	34423.90					

Electricity Consumption Analysis

Patterns and Peaks:

- Nov-23: 2,863 kWh
- Dec-23: 2,935 kWh
- Jan-24: 3,448 kWh
- Feb-24: 2,876 kWh
- Mar-24: 3,321 kWh
- Apr-24: 3,046 kWh

Potential Causes for Peaks:

1. January 2024:
    - High consumption likely due to increased indoor activities during the New Year celebrations.
    - Special events and functions, such as community gatherings, cultural shows, and workshops, which require extensive use of lighting and electronic equipment.
2. March 2024:
    - Increased activities related to community events such as health and wellness workshops, sports tournaments, and educational programs.

   - These events necessitate the use of air conditioning, lighting, and other electronic devices for longer durations.

Identified High-Consumption Areas:

- Sports Facilities: Includes a basketball court, gym, and multi-purpose sports halls. High usage of lighting and air conditioning, especially during evening hours.
- Offices and Meeting Rooms: Continuous usage of lighting, computers, and air conditioning.
- Function Halls: Frequently used for events, workshops, and community gatherings leading to spikes in energy consumption.

Water Consumption Analysis

Patterns and Peaks:

- Nov-23: 566.14 cu m
- Dec-23: 591.79 cu m
- Jan-24: 757.32 cu m
- Feb-24: 549.03 cu m
- Mar-24: 692.61 cu m
- Apr-24: 709.98 cu m

Potential Causes for Peaks:

1. January 2024:
   - Increased water usage during community events and functions, leading to higher consumption for cleaning and maintenance activities.
   - Possible maintenance and cleaning operations post-New Year celebrations.
2. March and April 2024:
   - Higher water usage due to maintenance of outdoor green spaces and gardens, especially in preparation for spring events.
   - Possible increase in visitor numbers during school holidays and other community programs.

Identified High-Consumption Areas:

- Restrooms and Showers: High usage by visitors and staff.
- Cafeteria and Kitchen Areas: Significant water usage for cooking, cleaning, and dishwashing activities.
- Landscaping and Irrigation: Maintenance of outdoor green spaces and gardens.

Waste Consumption Analysis

General Waste Patterns:

- Nov-23: 5,700 kg
- Dec-23: 5,950 kg
- Jan-24: 6,020 kg

- Feb-24: 4,950 kg
- Mar-24: 4,860 kg
- Apr-24: 5,490 kg

Recyclables Patterns:

- Nov-23: 210 kg
- Dec-23: 120 kg
- Jan-24: 160 kg
- Feb-24: 110 kg
- Mar-24: 160 kg
- Apr-24: 150 kg

Potential Causes for Peaks:

1. January 2024:
   - High waste generation from New Year celebrations and community events, including food waste and disposable items from large gatherings.
   - Decorations, event materials, and increased foot traffic leading to more general waste.
2. April 2024:
   - Higher general waste due to events, workshops, and increased activity in the community center.
   - Spring cleaning and maintenance activities may contribute to increased waste.

Identified High-Waste Areas:

- Cafeteria and Kitchen: High levels of food waste and packaging materials.
- Offices and Meeting Rooms: Paper waste from administrative activities and meetings.
- Function Halls: Waste from events, including food waste, disposable items, and decorations.

Business and Shops in Hillview Community Club

Research on Business and Shops:

1. Hillview Community Club Facilities:
   - Offers a variety of services including educational workshops, sports facilities, and community events.
   - Facilities such as the basketball court, multi-purpose hall, and meeting rooms contribute significantly to energy and water usage.
   - Cafeteria and kitchen areas generate considerable food waste and packaging materials.
2. Activities Impacting Consumption and Waste Generation:
   - Sports Activities: Frequent use of the gym, basketball court, and other sports facilities increases electricity and water consumption.
   - Community Events: Workshops, cultural shows, and gatherings significantly impact energy, water, and waste generation, especially during peak periods.

   - Educational Programs: Classes and workshops for children and adults contribute to the overall usage of resources.
3. Specific Businesses and Shops:
   - Retail Outlets: Generate waste from packaging and consumer goods.
   - Food and Beverage Outlets: Contribute to food waste, packaging materials, and water usage for cooking and cleaning.

Efficiency Improvement and Carbon Reduction Targets

Requirements for Hillview Community Center to Achieve Different Green Mark Ratings

The Building and Construction Authority (BCA) Green Mark Certification Scheme has different assessment criteria for various building types. For Hillview Community Center, which falls under non-residential buildings, here are the summarized requirements for achieving different Green Mark ratings:

Green Mark Ratings:

1. Certified
   - Energy Efficiency: Achieve a minimum of 25% energy savings compared to the 2005 building code.
   - Water Efficiency: Implement water-efficient fittings and practices.
   - Sustainable Construction: Use sustainable and recycled materials.
   - Indoor Environmental Quality: Ensure good indoor air quality and comfort.
   - Other Green Features: Incorporate additional green features and innovations.
2. Gold
   - Energy Efficiency: Achieve at least 30% energy savings.
   - Water Efficiency: Advanced water-saving measures and monitoring.
   - Sustainable Construction: Higher use of sustainable materials.
   - Indoor Environmental Quality: Enhanced indoor air quality management.
   - Other Green Features: Additional innovations and higher standards in green features.
3. GoldPLUS
   - Energy Efficiency: Achieve at least 35% energy savings.
   - Water Efficiency: Comprehensive water-saving measures and real-time monitoring.
   - Sustainable Construction: Maximum use of sustainable and recycled materials.
   - Indoor Environmental Quality: Superior indoor air quality and comfort levels.
   - Other Green Features: Significant green innovations and features.
4. Platinum
   - Energy Efficiency: Achieve at least 40% energy savings.
   - Water Efficiency: Implement state-of-the-art water-saving technologies.
   - Sustainable Construction: Extensive use of sustainable and recycled materials.
   - Indoor Environmental Quality: Optimal indoor air quality and occupant comfort.
   - Other Green Features: Cutting-edge green features and significant innovations.

Detailed Steps and Analysis:

1. Energy Efficiency:

  - Solar Panels: Install solar panels to generate renewable energy.
  - Lighting: Upgrade to LED lighting and install motion sensors.
  - HVAC Systems: Optimize HVAC systems with smart controls and regular maintenance.
2. Water Efficiency:
  - Low-Flow Fixtures: Install low-flow faucets and dual-flush toilets.
  - Rainwater Harvesting: Use harvested rainwater for irrigation and other non-potable uses.
  - Water Monitoring: Implement real-time water usage monitoring.
3. Sustainable Construction:
  - Materials: Use eco-friendly building materials and recycled content.
  - Waste Management: Implement comprehensive waste management and recycling programs during construction.
4. Indoor Environmental Quality:
  - Air Quality: Use low-VOC paints and materials, and ensure good ventilation.
  - Comfort: Optimize thermal comfort with smart HVAC controls.
5. Other Green Features:
  - Green Spaces: Incorporate green walls and rooftop gardens.
  - Innovation: Implement smart building technologies and innovative sustainability practices.

Efficiency Improvement Targets and Carbon Reduction Calculation

Targets for Efficiency Improvement

Electricity:

- Current Consumption (6 months): 18,489 kWh
- Improvement Target: 100%
- Reduction Target: 18,489 kWh

Water:

- Current Consumption (6 months): 3,866.87 cu m
- Improvement Target: 5-10%
- Reduction Target: 193.34 – 386.69 cu m

General Waste:

- Current Consumption (6 months): 32,970 kg
- Improvement Target: 5-10%
- Reduction Target: 1,648.5 – 3,297 kg

Recyclables:

- Current Consumption (6 months): 910 kg
- Improvement Target: 5-10%
- Increase Target: 45.5 - 91 kg

Target Carbon Reduction Targets

Electricity Emissions Reduction:

- Current Emissions: 7,706.22 kg CO_2
- Reduction: 18,489 kWh * 0.4168 kg CO_2/kWh = 7,706.22 kg CO_2
- New Emissions: 0 kg CO_2

Water Emissions Reduction:

- Current Emissions: 1,624.07 kg CO_2
- Reduction: 193.34 cu m * 0.42 kg CO_2/cu m = 81.20 kg CO_2
- New Emissions: 1,542.87kg CO_2

General Waste Emissions Reduction:

- Current Emissions: 25,057.2 kg CO_2
- Reduction: 1,648.5 kg * 0.76 kg CO_2/kg = 1,252.86 kg CO_2
- New Emissions: 23,804.34 kg CO_2

Recyclables Increase:

- Current Emissions: 36.4 kg CO_2
- Reduction: 45.5 kg * 0.04 kg CO_2/kg = 1.82 kg CO_2
- New Emissions: 34.58 kg CO_2

Target Total Carbon Reduction

Current Total Emissions:
7,706.22 (electricity)+1,624.07 (water)+25,057.2 (waste)+36.4 (recyclables)=34,423.91 kg CO_2

New Total Emissions:
0 (electricity)+1,542.87 (water)+23,804.34 (waste)+34.58 (recyclables)=25,381.79 kg CO_2

Extra Emissions Reduction (from excess electricity produced):

=-(Current Emissions(electricity)−Reduced Emissions from Consumption(electricity)-Reduced Emissions from Generation(electricity))

=-(7706.22-2056.15-18973.12)

=13323.05

Total Reduction:
34,423.91 kg CO_2−25,381.79+13,323.05 kg CO_2=22,365.17 kg CO_2

Alignment with Green Mark Criteria:

1. Energy Efficiency:

- Achieving a full reduction in electricity usage aligns with higher energy efficiency criteria required for Green Mark Gold or GoldPLUS certification.

Potential Green Mark Certification:

Given the achieved improvements and reductions, Hillview Community Center is likely to qualify for Green Mark Gold or potentially GoldPLUS certification. To achieve these ratings, the center must demonstrate the following:

- Gold: At least 30% energy savings, comprehensive water-saving measures, enhanced indoor environmental quality, and additional green features.
- GoldPLUS: At least 35% energy savings, advanced water-saving measures with real-time monitoring, maximum use of sustainable materials, and superior indoor air quality.

4. Areas Identified for Improvements & Proposals

4.1 CASE STUDY 1

Energy Efficiency with a Solar Panel Roof Over the Basketball Court

4.11 CONCEPT

Hillview Community Club (CC) relies heavily on non-renewable energy sources to meet its operational needs. This dependence on fossil fuel-based energy contributes to greenhouse gas emissions.

While the Club recognizes the importance of sustainability and reducing its carbon footprint, it faces challenges on the shortage of suitable space to install the solar panels without scarifying the current usable areas.

We have identified one potential area for the solar panel installation, that is the area on the roof top of the 5^{th} storey marked as **(Area A)** in Figure 12. With an approximate area of 500 square meters but considering the obstructions in the center of the area, the actual usable areas may be less than 300 square meters.

Therefore, to increase the usable area for installation solar panels, we feel that we can be more innovative in finding other suitable spaces to install the solar panels in the CC. By referring to some overseas sports facilities of their success cases. We are keen to propose that a new roof over the open basket court marked as **(Area B)** in Figure 12 and the solar panels can be installed on this new roof.

Figure 12 Roof Top of the 5th Storey and Basketball Court

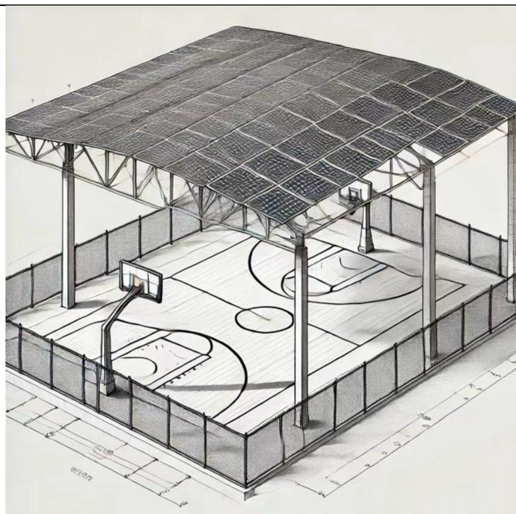


Figure 13 Figure 10 Solar Panel Roof Over the Basketball Court

(Image generated by AI, for illustration purpose only)

4.12 DESIGN CONCEPT

We propose an innovative solution – constructing a solar panel roof over the outdoor basketball court with an approximate area of **474 square meters**. This design can efficiently utilize the overhead space of the basketball court without encroaching on existing facilities. By integrating solar panels into this overhead structure, we can harness solar energy while leaving other existing rooftop facilities undisturbed.

The proposed solar panel roof will span the entire basketball court area, this approach not only allows for on-site renewable energy production but also provides a sheltered environment for the basketball court users, shielding them from harsh sunlight and inclement weather. Consequently, the solar panel roof will encourage the community members to utilize the basketball court more.

The solar panel roof will feature a modular and adaptable design, allowing for efficient construction and minimal disruption to community activities. The structure will comprise prefabricated steel frames and trusses that can be easily assembled on-site.

The solar panels will be mounted on a supporting structure with a gradient to optimize exposure to sunlight. The modular system also enables flexibility in the overall layout.

Beneath the solar panels, a netting system will be fixed from the steel framework. This net will protect the solar panels from the basketballs.

The solar roof's height will match the height of the Hillview CC building to ensure maximum solar exposure while maintaining a safe playing environment for basketball players.

Figure 14 Hillview Community Club Basketball Court

4.13 Feasibility Study & Calculations

Basketball Court Dimensions
Length: 28 meters
Width: 16.93 meters
Gross Area: 474.04 m²

Solar Panel Roof Specifications
Length: 28 meters
Width: 17.19 meters
Height: 8 meters above the court surface
Solar Panels: Monocrystalline solar panels with a power capacity between 320 and 375 watts.
Slope Design: 10-degree slope for effective water drainage.

Solar Energy Generation Calculations
Key Parameters
Gross Area Utilized: 474.04 m²
Net PV Area: 379.23 m² (Assume Space Utilization: 80%)
Module Efficiency: 20%
PV Capacity: 75.85 kWp
Annual Irradiation: 1600 kWh/m²
Performance Ratio: 0.75
Annual Energy Generation
The annual energy generation is calculated as follows:

Annual Energy Generation
=PV Capacity * Annual Irradiation * Performance Ratio
= 75.85 kWp * 1600 kWh/m² × 0.75
= 91,020.00 kWh

CO2 Emissions can be offset
= 91,020x0.4169
= 37,946.24 kg

Net Energy Generation
The estimated energy consumption for Hillview Community Center over one year is 37,000 kWh. Therefore, the net energy generated for net metering is:
Net Metering = Annual Energy Generation − Energy Consumption
Net Metering= 91,020 kWh−37,000 kWh=54,020 kWh

4.14 Potential Benefits

Environmental Sustainability - By generating clean, renewable energy on-site, the facility can reduce its carbon footprint and reliance on non-renewable sources.

Energy Cost Savings - Solar panel roof offers substantial environmental benefits to offset a portion of Hillview CC's electricity costs, approximately **630 kWh** of energy per day, resulting in long-term greenhouse gas reduction.

Enhanced User Experience - By shading the outdoor basketball court, players can enjoy a more comfortable environment, sheltered from the harsh sun and inclement weather. This improvement is expected to encourage more usage of the court to promote a healthy lifestyle.

Thermal Comfort - The solar panel roof offers an added advantage by providing shading to the Hillview community club building, reducing the amount of direct sunlight absorbed by the walls. This passive cooling minimizes the need for excessive air conditioning, leading to energy savings and enhanced thermal comfort for visitors.

Community Engagement and Education - Beyond its practical benefits, the solar panel roof demonstrates Hillview CC's commitment to sustainability, fostering community engagement and education. The installation showcases the adoption of renewable energy solutions, promoting awareness and understanding among members and visitors and educating the public on the importance of adopting sustainable practices in their everyday lives.

4.15 Design Implementation

According to the US Energy Information Administration (2024), a photovoltaic (PV) system can produce energy equivalent to the energy used for manufacture within 1 to 4 years. Furthermore, most PV systems have operating lives of up to 30 years or more, ensuring a prolonged return on investment and environmental impact.

Refer to a similar solar project at Broward County's basketball courts in Fort Lauderdale, Florida. Two solar panel roofs are installed over the basketball courts, providing shade and more cooling playing conditions for the players while generating renewable energy to offset 30 per cent of the energy usage of the nearby cultural center. The cost of this project was US$ 900,000 (WLRN, 2023).

Figure 15 Solar Panel Roofs at Broward County's basketball courts

Another inspiring example is the Taiwan New Taipei City's basketball court rooftop solar system. It can provide approximately **200 KiloWatt-peak (kWp)** of renewable electricity and offset the equivalent of **171 metric tonnes** of carbon emissions. (EDPR, 2022).

Figure 16 Solar Panel Roofs at Taiwan New Taipei City's basketball court

4.2 CASE STUDY 2

Greenery Integration with Extended Green Wall

4.21 CONCEPT

The existing green walls at the Hillview Community Club (HCC) have shown promise in enhancing the building's sustainability. However, there is significant potential to expand these green walls to other parts of the building to better integrate with the nearby Bukit Timah Nature Reserve. This extension will not only beautify the building's external facades but also further reduce air-conditioning loads, enhancing the building's energy efficiency.

Green walls reduce heat absorption, thus regulating internal temperatures and lessening the need for air-conditioning. This not only enhances indoor comfort but also reduces energy consumption and greenhouse gas emissions.

The existing concrete walls highlighted in Figures X provide an ideal canvas for the extended green walls, with a total surface area of **823 square meters**. Retrofitting these walls with bio-colonization panels can significantly improve the building’s thermal performance. A study in Singapore demonstrated that green walls resulted in indoor temperature reductions of 2.4°C, energy savings of 10.97 MW, positive perceptions from 79% of people, human thermal comfort for 58% of inhabitants, and visual comfort for 89.5%.

Figure 17 Proposed location of Installation

4.22 DESIGN CONCEPT

GREEN WALLS RETROFIT:

The proposed solution involves retrofitting the existing concrete walls with a new type of bio-colonization panels known as **Living Layered Concrete (LLC) panels.** These panels will incorporate advanced irrigation systems, including drip irrigation or capillary mats, to ensure efficient water distribution and plant health. Additionally, utilizing smart irrigation controllers linked to weather data will optimize watering schedules, minimizing water wastage.

Introduction of LLC Panels

The LLC panels are innovative building panels designed to facilitate the growth of plants, particularly non-vascular plants like mosses, fungi, lichens, and algae, directly on vertical concrete surfaces. These panels are developed with specific properties to promote the natural colonization of these plants, providing benefits similar to traditional green walls but with simplified installation and reduced maintenance requirements.

Feature & Concepts of LLC Panels:

- Bio-receptivity: LLC panels are engineered to be bio-receptive, meaning they have properties that encourage the growth and colonization of non-vascular plants without the need for additional substrates like felt or soil. This bio-receptivity is achieved through specific concrete formulations and surface treatments that promote the attachment and growth of plants.

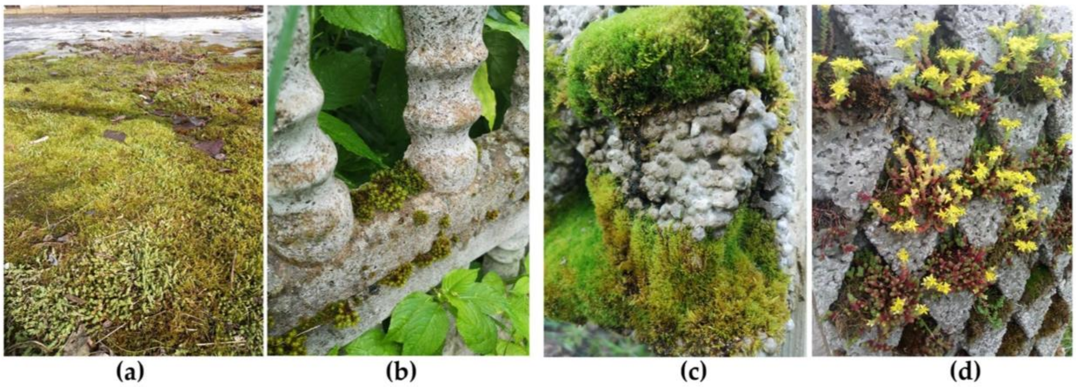


Figure 18 These figures show the growth of moss on the LLC panel two years after installation and the flowering of Sedums on the LLC panel. These images visually demonstrate the bio-receptivity and successful plant colonization of the panels.

- Panel Structure: LLC panels consist of two main layers:
    - Pervious Lightweight Concrete Layer: This layer is characterized by high porosity and permeability, providing an ideal environment for plant colonization. Porosity allows water and air to penetrate, supporting the growth of mosses and other organisms.
    - High-Strength Fiber-Reinforced Concrete Layer (HPC): This layer ensures the structural integrity of the panel, allowing it to be used as a building material while supporting the bio-receptive surface layer.

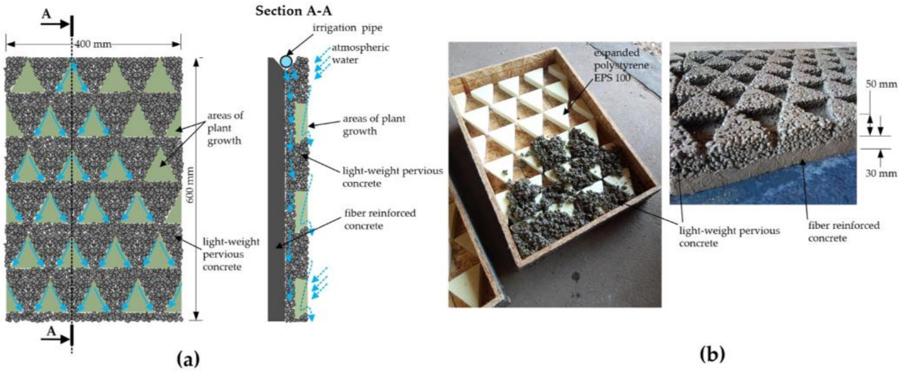


Figure 19 This figure provides a schematic view of the layered segmental concrete panel, illustrating the two main layers: the pervious lightweight concrete layer and the high-strength fiber-reinforced concrete layer.

- Plant Selection and Growth: The LLC panels are specifically designed to host mosses due to their ability to thrive on vertical surfaces and their capacity to absorb moisture and nutrients directly from the air. Mosses are chosen for their suitability in vertical applications and their ability to provide environmental benefits like air filtration and temperature regulation.

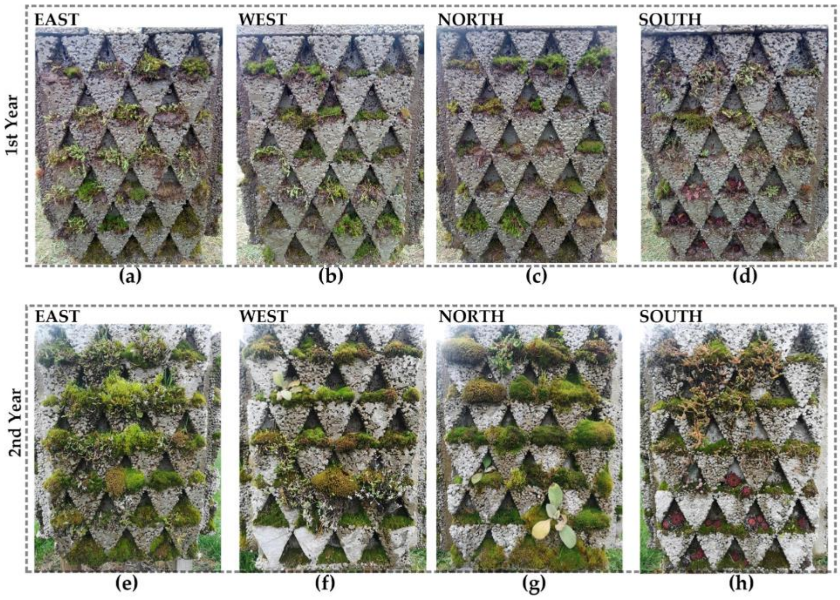


Figure 20 This figure shows plant development on LLC walls of different orientations during the first and second years of field testing. It highlights the suitability of mosses, sedums, and several other lithophyte plant species such as saxifraga and jovibarba.

- Bio-booster Technology: An innovative bio-booster is integrated into the panel to enhance plant growth and colonization. This technology aids in accelerating the initial phase of plant colonization on the concrete surface, promoting the establishment of a sustainable green wall over time.

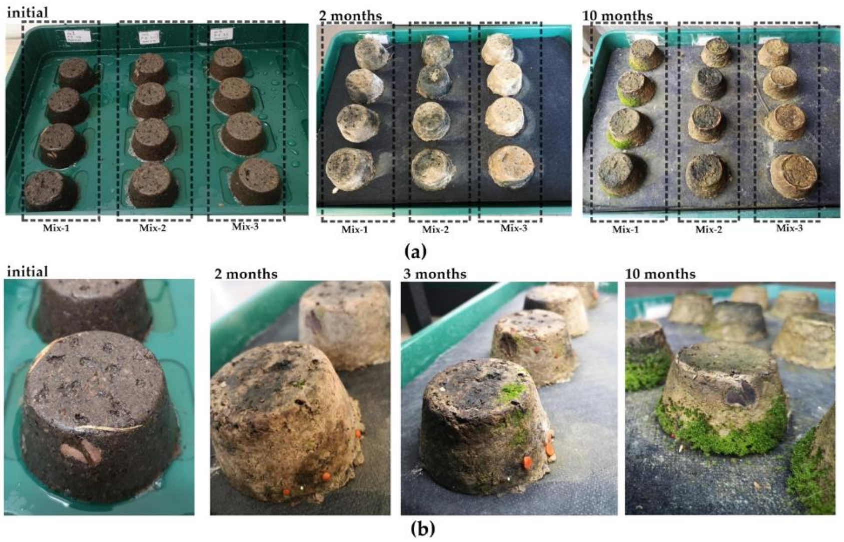


Figure 21 These figures compare plant development on different composition boosters and show the development of fungi and mosses on the booster of Mix-1 composition; mass ratio of recycled paper pulp to forest topsoil: 1:1 (Mix-1),. These images support the innovative bio-booster technology that enhances plant growth and colonization.

- Triangular Surface Texture: The pervious concrete layer is textured with triangular indentations. These indentations serve as planting pockets for the initial manual planting of mosses and indigenous plant species during the setup phase.

Figure 22 This figure shows the production of the wall panel with a triangular indentation pattern created using expanded polystyrene inserts. This visual supports the explanation of the triangular surface textures serving as planting pockets.

- Cost-Effectiveness and Maintenance: One of the main advantages of LLC panels is their potential to significantly reduce the cost of green wall installations. By focusing on non-vascular plants like mosses, LLC panels eliminate the need for complex irrigation systems, fertilizers, and ongoing maintenance typically required by vascular plants used in traditional living wall systems.

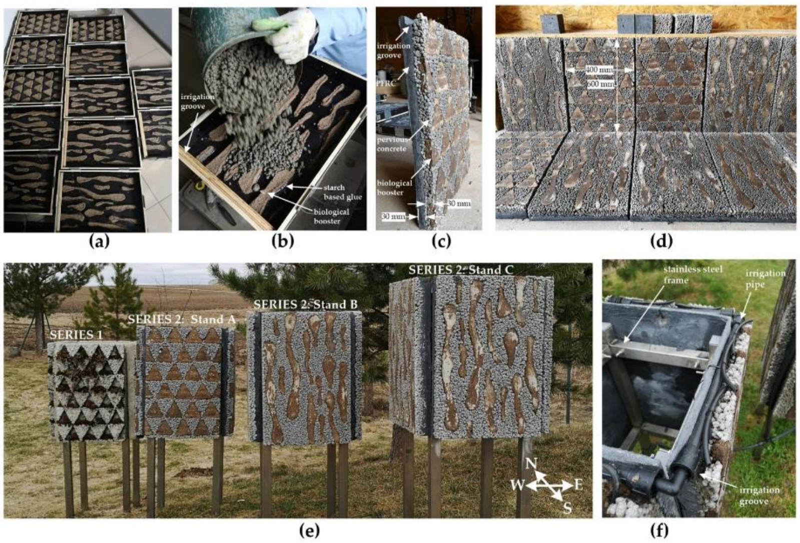


Figure 23 This series of figures demonstrates the production and installation process of the LLC wall panels for Test Series 2. It includes steps such as preparing formworks with bio-booster inserts, pouring the pervious concrete layer, and installing the irrigation system. These images illustrate the practical and cost-effective aspects of LLC panel production and maintenance.

4.23 Feasibility and Design Guidelines:

The study "The Role of Geometry on a Self-Sustaining Bio-Receptive Concrete Panel for Facade Application" conducted by Mustafa, Prieto, and Ottele demonstrates the feasibility of LLC panels through detailed experimental methods and results.

- **Material Composition:** The study starts by creating a concrete mixture that promotes bio-receptivity. The mixture includes blast furnace cement with 75% slag, water/cement ratio of 0.6, and specific sand and gravel sizes. This composition results in highly porous concrete panels ideal for plant colonization.

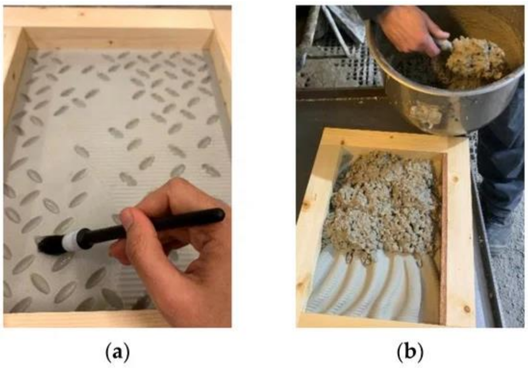


Figure 24 Coating the designed Molds with releasing agent; (b) casting the concrete panel(s).

- **Surface Geometry and Roughness:** The research investigates the role of surface geometry in enhancing bio-receptivity. Panels with different geometrical designs were fabricated to test how surface roughness and geometry affect water retention and plant growth. The study found that panels with prominent surface geometries, such as deep alcoves and grooves, retained more water and promoted better plant growth.

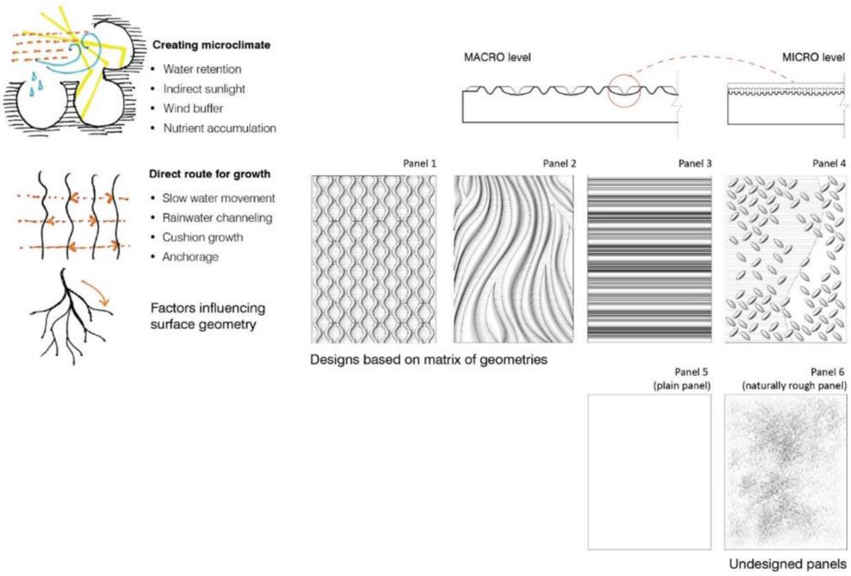


Figure 25 Proposed design scenarios.

- **Water Retention Experiment:** Quantitative measurements for weight, relative humidity, and temperature at several intervals demonstrated that certain geometries improve water retention. Panels with deeper grooves and macro-geometric features showed better water absorption and retention, crucial for supporting moss growth.
- **Moss-Growing Experiment**: Conducted in a controlled greenhouse environment, this experiment tested the ability of the panels to support moss growth. The study inoculated panels with moss spores and monitored their growth over 12 weeks. Panels with specific geometries (e.g., Panel 2) showed the highest levels of bio-colonization, indicating the importance of surface design in promoting plant growth.

Figure 26 Warmer tropical greenhouse (average temperature 20–24 °C).

- **Comparative Analysis:** The study compared the water retention capacities and bio-colonization rates of different panels. It found that geometry plays a significant role in creating microclimates conducive to plant growth. Panels with macro-depths and micro-grooves facilitated better water catchment and retention, essential for sustained plant growth.

Figure 27 Geometric features to enhance bio-receptive qualities in comparison to natural surfaces.

- **Design Guidelines:** Based on the experimental results, the study formulated design guidelines for creating bio-receptive concrete panels. These guidelines emphasize the importance of combining macro-depths with micro-grooves and using continuous flow geometries to enhance water retention and plant growth.

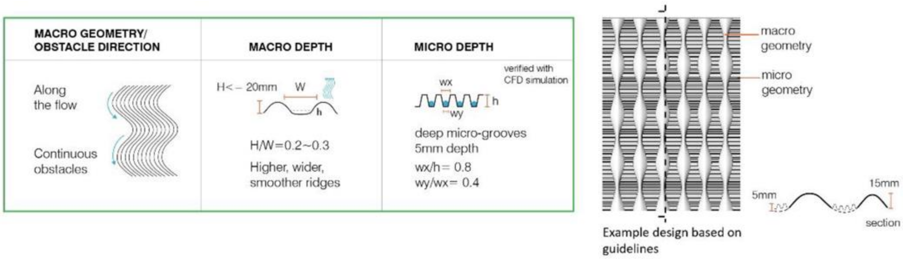


Figure 28 The pros and cons of the geometry features of the chosen panels.

4.24 Design Influence

The research confirms the feasibility of LLC panels for sustainable green wall applications. The detailed experiments and design guidelines ensure the effectiveness of these panels in promoting plant growth, improving air quality, and reducing maintenance costs. For the Hillview Community Center wall, the LLC panels will be designed with the following considerations:

1. High porosity concrete with specific formulations for bio-receptivity.
2. Macro-depths and micro-grooves to enhance water retention and promote plant growth.
3. Integration to accelerate initial plant colonization.
4. Focus on non-vascular plants to reduce installation and maintenance costs.

4.25 Adaptability for Retrofitting (in response to existing concrete wall)

LLC panels are designed to be highly adaptable, making them suitable for retrofitting onto existing concrete walls. This feature allows for the enhancement of current building facades without the need for extensive structural modifications. The key aspects of this adaptability include:

1. Compatibility with Existing Structures:
    - LLC panels can be seamlessly attached to existing concrete walls using standard mounting techniques. This ensures that the panels are securely fixed while maintaining the structural integrity of the original wall.
2. Surface Integration:
    - The bio-receptive surface of LLC panels, characterized by its triangular indentations and specific concrete formulations, can be integrated with existing walls. This integration promotes plant growth directly on the panel surface, transforming the aesthetic and functional properties of the existing wall.
3. Lightweight Design:
    - The pervious lightweight concrete layer reduces the overall weight of the LLC panels. This lightweight nature makes the panels easier to handle and install on existing structures without adding significant load.
4. Structural Support Layer:
    - The high-strength fiber-reinforced concrete layer (HPC) ensures that the LLC panels provide additional structural support while being retrofitted. This layer contributes to the durability and longevity of the panels when installed on existing walls.
5. Minimal Disruption:
    - Installing LLC panels on existing walls involves minimal disruption to the building's operation and occupants. The installation process is streamlined, reducing the time and labor required for retrofitting.

4.26 Implementation Process:

When installing LLC (Layered Living Concrete) panels onto an existing concrete wall, several critical steps and considerations ensure proper installation and the effective growth of plants over time.

1. Wall Preparation

- **Cleaning:** Thoroughly clean the existing concrete wall surface to remove dirt, dust, and debris. Use a pressure washer or scrubbing brush along with water and mild detergent if necessary.
- **Inspection and Repair:** Inspect the wall for cracks, holes, or other damage. Repair these areas using appropriate concrete patching materials to ensure a smooth and uniform surface.

2. Selection and Preparation of LLC Panels

- **Panel Selection:** Choose LLC panels that are suitable for the specific wall dimensions and desired aesthetic. Ensure the panels have the necessary layers (pervious concrete, bio-booster, and HPC) for optimal plant growth.
- **Planting Pockets:** If the LLC panels require manual planting of initial vegetation (such as mosses or indigenous plant species), prepare these planting pockets or indentations as per the panel design.

3. Installation Process

- **Fastening Systems:** Attach the LLC panels securely to the existing concrete wall using appropriate fastening systems. Options include:
    - **Mechanical Anchors:** Expansion anchors or screw anchors drilled into the existing concrete wall provide strong resistance against pulling forces and securely hold the LLC panels in place.
    - **Adhesive Anchors:** Specialized chemical adhesives can bond mounting hardware directly to the concrete surface, providing a strong and durable connection.
- **Leveling and Spacing:** Ensure that the panels are level and evenly spaced for a cohesive look.
- **Bio-Booster Application:** If the LLC panels include a bio-booster layer, apply this mixture over the pervious concrete layer according to the manufacturer's instructions. Ensure even distribution and proper adhesion to the concrete surface.

4. Irrigation and Maintenance

- **Irrigation System:** Implement an irrigation system if necessary to ensure adequate moisture levels for plant growth. This system may involve drip irrigation or periodic manual watering.
- **Monitoring:** Regularly monitor the LLC panels for plant growth and health. Prune or replace vegetation as needed to maintain the desired aesthetic and promote healthy growth.

5. Long-Term Considerations

- **Natural Colonization:** Over time, monitor the LLC panels for natural colonization by mosses, fungi, lichens, and algae. Allow the panels to evolve naturally and adapt to changing environmental conditions.
- **Climate Considerations:** Consider the local climate and environmental factors when selecting plant species and maintaining the LLC panels. Some plants may thrive better than others based on sunlight exposure, humidity levels, and temperature fluctuations.

6. Regular Inspections

- **Inspection Routine:** Conduct regular inspections of the LLC panels to check for any signs of deterioration or damage. Address any issues promptly to ensure the longevity and effectiveness of the green facade.

4.27 Implementation to Hillview Community Centre, Singapore, Context

The Layered Living Concrete (LLC) panel concept presents an innovative approach to sustainable urban greening that could be well-suited for Singapore's climate. Singapore's tropical rainforest climate, characterized by high humidity and frequent rainfall, provides an ideal backdrop for the growth of plants essential for the LLC panels' greening effect. The average temperature ranges between 25°C and 31°C. Thunderstorms occur on 40% of all days, and relative humidity is between 70% and 80%. April is the warmest month, January is the coolest, and November is the wettest. LLC panels can capitalize on these moisture-rich conditions to sustain plant growth without heavy reliance on artificial irrigation systems. Furthermore, sunlight exposure is crucial for photosynthesis and plant development, which the LLC panels can harness efficiently without overheating.

Implementing LLC panels at the Hillview Community Center can significantly enhance local biodiversity. The panels support the growth of non-vascular plants such as mosses, fungi, and lichens, which can create microhabitats for various small organisms. Over time, this can attract a diverse range of insects and small animals, contributing to a richer urban ecosystem. This biodiversity can benefit the community by improving air quality, providing educational opportunities, and creating a more pleasant and engaging environment.

Concrete Example: At The Bartlett School of Architecture, LLC facade panels have been installed to promote biodiversity. These panels support the growth of a variety of plants and contribute to local biodiversity by providing habitats for insects and birds. Similarly, at the Hillview Community Center, LLC panels can serve as living laboratories, where students and community members can observe and learn about local flora and fauna, fostering a deeper connection to nature and awareness of environmental issues.

Figure 29 Results of experiments from Professor Marcos Cruz and lecturer Richard Beckett in Bartlett School of Architecture at University College London. Which they have been researching how concrete can be made more bioreceptive, and have developed facade panels specially designed to encourage the growth of cryptogams.

4.28 Plant Survival under Harsh Sun in Singapore (Feasibility Studies)

The LLC panels are specifically designed to host non-vascular plants such as mosses, lichens, and certain types of hardy plants that are well-adapted to vertical surfaces and can thrive under varying environmental conditions, including exposure to harsh sunlight. Mosses are highly adaptable, capable of thriving in both shaded and sunny environments, and possess mechanisms to withstand periods of dryness by quickly rehydrating when moisture is available. Similarly, hardy succulents like Sedums can store water in their leaves, allowing them to survive prolonged periods of sunlight and dryness, making them ideal for green walls due to their drought-resistant properties. Additionally, the triangular indentations in the LLC panels create microclimates that reduce direct sun exposure on plant surfaces, helping to retain moisture and protect plants from extreme heat. The pervious lightweight concrete layer in the LLC panels also retains water, providing a consistent moisture source crucial for plant survival during intense sunlight periods.

Concrete Example: Singapore highlight the feasibility of green walls in harsh sun conditions. At Changi Airport, green walls use a variety of plant species that thrive in the tropical climate, demonstrating the effectiveness of vertical gardens in such environments. Similarly, the PARKROYAL on Pickering hotel features extensive vertical gardens with plants selected for their ability to withstand Singapore’s climate. These installations showcase that with appropriate plant selection and design, green walls can flourish in sunny, tropical environments. Research conducted at institutions like The Bartlett School of Architecture further supports that bioreceptive concrete panels can support a variety of plant species in different climates, reinforcing that LLC panels, with the right combination of plant species and design elements, can provide a robust and resilient green infrastructure solution for urban areas in Singapore.

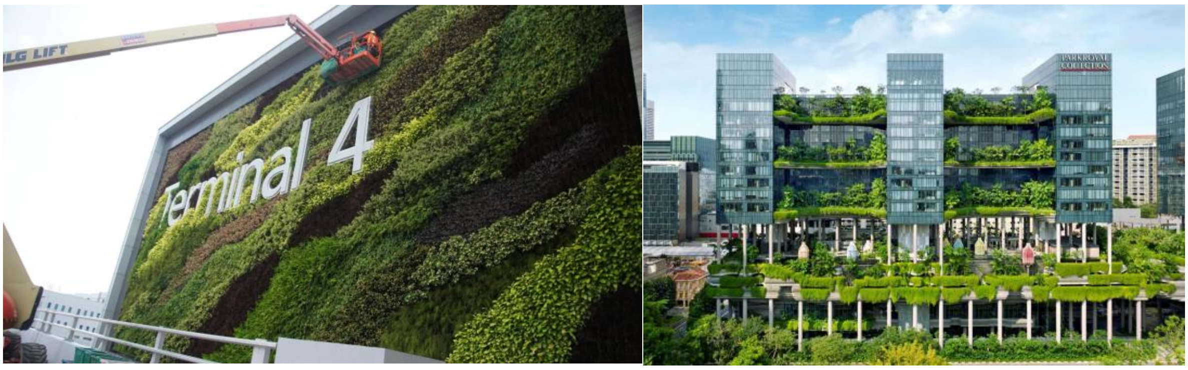


Figure 30 (Right) Changi Airport Green Wall. (Left) Green integration in PARKROYAL Hotel.

4.29 Conclusion and Feasibility

Based on the research, LLC panels demonstrate significant feasibility for sustainable green wall installations. They offer a cost-effective, low-maintenance solution that promotes biodiversity, improves air quality, and enhances thermal regulation. The use of bio-receptive concrete and innovative bio-booster technology ensures robust plant growth and long-term sustainability.

4.3 DESIGN CONCEPT PART 2 (Continued)

WATER INTEGRATION SYSTEM:

Implementing an effective water integration system is crucial to support the sustainability and longevity of Layered Living Concrete (LLC) panels used for green wall applications, especially in a climate like Singapore's. A well-designed water integration system ensures optimal moisture levels for plant growth, minimizes water wastage, and contributes to the overall efficiency of the green facade. Here's a detailed outline of a water integration system suitable for supporting LLC panels:

Drip Irrigation System with Smart Controllers

A drip irrigation system is an ideal choice for watering LLC panels, providing targeted and efficient water distribution directly to the plant roots. This system consists of a network of tubing with emitters strategically placed along the LLC panels. The emitters deliver water in controlled drips, minimizing runoff and evaporation while maximizing plant uptake.

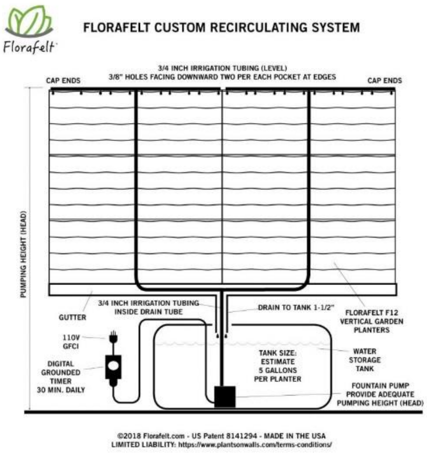


Figure 31 Recirculating System Overview

4.31 Components and Design

The drip irrigation system includes:

- Main Water Supply: A reliable water source, such as a municipal water line or rainwater harvesting system, supplies water to the irrigation system.
- Filter and Pressure Regulator: A filter is installed to remove debris and sediment from the water, ensuring clean water reaches the emitters. A pressure regulator maintains consistent water pressure throughout the system.
- Tubing and Emitters: High-quality, UV-resistant tubing distributes water along the LLC panels. Inline emitters or micro-sprinklers are spaced evenly to deliver water directly to the base of each LLC panel, ensuring uniform moisture distribution.
- Smart Irrigation Controller: Integrating a smart irrigation controller enhances water efficiency by adjusting watering schedules based on real-time weather data, plant needs, and local climate conditions. These controllers can be programmed remotely and may incorporate sensors to measure soil moisture levels, temperature, and humidity.

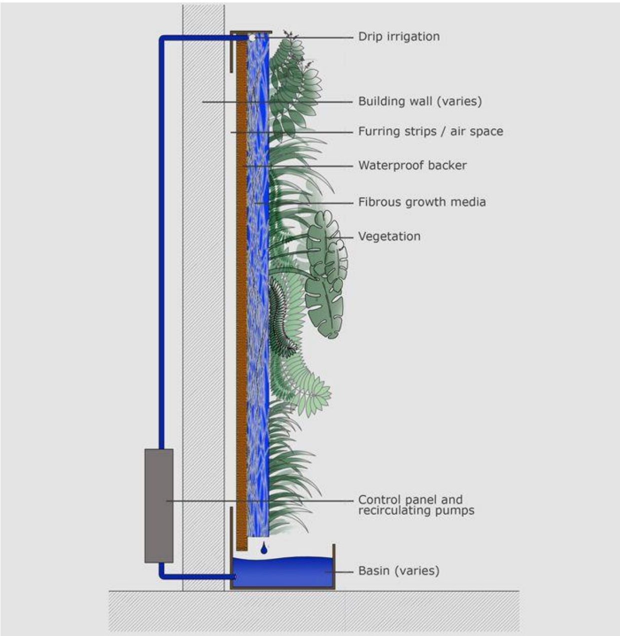


Figure 32 Living wall / green wall projects, featuring Furbish's BioWall

4.32 Use of Non-Potable Water Tank

To further support the sustainability of the water integration system, non-potable water from tanks already implemented on the building's roof can be used. This approach not only conserves potable water but also takes advantage of the existing infrastructure to enhance the efficiency and environmental impact of the green wall. The Hillview Community Center is equipped with the following water sources that can be utilized for the drip irrigation system:

1. **Rainwater Harvesting Tanks**: The building is designed with rainwater harvesting systems that collect and store rainwater. These tanks capture runoff from the roof, providing a sustainable and ample water supply that can be used for irrigating the LLC panels. The stored rainwater is naturally collected and can be filtered and distributed through the drip irrigation system.
2. **Non-Potable Water Storage Tanks**: Additional non-potable water storage tanks are installed on the roof and other strategic locations within the building. These tanks can store supplementary water from various non-potable sources, ensuring a consistent water supply for the drip irrigation system, even during dry periods.

The Hillview Community Center may also implement a greywater recycling system that treat and reuse water from sinks, showers, and other non-potable sources within the building. This recycled greywater can be a reliable source for the irrigation system, reducing the demand on municipal water supplies.

Water Requirements for Vegetation

According to guidelines, mosses require regular misting and watering about twice a week. For example, moss of 16 inches needs approximately 9.3 cups (2.2 liters) of water every 16 days. This translates to around 0.1375 liters per day for a 16-inch square. Scaling this up:

- Water Requirement for Moss: 0.1375 liters/day for a 16-inch square.
- Equivalent for 1 Square Meter: Approximately 12 times the area of 16 inches square, requiring around 1.65 liters/day per square meter.

Given Singapore's climate and the need for regular watering:

- Water Requirement for LLC Panels: Approximately 1.65 liters/day per square meter for mosses and other similar vegetation.

4.33 Total Water Requirement for Each Green Wall

Using the above water requirements:

- Green Wall 1 (185m²): 185 * 1.65 = 305.25 liters/day
- Green Wall 2 (220m²): 220 * 1.65 = 363 liters/day
- Green Wall 3 (225m²): 225 * 1.65 = 371.25 liters/day
- Green Wall 4 (100m²): 100 * 1.65 = 165 liters/day
- Green Wall 5 (180m²): 180 * 1.65 = 297 liters/day

Cumulative Daily Water Requirement:

- Total: 1,501.5 liters/day for all green walls.

By leveraging non-potable water from existing roof tanks, the LLC panels can be effectively maintained, ensuring sustainability and efficiency while providing the necessary hydration for plant survival and growth in Singapore's challenging climate.

4.34 Smart Watering Controls

To optimize water, use and prevent over-watering, smart irrigation controllers play a crucial role. These controllers adjust watering schedules based on real-time weather data, ensuring that the plants receive adequate moisture without wasting water. In high-moisture environments or during periods of rainfall, the smart controllers reduce or halt the watering process, preventing over-watering and conserving water resources.

- **Rain and Moisture Sensors:** These sensors detect rainfall and high moisture levels, automatically adjusting the irrigation schedule to reduce water delivery when natural precipitation is sufficient.
- **Remote Monitoring and Adjustments:** The smart controllers can be monitored and adjusted remotely, allowing for real-time management of the irrigation system. This flexibility ensures that the green wall system remains efficient and responsive to changing weather conditions.

By leveraging these advanced technologies, the LLC panels' water integration system can maintain optimal moisture levels for plant growth while minimizing water wastage and maximizing sustainability.

4.4 DESIGN CONCEPT PART 3 (Continued)

4.41 Comparisons, Feasibility & Benefits of LLC Panels

Why LLC is a Good Investment Choice Compared to Other Types of Green Walls

Figure X presents various types of vertical greenery systems, categorized into ground-based and wall/structure-based systems, ranging from extensive to intensive types. LLC (Layered Living Concrete) panels offer several advantages that make them a superior investment choice compared to the other types:

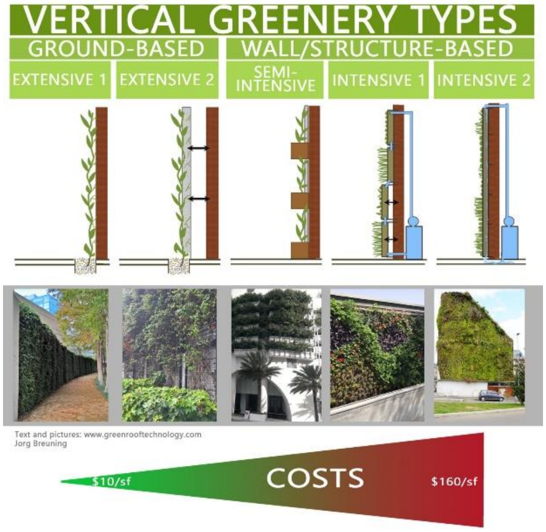


Figure 33 Green Wall Types

1. Cost-Effectiveness

- **Lower Installation and Maintenance Costs**: LLC panels are designed to host non-vascular plants like mosses and lichens, which do not require complex irrigation systems, fertilizers, or frequent maintenance. This reduces both initial installation and ongoing maintenance costs.
- **Durability and Longevity**: The high-strength fiber-reinforced concrete layer of LLC panels ensures structural integrity and longevity, making them a more durable option compared to other green wall systems that may require more frequent repairs or replacements.

2. Water Integration System

- **Efficient Water Use**: The drip irrigation system integrated into LLC panels provides targeted and efficient water distribution directly to plant roots, minimizing water wastage. This system, combined with smart controllers, optimizes water usage based on real-time weather data, making it more efficient than the water systems used in other green wall types.

- **Moisture Retention**: The pervious lightweight concrete layer in LLC panels retains water, providing a consistent moisture source for the plants, which is crucial in climates like Singapore's. This reduces the need for artificial irrigation and makes the system more sustainable.

3. Adaptation to Climate

- **Suitable for Harsh Sunlight**: LLC panels are designed to support hardy plants such as mosses and succulents that can thrive under varying environmental conditions, including exposure to harsh sunlight. The triangular surface textures create microclimates that help retain moisture and protect plants from extreme heat, ensuring their survival and growth.
- **Biodiversity Enhancement**: LLC panels support a diverse range of plant species, contributing to urban biodiversity. This makes them more versatile and beneficial for the environment compared to more traditional green wall systems that may only support a limited range of plants.

4. Integration and Aesthetic Appeal

- **Versatility in Design**: LLC panels can be integrated into various building facades, providing both aesthetic and functional benefits. The ability to incorporate bio-receptive surfaces with different textures and shapes allows for greater design flexibility.
- **Urban Heat Island Mitigation**: By enhancing the thermal regulation of buildings, LLC panels help reduce the urban heat island effect, improving the overall microclimate of urban areas. This benefit is particularly valuable in dense urban settings like Singapore.

4.42 Estimated Cost of Implementation of LLC Panels

1. Material Costs

- **Concrete Panels**
  - **High-Strength Fiber-Reinforced Concrete Layer**: $68 to $102 per square meter.
  - **Pervious Lightweight Concrete Layer**: $68 to $102 per square meter.
- Vegetations
  - Non-Vascular Plants (Mosses, Lichens): $14 to $27 per square meter.
  - Hardy Succulents (Sedums): $27 to $41 per square meter.
- Panel Fastening Systems
  - Mechanical Anchors: $5 to $10 per square meter.
  - Adhesive Anchors: $10 to $15 per square meter.
  - Leveling and Spacing: $2 to $4 per square meter for labor.
- Bio-Booster Application: $10 to $15 per square meter for the bio-booster mixture.

2. Irrigation System

- **Drip Irrigation Components:**

- **Florafelt Irrigation Control Box:** $295.00 (one-time cost, distribute across the total area)
- **Drip Tubing & Emitter Kit:** $90.00 per kit (estimate one kit per 10 square meters)
- **Florafelt Irrigation Timer for Large Walls:** $195.00 (one-time cost, distribute across the total area)
- **Florafelt Slimline Drain Tray:** $65.00 per tray (estimate one tray per 10 square meters)
- **EPDM Pond Liner:** $5.00 per square meter
- **Florafelt Pro System Drain Tray:** $36.00 per tray (estimate one tray per 10 square meters)
- **Woods Digital Timer:** $39.00 (one-time cost, distribute across the total area)
- **Jebao Water Pump:** $41.00 per pump (estimate one pump per 20 square meters)
- **Florafelt Recirc Tubing Kit**: $79.00 per kit (estimate one kit per 10 square meters)
- **Florafelt WIFI Moisture Sensor:** $75.00 per sensor (estimate one sensor per 20 square meters)
- **Dosatron Fertilizer Injector:** $395.00 (one-time cost, distribute across the total area)

3. Installation Costs

- Labor Labor Costs: $68 to $95 per square meter.
- Scaffolding and Equipment Scaffolding: $13 to $20 per square meter.
- Connection Systems: $13 to $27 per square meter.

Summary of Total Initial Costs per square meter

- Minimum: $204 + $94 + $38.93 = $336.93
- Maximum: $316 + $142 + $38.93 = $496.93

<u>Individual Green Wall Location Costs using LLC Panels</u> (rounded up to thousands)

- Green Wall 1: $63,000 to $92,000
- Green Wall 2: $75,000 to $110,000
- Green Wall 3: $76,000 to $112,000
- Green Wall 4: $34,000 to $50,000
- Green Wall 5: $61,000 to $90,000

Cumulative Cost: $309,000 to $454,000

4.43 Environmental Benefits of Implementing LLC Panels at Hillview Community Center

Implementing Layered Living Concrete (LLC) panels on the existing concrete walls of the Hillview Community Center, which face north, south, and east, and covering spaces such as fire-escape staircases, functioning rooms, and open spaces, can bring significant environmental benefits. These benefits include enhanced biodiversity, improved air quality, thermal regulation, water conservation, and aesthetic enhancement. Below are the detailed environmental benefits, supported by statistical data.

Detailed Calculation of CO2 Reduction Using LLC Panels

Improved Air Quality

Pollutant Absorption:

- According to Ecobnb, one square meter of living wall can extract 2.3 kg of CO2 per annum.

Assumptions:

- Total area of LLC panels installed: 1,000 square meters.

Annual CO2 Reduction Calculation:

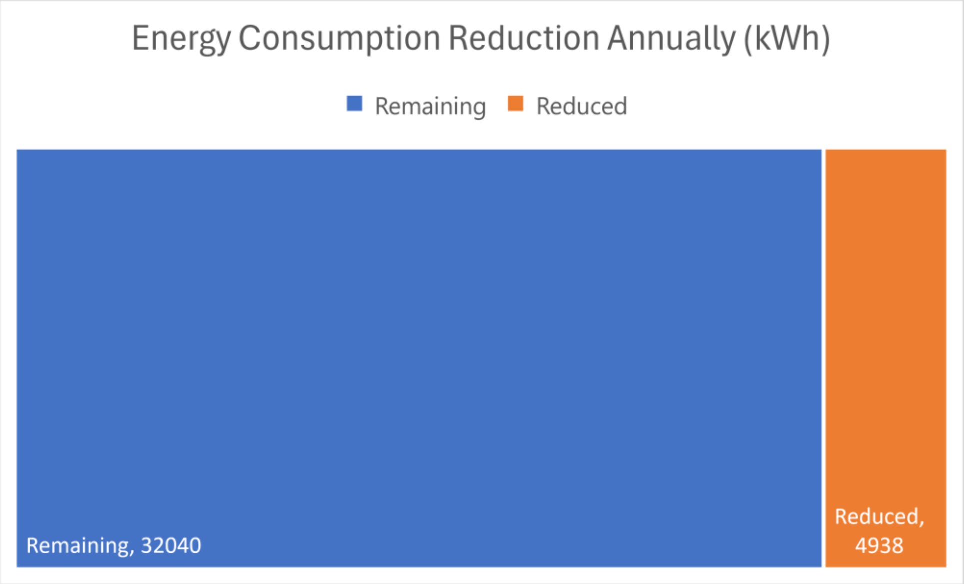
Total CO2 Reduction=Total Area×CO2 Absorption per sq meter\text{Total CO2 Reduction} = \text{Total Area} \times \text{CO2 Absorption per sq meter}Total CO2 Reduction=Total Area×CO2 Absorption per sq meter
Total CO2 Reduction=1,000 sq meters×2.3 kg CO2/sq meter/year\text{Total CO2 Reduction} = 1,000 \, \text{sq meters} \times 2.3 \, \text{kg CO2/sq meter/year}Total CO2 Reduction=1,000sq meters×2.3kg CO2/sq meter/year
Total CO2 Reduction=2,300 kg CO2/year\text{Total CO2 Reduction} = 2,300 \, \text{kg CO2/year}Total CO2 Reduction=2,300kg CO2/year

Summary of Benefits:

1. Improved Air Quality:
   - CO2 Absorption: 2,300 kg of CO2 per year**.**
   - Oxygen Production**:** Each square meter produces 1.7 kg of oxygen annually, contributing to a healthier environment.
2. Thermal Regulation and Energy Savings:
   - Heat Island Effect Mitigation: Reduction of surrounding air temperature by up to 10 degrees Celsius.
   - Insulation: Reduction of surface temperatures by up to 12 degrees Celsius, lowering energy costs by up to 23%.

Energy Consumption Reduction: Potential reduction of 3-6 kWh per square meter annually, totaling a maximum of 4,938 kWh annually.

The potential reduction of 4,938 kWh annually through the use of LLC panels would result in a CO2 reduction of approximately <u>2,056.16 kg CO2 per year.</u>



3. **3.** Water Conservation:
    - Efficient Water Use: Smart drip irrigation system fed by non-potable water from rainwater harvesting and greywater recycling.
    - Daily Water Requirement: Approximately 1,358.95 liters/day for all LLC panels.
4. **4.** Enhanced Biodiversity:
    - Habitat Creation: LLC panels provide habitats for insects, birds, and other small wildlife, increasing local biodiversity.

Conclusion:

The installation of 1,000 square meters of LLC panels at Hillview Community Center can reduce CO_2 emissions by 2,300 kg annually, significantly improve air quality, and contribute to energy savings through thermal regulation. Additionally, the panels will support water conservation efforts and enhance local biodiversity, aligning with the sustainability goals of the Green Mark certification.

4.44 HUMAN-CENTRIC DESIGN WITH LLC PANELS

Integrating LLC panels into the existing concrete walls of the Hillview Community Center not only enhances environmental sustainability but also significantly contributes to a human-centric design. This approach focuses on creating spaces that improve the well-being, comfort, and quality of life for the community members. Below is an outline of how human-centric design principles are related to the proposal of LLC panels for each specific green wall placement.

Green Wall 1 (185 m²) - Facing South, Basketball Court

- **Visual Appeal and Engagement:** The green wall facing the basketball court enhances the aesthetic appeal of the area, creating a more inviting and engaging environment for sports and recreational activities.

- **Thermal Comfort:** The green wall provides shade and cooling effects, making the outdoor space more comfortable for players and spectators, reducing the need for artificial cooling.
- **Noise Reduction**: By acting as a natural sound barrier, the green wall helps reduce noise pollution from the basketball court, contributing to a more pleasant environment for nearby residents and users.

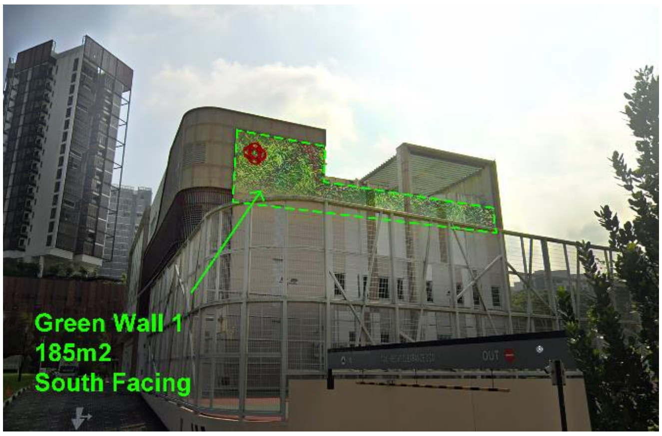


Figure 34 Location of LLC Panel, Green Wall 1

Green Wall 2 (220 m²) - Facing North, Roads and Residential Buildings

- **Aesthetic Enhancement**: Transforming a bare concrete wall into a lush, green facade enhances the visual appeal of the neighborhood, promoting a sense of well-being and pride among residents.
- **Noise Mitigation:** The green wall acts as a buffer, reducing traffic noise and creating a quieter, more peaceful residential environment.

Figure 35 Location of LLC Panel, Green Wall 2

Green Wall 3 (225 m²) - Facing Key Roads and Pedestrians

- **Pedestrian Experience**: Enhancing the walking experience with a visually appealing green wall can encourage walking and outdoor activities, contributing to better physical health.
- **Urban Cooling:** The cooling effect of the green wall can lower the temperature along key pedestrian pathways, making them more comfortable during hot days.
- **Biodiversity**: Introducing green spaces along pedestrian routes fosters urban biodiversity, creating opportunities for community members to connect with nature.

Green Wall 4 (100 m²) - Roof Playground Walls

- **Safety and Comfort**: The green wall at the roof playground enhances safety by providing a softer surface compared to bare concrete, and its cooling effects make the playground more comfortable for children.
- **Educational Opportunities:** The green wall serves as a living laboratory, offering educational opportunities for children to learn about plants, ecology, and sustainability.
- **Play Environment**: Creating a green, vibrant play environment stimulates children's imagination and promotes active play, contributing to their overall development and well-being.

Figure 36 Location of LLC Panel, Green Wall 3 & 4

Green Wall 5 (180 m²) - First Storey, Semi-Open Interior Facing Entrance

- **Welcoming Atmosphere**: A green wall at the entrance of the community centre creates a welcoming and calming atmosphere, making visitors feel more at ease and connected to nature.
- **Indoor Air Quality**: Improving indoor air quality by incorporating green walls in semi-open spaces helps reduce stress and enhance the health and well-being of visitors and staff.

- **Aesthetic Integration**: Integrating green walls within the building aligns with biophilic design principles, which advocate for incorporating natural elements into built environments to enhance human health and productivity.

Figure 37 Location of LLC Panel, Green Wall 5

User and Community Connection

The implementation of Layered Living Concrete (LLC) panels at the Hillview Community Center offers numerous opportunities for fostering a stronger connection between users and the community. Green walls serve not only as functional elements but also as interactive and educational resources that promote environmental awareness and community engagement.

Visual Appeal and Aesthetic Enhancement

The introduction of green walls transforms the Hillview Community Center into a visually appealing and inviting space. The lush, green facades provide a stark contrast to the urban concrete environment, creating a sense of tranquility and beauty. This aesthetic enhancement encourages community members to spend more time at the center, engaging in various activities and enjoying the natural surroundings.

Educational Opportunities

Learning and Awareness

Green walls can serve as living laboratories, offering educational opportunities for both children and adults. Schools and educational groups can organize tours and workshops to learn about the plants, ecology, and the environmental benefits of green infrastructure. Informational plaques and QR codes linked to detailed online content can provide visitors with in-depth knowledge about the specific plant species, their role in the ecosystem, and the benefits they bring to urban environments.

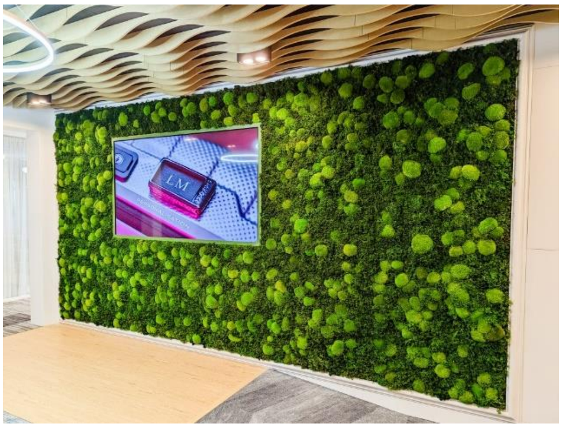


Figure 38

Interactive Experiences

Interactive features such as guided planting sessions, community gardening events, and hands-on workshops can be integrated into the green wall areas. These activities allow community members to participate directly in the care and maintenance of the green walls, fostering a sense of ownership and pride in their local environment. This hands-on involvement helps build a stronger community bond and a shared commitment to sustainability.

Figure 39

Health and Well-being

Mental and Physical Health Benefits

Exposure to greenery and natural environments has been shown to reduce stress, lower blood pressure, and improve overall mental health. The presence of green walls at the Hillview Community Center provides a calming and restorative environment for visitors, contributing to better mental well-being. Additionally, the improved air quality resulting from the green walls' pollutant-absorbing capabilities enhances physical health, making the community center a healthier place to visit and spend time.

Figure 40

<u>Encouraging Physical Activity</u>
The green walls can encourage more physical activity by making the community center and its surroundings more pleasant and inviting. Improved aesthetics and air quality can motivate people to walk, jog, or engage in outdoor activities, contributing to better physical health. For example, the green wall facing the basketball court enhances the visual appeal and comfort of the area, making it more attractive for sports and recreational activities.

Figure 41

Social Interaction and Community Building

<u>Creating Gathering Spaces</u>
Green walls can help create inviting gathering spaces where community members can socialize and interact. The improved aesthetics and comfort of these spaces encourage people to come together, fostering social interaction and community building. For instance, the green wall at the entrance of the community center provides a welcoming atmosphere, making it a natural meeting point for visitors.

Figure 42

Promoting Environmental Stewardship

By involving the community in the care and maintenance of the green walls, a sense of environmental stewardship is cultivated. Community members who participate in planting and maintenance activities develop a deeper appreciation for nature and sustainability. This shared responsibility promotes a culture of environmental awareness and collective action towards a greener and more sustainable future.

Figure 43 Residents of Seattle's South Park immigrant community build the kind of walls they can support

4.5 CASE STUDY 3

"Growing With Us" – Community Farming

4.51 GENERAL CONCEPT

The Hillview Community Garden project seeks to transform Hillview Community Club into a centre for sustainability and community engagement through innovative hydroponic farming. This initiative will not only connect residents and educate them on sustainable practices but also promote filial piety and intergenerational interaction, which are vital components of a cohesive society. The project will foster a sense of community responsibility and environmental stewardship. We anticipate considerable reductions in energy and water consumption, as well as an increase in recycling rates, thus contributing to a more sustainable and engaged community.

We propose to introduce this community farming project at three strategic locations.

4.52 Design Concept

Location 1: Children's Playground at the Rooftop:

Figure 44 Rooftop Children's Playground, hydroponic farming

Educational Integration:

- **Interactive Learning Environment:**

Experiential Learning: The placement of a hydroponic garden adjacent to the children's playground creates an enriching environment where play meets education. Children can actively participate in gardening activities during their playtime, such as planting seeds, tending to the plants, and observing the growth process. This hands-on approach not only makes learning enjoyable but also instils an early interest in environmental stewardship and sustainability.

Sensory Engagement: Gardening engages multiple senses – sight, touch, smell, and sometimes taste – which can enhance children's learning experiences. For instance, children can feel the texture of leaves, smell the herbs, and see the vibrant colors of various plants, making the learning process more immersive and memorable.

Workshops and Activities:

Tailored Educational Programs: The rooftop garden will host a variety of workshops and activities specifically designed for children. These programs can cover topics such as the life cycle of plants, the importance of water conservation, and the benefits of growing one's own food. By participating in these workshops, children can gain a deeper understanding of natural processes and the impact of human activities on the environment.

Seasonal Activities: Throughout the year, different gardening activities can be organized based on the seasons. For example, spring planting, summer care, autumn harvest, and winter preparations. These seasonal activities not only teach children about the cyclical nature of agriculture but also keep them engaged and excited about the garden.

- **Safety and Accessibility:**

Secure Environment: The rooftop playground is designed to be a safe, enclosed space where children can explore freely under the supervision of caregivers and staff. This secure environment ensures that children can engage with the hydroponic garden without the risk of wandering off or encountering potential hazards.

Supervised Activities: All gardening activities will be conducted under the watchful eyes of trained staff or volunteers, ensuring that children can participate safely. This supervision provides peace of mind for parents and allows children to explore the garden confidently.

- **Engagement with Parents:**

Family Bonding: The garden provides a unique opportunity for parents to engage in meaningful activities with their children. Parents can join their children in planting, watering, and harvesting, creating shared experiences that strengthen family bonds. These activities offer parents a chance to teach their children about sustainability while spending quality time together.

Parental Education: While children are learning, parents can also gain valuable knowledge about hydroponic farming and sustainable practices. This dual-learning environment encourages families to adopt and promote sustainable habits at home, extending the benefits of the project beyond the community garden.

Location 2: Outside the Childcare Centre on the First Floor:

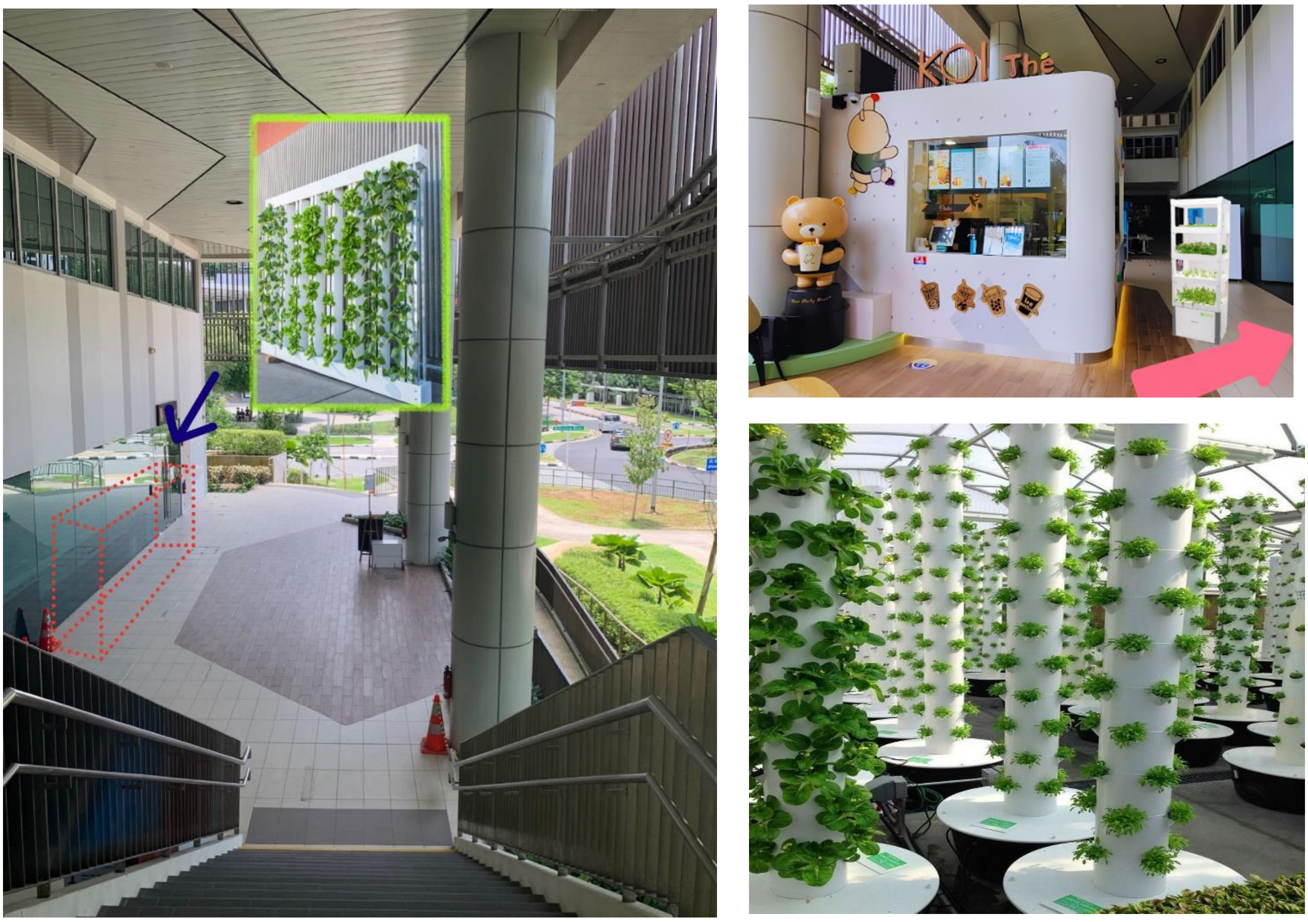


Figure 46 Outside Childcare Centre

Convenience and Visibility:

- **High Foot Traffic:**

Daily Exposure: The area outside the childcare center is one of the busiest spots within the community club, with parents, children, and staff passing by multiple times a day. Placing the hydroponic garden here ensures it receives constant visibility, sparking curiosity and encouraging engagement from everyone who passes by.

Routine Interaction: The regular foot traffic means that the garden becomes a familiar part of the daily routine for many residents. Children can observe the growth and changes in the garden every day, fostering a continuous learning process. Parents and staff will also interact with the garden frequently, making it a central feature of the community's daily life.

- **Daily Integration:**

Incorporation into Curriculum: The proximity to the childcare center allows the garden to be seamlessly integrated into the educational curriculum. Teachers can plan regular visits to the garden as part of their lessons, providing children with hands-on learning experiences related to science, nutrition, and ecology.

Regular Care and Maintenance: Having the garden just outside the childcare center makes it easy for children and staff to participate in its care. Simple tasks like watering the plants or checking for growth can be incorporated into the daily schedule, making the garden a living classroom that evolves with the children's involvement.

Community Involvement:

- **Parental Participation:**

Drop-off and Pick-up Engagement: Parents dropping off and picking up their children can easily get involved in the garden's activities. This could be as simple as spending a few minutes helping with tasks like watering or harvesting. This routine involvement helps to foster a sense of community and shared responsibility for the garden's success.

Family Involvement: Parents can take what they learn from the garden and apply it at home, possibly starting their own small-scale hydroponic setups. This not only extends the educational impact of the project but also promotes sustainable living practices within the community.

- **Staff Engagement:**

Educator Involvement: Childcare staff can play a crucial role in the garden's success. They can use the garden as a practical tool to teach children about plant biology, environmental science, and the importance of healthy eating. The garden provides a dynamic and engaging way to bring theoretical lessons to life.

Professional Development: Staff can receive training in hydroponic gardening techniques, which enhances their professional skills and equips them to lead educational activities. This involvement also ensures the garden is well-maintained and used to its full potential as an educational resource.

3. Along the Old Memory Gallery at the Rooftop:

Figure 47 Along Old Memory Corridor

Cultural and Historical Connection:

- **Heritage Education:**

Historical Context: Placing the hydroponic garden along the Old Memory Gallery, which showcases the history and heritage of the area, provides a meaningful educational backdrop. Visitors can learn about the region’s agricultural past and its transformation over time. This context enhances the garden's educational value, linking modern hydroponic techniques with traditional farming practices.

Storytelling: The gallery can feature stories and exhibits about the area's farming heritage, explaining how agricultural practices have evolved. This narrative can highlight the importance of sustainability and innovation in preserving our environment, making the garden a living exhibit that bridges past and present.

- **Intergenerational Interaction:**

Engagement Across Ages: The Old Memory Gallery attracts visitors of all ages, making it an ideal location for promoting intergenerational interaction. Older residents can share their experiences and stories related to traditional farming with younger generations, enriching the learning experience and fostering a sense of community.

Cultural Transmission: The garden serves as a venue where cultural knowledge and traditions can be passed down. Workshops and storytelling sessions can be organized, where elders teach children about the historical significance of farming and the values associated with sustainable living.

Aesthetic and Reflective Space:

- **Calm and Reflective Environment:**

Serene Atmosphere: The rooftop area of the Old Memory Gallery offers a peaceful and reflective environment. The presence of a hydroponic garden adds to this serenity, creating a green oasis where visitors can relax and connect with nature. This tranquil setting is perfect for contemplation and learning, providing a break from the hustle and bustle of daily life.

Visual Appeal: The garden enhances the aesthetic appeal of the gallery, with vibrant plants and flowers creating a visually pleasing landscape. This not only attracts visitors but also makes the gallery a more inviting and engaging space.

- **Community Events:**

Historical and Sustainability Workshops: The garden can host events that combine history and sustainability, such as heritage tours followed by gardening workshops. These events offer a multifaceted educational experience, attracting diverse groups and promoting holistic community engagement.

Seasonal Celebrations and Festivals: Organize seasonal events like heritage-themed festivals, plant sales, and eco-fairs. These celebrations provide opportunities for residents to come together, celebrate their shared heritage, and learn about sustainable practices in a fun and engaging way.

Community Engagement:

- **Workshops and Events:**

Regular Programming: The garden can host regular workshops, tours, and community events that teach residents about hydroponics, sustainability, and healthy living. These events will foster community spirit and collective learning, bringing residents together around common goals and interests.

Heritage and Sustainability Synergy: Combine historical exhibits with sustainability education. For example, a workshop could explore the history of local agriculture followed by a hands-on session in the hydroponic garden, creating a synergistic learning experience.

- **Volunteer Programs:**

Community Volunteers: Establish a volunteer program where residents can sign up to help maintain the gardens. Volunteers can include individuals, families, school groups, and local organiations, ensuring wide community involvement and ownership of the project.

Skill Development: Provide training sessions for volunteers, helping them develop skills in gardening, hydroponics, and sustainability. This benefits the garden and empowers residents with valuable knowledge and skills.

Why these three locations are optimal?

Community Engagement:

- **Workshops and Events:**
  - **Regular Programming:** All three locations can host regular workshops, tours, and community events that teach residents about hydroponics, sustainability, and healthy living. These events will foster community spirit and collective learning.
  - **Seasonal Celebrations:** Organize seasonal celebrations like harvest festivals, plant sales, and eco-fairs. These events provide opportunities for residents to come together, celebrate their achievements, and share produce.
- **Volunteer Programs:**
  - **Community Volunteers:** Establish a volunteer program where residents can sign up to help maintain the gardens. Volunteers can include individuals, families, school groups, and local organizations, ensuring wide community involvement.
  - **Skill Development:** Provide training sessions for volunteers, helping them develop skills in gardening, hydroponics, and sustainability. This not only benefits the garden but also empowers residents with valuable knowledge and skills.
- **Social Media Engagement:**
  - **Digital Outreach:** Use social media platforms to share updates, success stories, and educational content about the hydroponic gardens. Engaging online content can reach a broader audience and encourage more residents to participate.
  - **Virtual Tours and Workshops:** Offer virtual tours and workshops for those unable to visit in person. This ensures inclusivity and allows the wider community to engage with the project from the comfort of their homes.

4.54. Specifications, Innovation, and Implementation

Hydroponic Farming

Description: Implement hydroponic systems that enable soil-free farming. This method makes the gardening process easier to maintain and more sustainable, as it uses water-based nutrient solutions to grow plants directly.

Figure 48 Vertical Farming, Hydroponic farming, and Conventional Soil-Based Farming

Benefits:

1. **Efficient Use of Space and Water:** Hydroponic systems can be set up in limited spaces, such as vertical gardens, making them ideal for urban areas. They also use up to 90% less water compared to traditional soil-based gardening.
2. **Higher Yield:** Plants grow faster and produce higher yields in hydroponic systems due to the controlled environment and efficient delivery of nutrients.
3. **Reduced Need for Pesticides:** The controlled environment reduces the likelihood of pests and diseases, minimising the need for chemical pesticides.

Unique Aspect: Unlike traditional community gardens, hydroponic systems provide a modern, clean, and educational approach to urban farming. This innovative method is particularly appealing for urban settings, offering a sustainable and aesthetically pleasing solution to community gardening.

A relevant case study is the "Sky Greens" in Singapore. Sky Greens successfully implemented vertical hydroponic systems in urban areas to produce fresh, sustainable food. This initiative demonstrated several key benefits of hydroponics:

1. Space Efficiency: Sky Greens utilises vertical hydroponic systems, allowing them to grow a large quantity of produce in a compact urban space. This approach maximises the use of available space and makes urban farming feasible in dense city environments.
2. Water Conservation: The hydroponic systems use significantly less water than traditional farming methods. Sky Greens reports using up to 95% less water compared to conventional agriculture, highlighting the water-saving benefits of hydroponics.
3. High Yield and Quality: The controlled environment of the hydroponic systems leads to faster plant growth and higher yields. The produce is also of higher quality, free from soil-borne diseases and pests, reducing the need for pesticides.

4. Educational Impact: Sky Greens offers educational programs and tours to teach the public about sustainable farming practices and the benefits of hydroponics. This educational component helps raise awareness and support for urban agriculture (Sky Greens, 2020).

S'pore high-tech farms seek to export not just produce but their technology too

Minister for Trade and Industry Chan Chun Sing at the launch event for the new micro-farming system by Sky Urban Solutions on March 16. ST PHOTO: MARK CHEONG

~~*Figure 50 Minister for Education visited Hydroponic garden at Sky Green Singapore*~~

Sky Greens, situated in Singapore, showcases the innovative use of rotating systems in vertical farming. The rotating structure allows crops to receive uniform light exposure, promoting optimal growth. Sky Greens demonstrates the adaptability of vertical farming to limited land availability in densely populated cities.

Hillview Community Garden project stands out for several reasons:

1. **Modern and Clean Farming:**
- Hydroponic systems eliminate the need for soil, resulting in a cleaner and more hygienic farming environment. This makes the garden more accessible and appealing, especially in an urban setting where soil contamination can be a concern.
2. **Educational Opportunities:**
- The project will serve as a living laboratory for sustainability and urban farming practices. Regular workshops and educational tours will be conducted to teach residents about hydroponics, sustainability, and the importance of local food production. This hands-on learning approach can inspire more community members to adopt sustainable practices in their daily lives.
3. **Community Engagement and Filial Piety:**
- By engaging residents of all ages in the garden's activities, the project promotes intergenerational interaction and filial piety. Parents and children can work together in the garden, strengthening family bonds and fostering a sense of community responsibility.
4. **Sustainable Waste Management:**
- Collaboration with local F&B establishments to recycle organic waste into compost demonstrates a commitment to sustainable waste management. This initiative not only reduces landfill waste but also provides nutrient-rich compost for the garden, creating a circular economy model within the community.

4.55 Implementation Strategy

Site Preparation

Rooftop Structural Assessment: Ensure that the rooftop areas designated for the hydroponic gardens (children's playground and Old Memory Gallery) can support the weight of the hydroponic systems, water, and plants. This may require consulting with a structural engineer.

Utility Access: Verify that there is adequate access to water and electricity at all locations. Install necessary plumbing and electrical connections if not already available.

Environmental Control: For the outdoor locations, consider installing windbreaks, shade cloths, or other protective measures to shield plants from harsh weather conditions.

4.552 Hydroponic System Selection

Types of Systems:

Nutrient Film Technique (NFT): Ideal for leafy greens and herbs. This system uses a thin film of nutrient-rich water flowing over the roots of the plants.

Deep Water Culture (DWC): Suitable for larger plants like tomatoes and peppers. Plants are suspended in nutrient-rich water with roots submerged, often with air stones to oxygenate the water.

Ebb and Flow (Flood and Drain): Versatile system suitable for various types of plants. Nutrient solution periodically floods the grow bed and then drains away, providing plants with nutrients and oxygen.

Aeroponics: Best for maximizing space and growth rate. Plants are suspended in the air, and nutrient solution is misted onto the roots.

4.553 Equipment and Materials

Growing Medium: Use inert growing media such as rockwool, coco coir, perlite, or clay pellets to support plant roots and retain moisture.

Nutrient Solutions: Purchase or formulate nutrient solutions specifically designed for hydroponic systems. These should provide all essential macro and micronutrients required for plant growth.

Pumps and Reservoirs: Install water pumps and nutrient reservoirs to circulate the nutrient solution through the hydroponic system. Ensure reservoirs are adequately sized for the number of plants and system type.

Grow Lights: For indoor systems or areas with insufficient natural light, install LED grow lights to provide the necessary light spectrum for plant growth.

Timers and Controllers: Use timers and controllers to automate watering schedules, light cycles, and nutrient delivery, ensuring consistent and optimal growing conditions.

4.554 System Setup and Installation

System Assembly: Assemble the hydroponic systems according to manufacturer instructions. Ensure all components are securely installed and properly connected.

Water and Nutrient Management: Fill reservoirs with water and mix in the appropriate amount of nutrient solution. Set up a schedule for monitoring and maintaining water and nutrient levels.

Planting: Start with seedlings or cuttings and place them in the growing medium. Ensure roots have contact with the nutrient solution.

4.555 Monitoring and Maintenance

Daily Checks: Monitor water levels, nutrient concentration (using a TDS or EC meter), and pH levels (using a pH meter). Adjust as necessary to maintain optimal conditions.

Pest and Disease Management: Regularly inspect plants for signs of pests or diseases. Implement integrated pest management (IPM) strategies to control any issues.

System Cleaning: Periodically clean and sterilize the hydroponic system components to prevent algae buildup and pathogen proliferation.

4.556 Education and Community Engagement

Workshops and Training Sessions: Organize workshops to educate the community on hydroponic farming techniques, system maintenance, and sustainable practices.

Volunteer Involvement: Encourage community members to participate in the maintenance and monitoring of the garden. Provide training and support to volunteers.

Educational Signage: Install informative signs around the hydroponic systems to explain how they work, the benefits of hydroponic farming, and tips for home gardening.

4.557 Sustainability and Expansion

Energy Efficiency: Use energy-efficient LED grow lights and consider renewable energy sources such as solar panels to power the hydroponic systems.

Water Conservation: Implement water-saving techniques, such as recirculating systems, and educate the community on the importance of water conservation.

Expansion Plans: Assess the success of the initial hydroponic systems and explore opportunities to expand the project to other community spaces or scale up the existing systems.

4.56 Feasibility Studies

4.561Environmental Factors

Climate Suitability:

Tropical Climate: Singapore's tropical climate, characterized by high humidity and consistent temperatures, is conducive to year-round farming. However, the high humidity levels can pose challenges for some hydroponic systems, necessitating adequate ventilation and humidity control.

Urban Environment: The urban environment of Hillview is suitable for hydroponic farming due to space constraints. Hydroponic systems can be set up in vertical and compact configurations, making efficient use of limited space.

Resource Availability:

Water Supply: Singapore has a reliable and high-quality water supply, which is essential for hydroponic systems. Water conservation practices will be critical given the country's emphasis on sustainable water use.

Renewable Energy: Singapore's commitment to sustainability includes a push towards renewable energy. Solar panels can be integrated into the project to power grow lights and pumps, reducing the overall carbon footprint.

4.562 Social Factors:

Community Engagement:

Educational Value: The hydroponic garden will serve as an educational tool, teaching residents about sustainable farming practices, healthy eating, and environmental stewardship. This aligns with Singapore's focus on education and innovation.

Intergenerational Interaction: The project will promote intergenerational engagement by involving children, parents, and elderly residents in gardening activities. This strengthens community bonds and fosters a sense of shared responsibility.

4.563 Health and Well-being

Mental Health Benefits: Gardening activities have been shown to reduce stress and improve mental health. Providing a green space where residents can relax and engage with nature will enhance overall well-being.

Physical Activity: Active participation in gardening promotes physical health, offering a beneficial alternative to sedentary lifestyles common in urban environments.

4.564 Technical Factors

System Design and Setup:

Hydroponic Systems: The choice of systems (e.g., NFT, DWC, ebb and flow) will be based on the types of plants to be grown and the available space. Technical expertise will be required for the installation and maintenance of these systems.

Site Preparation: Ensuring that the rooftop and other designated areas can support the weight and infrastructure of the hydroponic systems is crucial. This includes structural assessments and the installation of necessary utilities (water and electricity).

Maintenance and Operation:

Training and Education: Providing training for staff and volunteers on the operation and maintenance of hydroponic systems will be essential for the project's success. Workshops and manuals can be developed to ensure knowledge transfer.

Monitoring Systems: Implementing monitoring systems to track water quality, nutrient levels, and plant health will ensure optimal growing conditions and early detection of any issues.

4.57 SWOT Analysis:

- **Strengths:**
    - High visibility and engagement due to strategic locations.
    - Year-round growing conditions in Singapore's tropical climate.
    - Strong government support for urban farming and sustainability projects.
- **Weaknesses:**
    - Initial setup costs can be high.
    - Requires ongoing maintenance and technical expertise.
    - Potential challenges with pest control and disease management in a humid climate.
- **Opportunities:**
    - Potential for educational and community-building activities.
    - Revenue generation through produce sales and educational programs.
    - Expansion of urban farming initiatives in other parts of the community.
- **Threats:**
    - Possible structural limitations of rooftops.
    - Fluctuations in operational costs, such as electricity and water prices.
    - Environmental challenges such as extreme weather conditions.

4.58 Cost Estimation

4.581 Initial Investment:

Hydroponic Systems:

NFT Systems (2 units): SGD 1,200 per unit x 2 = SGD 2,400

DWC Systems (2 units): SGD 800 per unit x 2 = SGD 1,600

Ebb and Flow Systems (2 units): SGD 1,000 per unit x 2 = SGD 2,000

Total for Systems: SGD 6,000

Growing Medium and Seeds:

Rockwool/Coco Coir: SGD 500

Seeds and Seedlings: SGD 300

Total for Growing Medium and Seeds: SGD 800

Water and Nutrient Management:

Water Pumps and Timers: SGD 1,000

Nutrient Solutions (Initial Supply): SGD 500

Total for Water and Nutrient Management: SGD 1,500

Lighting (for indoor and shaded areas):

LED Grow Lights (10 units): SGD 100 per unit x 10 = SGD 1,000

Total for Lighting: SGD 1,000

Structural and Utility Preparation:

Rooftop and Site Preparation: SGD 2,000

Plumbing and Electrical Work: SGD 1,000

Total for Preparation: SGD 3,000

Miscellaneous Costs:

Tools and Equipment: SGD 500

Contingency Fund: SGD 700

Total for Miscellaneous: SGD 1,200

Overall Initial Investment: SGD 13,500

4.582 Operational Costs:

Monthly Costs:

Water: SGD 50

Nutrients and Supplies: SGD 100

Electricity for Pumps and Lights: SGD 150

Maintenance and Repairs: SGD 50

Total Monthly Costs: SGD 350

Annual Costs:

Workshops and Community Events: SGD 2,000

Training and Volunteer Programs: SGD 1,000

Total Annual Costs: SGD 3,000

Total Annual Operational Costs: SGD 7,200

4.583 Funding Sources

Government Grants:

Apply for urban farming and sustainability grants offered by Singaporean government agencies, such as the National Parks Board (NParks) or the Agri-Food & Veterinary Authority (AVA).

Potential Funding: SGD 5,000 - SGD 10,000

Corporate Sponsorships:

Seek sponsorships from local businesses and corporations interested in promoting sustainability and community engagement.

Potential Funding: SGD 5,000

Community Fundraising:

Organize community events and crowdfunding campaigns to raise additional funds. Engage local residents and businesses in supporting the project.

Potential Funding: SGD 3,000

4.59 Community Engagement

Community Members

Social Norms and Peer Influence:

- **Community Engagement**: The project will create a sense of community and shared purpose by involving residents in garden activities, workshops, and events. When community members see their peers actively participating in sustainable practices, it establishes social norms that encourage others to follow suit.
- **Public Commitments**: Encouraging residents to make public commitments to sustainable practices, such as pledging to reduce water use or recycle more, can enhance their commitment due to the desire to be consistent with their promises in front of others.

Convenience and Accessibility:

- **Ease of Participation**: Making it easy for residents to engage with the garden, such as providing convenient locations and flexible volunteer schedules, reduces barriers to participation and increases the likelihood of sustained involvement.

- **Visible Results**: Demonstrating the tangible benefits of sustainable practices, such as healthier plants and reduced waste, reinforces the positive impact of these behaviors and motivates continued effort.

Parents

Role Modeling and Family Involvement:

- **Leading by Example**: Parents who participate in garden activities and adopt sustainable practices serve as role models for their children. Behavioral studies show that children are more likely to adopt behaviors they observe in their parents.
- **Family Bonding**: Engaging in gardening activities together strengthens family bonds and creates a shared sense of responsibility for the environment. This collective experience fosters a supportive environment for sustaining these behaviors.

Educational Impact:

- **Parental Education**: Workshops and informational sessions will equip parents with knowledge about hydroponic farming, waste reduction, and energy conservation. Educated parents are more likely to implement these practices at home and encourage their children to do the same.
- **Practical Application**: Providing parents with practical tips and resources for sustainable living, such as how to set up a small hydroponic system at home or start composting, makes it easier for them to integrate these practices into their daily lives.

Children

Hands-on Learning and Experiential Education:

- **Interactive Activities**: Children will participate in hands-on gardening activities that engage multiple senses. Behavioral studies show that experiential learning is more effective in instilling new behaviors compared to traditional methods.
- **Seasonal Activities**: Organizing gardening activities that change with the seasons keeps children engaged and helps them understand the cyclical nature of agriculture and the environment.

Positive Reinforcement:

- **Reward Systems**: Implementing reward systems, such as stickers or small prizes for participating in gardening tasks or workshops, provides positive reinforcement that encourages continued participation.
- **Sense of Achievement**: Allowing children to see the fruits of their labor, such as harvested vegetables or thriving plants, gives them a sense of accomplishment and reinforces the benefits of sustainable practices.

Integration into Curriculum:

- **Educational Integration**: By incorporating the garden into the school curriculum, children receive consistent messages about the importance of sustainability. Lessons on plant biology, environmental science, and healthy eating are brought to life through practical, hands-on experiences.
- **Storytelling and Games**: Using storytelling and games to teach children about sustainability makes learning fun and memorable, helping to cement these concepts in their minds.

4.60 Behavioural Studies

The Hillview Community Garden project employs the COM-B model (Capability, Opportunity, Motivation-Behavior) to encourage sustainable behaviors:

Capability: Enhance community members' knowledge and skills through education and hands-on activities.

Opportunity: Provide easy access to participate in the garden and create a supportive community environment.

Motivation: Use social influence, positive reinforcement, and visible results to motivate sustained behavior change.

Ultimately, community members will collectively benefit from this sustainability program.

Current Targets:

- **Electricity:** 20% reduction (3,697.8 kWh)
- **Water:** 15% reduction (580.03 cu m)
- **General Waste:** 25% reduction (8,242.5 kg)
- **Recyclables:** 50% increase (455 kg)

Achieved Reductions:

- **Electricity:** 3,697.8 kWh (1,540.53 kg CO_2)
- **Water:** 580.03 cu m (243.61 kg CO_2)
- **General Waste:** 8,242.5 kg (6,266.3 kg CO_2)
- **Recyclables Increase:** 455 kg (18.2 kg CO_2)
- **Total CO_2 Reduction Target:** 8,068.64 kg CO_2

LLC Panel Implementation:

- **Total CO_2 Absorption:** 2,300 kg CO_2/year
- **Energy Savings:** 4,938 kWh/year (2,056.16 kg CO_2)

Current Status:

- **Total Achieved CO_2 Reduction:**
  - **From Electricity Savings:** 1,540.53 kg CO_2

- **From Water Savings:** 243.61 kg CO2
- **From Waste Reduction:** 6,266.3 kg CO2
- **From Recyclables Increase:** 18.2 kg CO2
- **From LLC Panels:** 4,356.16 kg CO2 (2,300 kg CO2 absorption + 2,056.16 kg CO2 from energy savings)

Total Achieved Reduction=1,540.53+243.61+6,266.3+18.2+4,356.16=12,424.8 kg CO2\text{ Total Achieved Reduction} = 1,540.53 + 243.61 + 6,266.3 + 18.2 + 4,356.16 = 12,424.8 \, \text{kg CO2}Total Achieved Reduction=1,540.53+243.61+6,266.3+18.2+4,356.16=12,424.8kg CO2

Conclusion:

- **Target:** 8,068.64 kg CO2
- **Achieved:** 12,424.8 kg CO2

Achieved Target:

Yes, the target carbon reduction has been achieved with a total reduction of 12,424.8 kg CO2, surpassing the target of 8,068.64 kg CO2.

Additional Solutions for Further Improvements:

1. **Enhanced Solar Integration:**
   - Install more solar panels on available rooftops and carpark areas to increase renewable energy generation.
2. **Advanced Waste Management:**
   - Introduce composting programs for organic waste to further reduce general waste.
   - Implement waste-to-energy conversion technologies.
3. **Water Efficiency:**
   - Install water-efficient fixtures and appliances.
   - Implement greywater recycling systems for all non-potable water uses.
4. **Building Insulation:**
   - Improve building insulation to reduce the need for heating and cooling, further reducing electricity consumption.
5. **Community Engagement:**
   - Conduct workshops and campaigns to educate the community on sustainable practices and the importance of reducing consumption and waste.

5.0 Conclusion

Current Targets:

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- Recyclables Increase: 455 kg (18.2 kg CO2)
- Total CO2 Reduction Target: 8,068.64 kg CO2

LLC Panel Implementation**:**

- Total CO2 Absorption: 2,300 kg CO2/year
- Energy Savings: 4,938 kWh/year (2,056.16 kg CO2)

Current Status:

- Total Achieved CO2 Reduction:
  - From Electricity Savings: 1,540.53 kg CO2
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Conclusion:

- Target: 8,068.64 kg CO2
- Achieved: 12,424.8 kg CO2

Achieved Target:

Yes, the target carbon reduction has been achieved with a total reduction of 12,424.8 kg CO2, surpassing the target of 8,068.64 kg CO2.

Additional Solutions for Further Improvements:

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- Conduct workshops and campaigns to educate the community on sustainable practices and the importance of reducing consumption and waste.

Conclusion

In conclusion, the Hillview Community Club's Sustainability Cities Challenge 2024 proposal stands as a visionary model for urban sustainability. By integrating renewable energy, green infrastructure, and innovative community farming, the proposal not only addresses environmental concerns but also fosters community engagement and education. These initiatives align perfectly with Singapore's broader vision of becoming a 'City in Nature,' demonstrating a commitment to environmental stewardship and community well-being. The transformative potential of these projects underscores Hillview Community Club's role as a leader in sustainable urban development, setting a benchmark for future community-driven sustainability efforts.

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