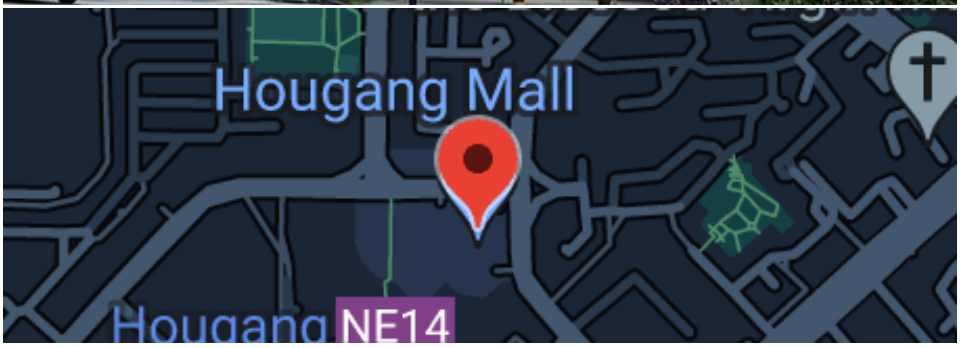
Sustainable Horizons: *Charting Paths to a Greener Tomorrow*



Case-study building: Hougang Mall
Assigned registration number: IHL030
Names of the group members:

- Magdalene Chia
- Caleb Tung
- Tian Siyue

School: Temasek Polytechnic

Background:

History:
Hougang Mall is a suburban retail mall constructed 27 years ago in 1997 and situated at 90 Hougang Avenue 10. Originally known as “NTUC Hougang Mall”, the building has undergone space refurbishments in its attempt to replace, remove and upgrade interior technology and keep up to date to better meet user needs. In 2020, Hougang Mall became under Frasers Property and remains so today.

Project Goal:

We aim to utilize our newly acquired skills and experiences to implement, integrate and redesign urban facilities to promote sustainability measures, in particular, Hougang Mall. We are committed to help the mall in its decarbonisation journey and push for innovative initiatives and eco-friendly practices to forge a sustainable future. Online research from the competition website (Pacific Light Crea8Sustainability) showed that the mall also underwent energy and carbon-efficient retrofitting and upgrades with the goal of improving tenant experience/retention, increasing its asset value, and regaining its competitive standing in the Hougang area. Analysis from our site visit results has proven that the building has a huge potential for areas of improvement which can allow it to meet these goals further.

Targeted Users:
1. Families
2. Seniors
3. Nearby Residents
4. Students

Site Visit Remarks:

Based on our physical site visits, we can conclude that during the afternoon, there appears to be a large amount of primary and secondary school students frequenting the mall, alongside a small portion of working adults and a good handful of the elderly.

Proposed improvement solutions for:

A) Energy Efficiency

B) Greenery Integration

C) Waste Management

Survey Analysis:

Through the survey that we have conducted, majority of the people find that more work can be done to Hougang Mall overall. Below are some opinions and ideas that have been raised to help improve Hougang Mall:

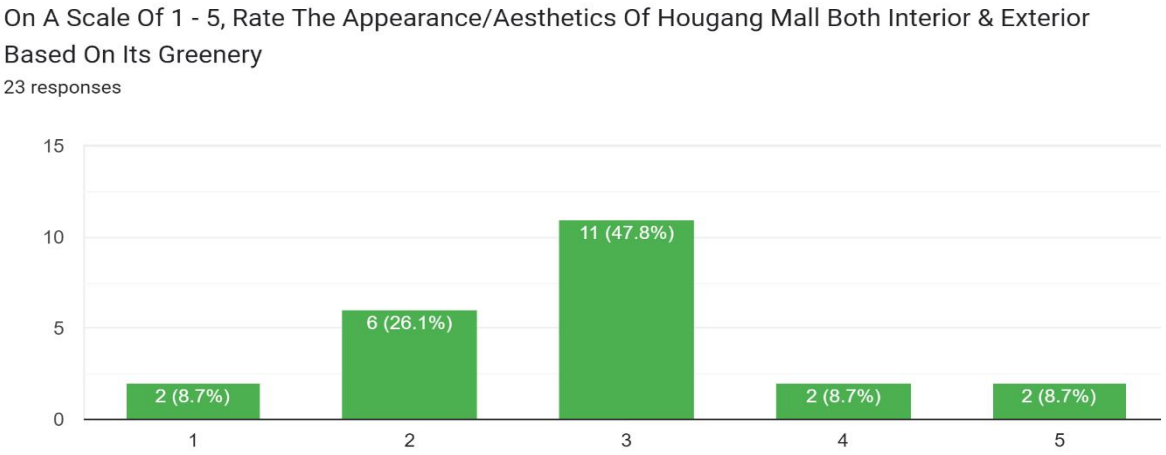


Figure 1

Through Figure 1, many feel that the appearance of the mall is leaning towards looking dull and boring with little aesthetics. There were also some comments that the mall looks run down and unattractive. Hence to improve the malls appearance, some ideas that we suggest is to add more greenery, more plants both indoor and outdoor, and build a rooftop garden, to make the mall look more vibrant.

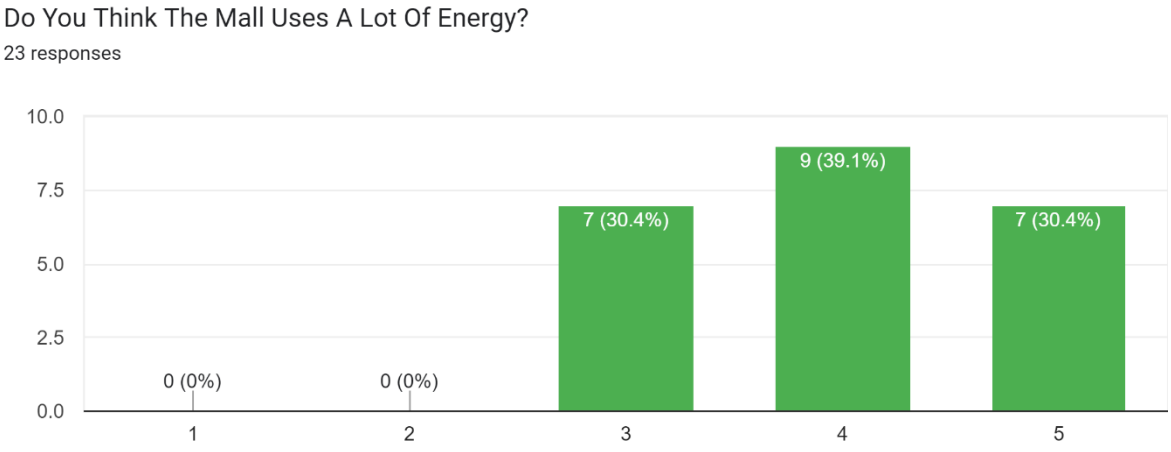


Figure 2

Based on Figure 2, it can be concluded that the public generally feels that the mall has a very high energy consumption. Hence, we came out with these few ideas to help reduce and improve the overall energy consumption in the mall, to install solar panels and install LED lightings / motion sensor lights / skylamps.

Figure 3

Based on Figure 3 above, there is a mixed reaction to whether the mall's waste management practices. There are a few that think it's not effective and some that think it's very effective. Hence, to help increase the effectiveness of the mall's waste management practices, some ideas we suggested are to implement more bins that are easily accessible and smart bins with sensors to warn of it being too filled/overflowing.

Data Calculation:

1) **Electricity Consumption (kWh)**
   a) **LANDLORD**

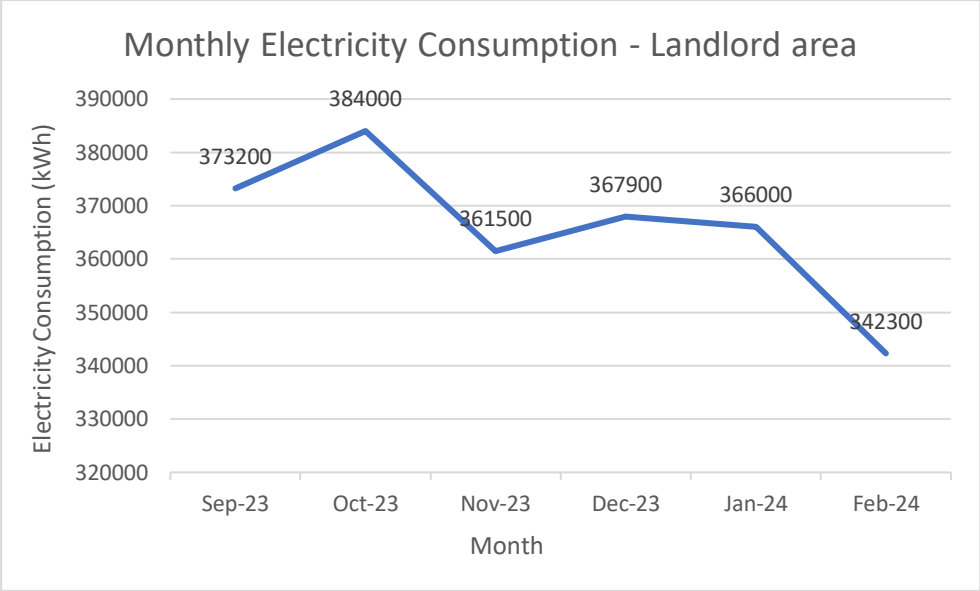


Figure 4

Analysis:
The consumption varies monthly but shows a general decreasing trend over the six months.
There might be some seasonal effects influencing consumption. The consumption peaks in October 2023, then generally declines toward February 2024.

- The electricity consumption shows a fluctuating pattern without a clear trend of increasing or decreasing consumption.
- The average monthly consumption is approximately 365,817 kWh.
- There are notable monthly changes, with the most significant decrease occurring from January 2024 to February 2024.
- The variance indicates that there are some noticeable fluctuations in the consumption data, but it is not extremely high.

b) TENANT

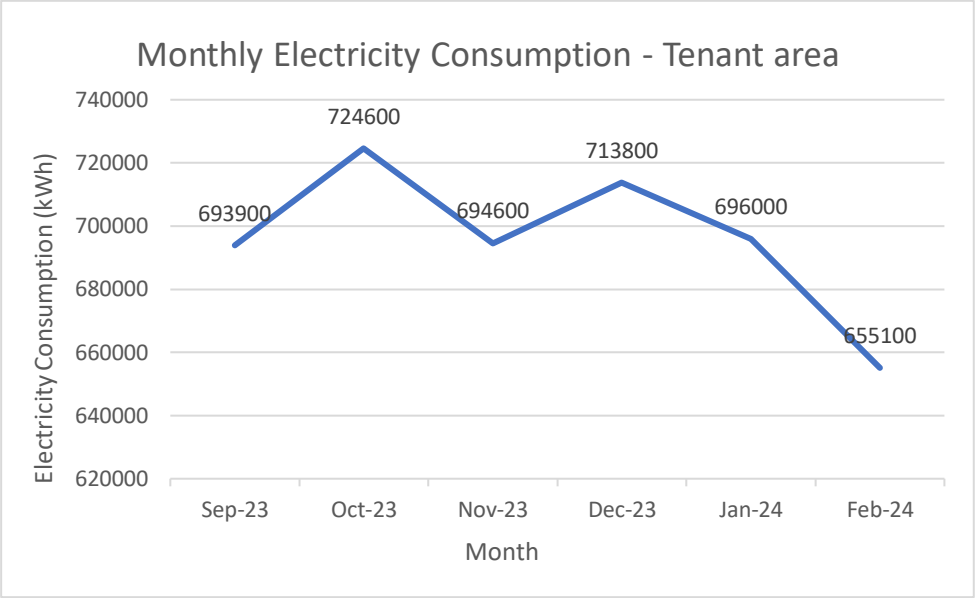


Figure 5

Analysis:
There is variability in monthly consumption, with October showing the highest consumption at 724,600 kWh and February the lowest at 655,100 kWh. Generally, consumption seems to fluctuate without a clear increasing or decreasing trend over the observed period.

Comparison:
As seen from the two data above, the monthly electricity consumption for the landlord area and tenant area is constant from Sep 2023 to Feb 2024 but the average electricity consumption of the tenant area is higher than the landlord area with a difference of around 330517kw.

Possible Reasons for High Tenant Consumption:

Operational Hours: Tenant spaces (shops, restaurants, entertainment facilities) might have longer operating hours compared to common areas managed by the landlord.

Equipment and Appliances:
Tenants might use more energy-intensive equipment such as HVAC systems, lighting, kitchen appliances, and electronic devices.
Foot Traffic: Higher foot traffic in tenant areas could lead to increased energy usage for climate control, lighting, and other services.

2. Waste Incineration (Kg) – Landlord Controlled

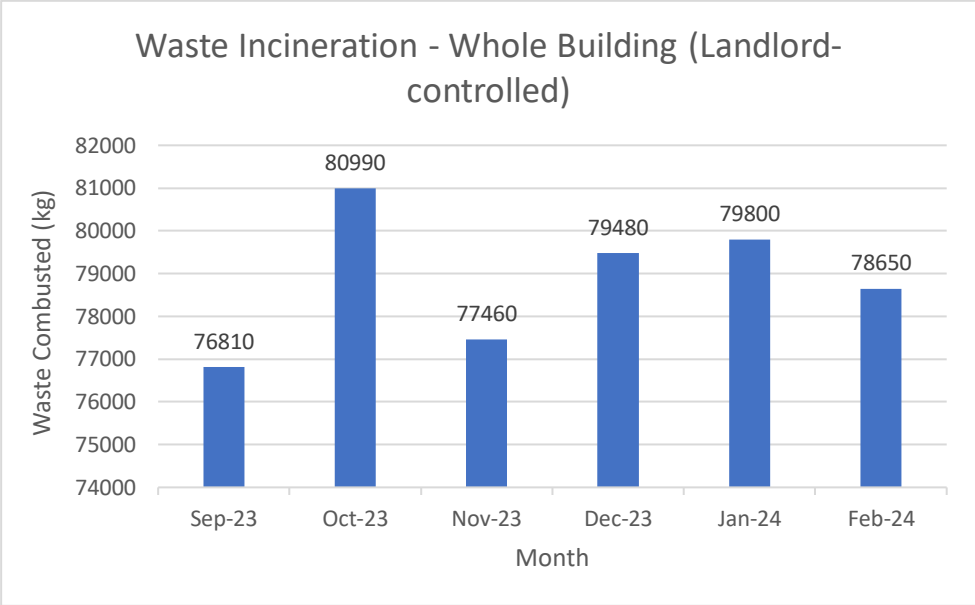


Figure 6

Trend Analysis:
The consumption peaks in October 2023 at 80,990 kWh.
The lowest consumption is observed in September 2023 at 76,810 kWh.
The general trend shows variation but remains within a range of approximately 4,180 kWh (from 76,810 kWh to 80,990 kWh).

Potential Factors Influencing Consumption
The highest consumption in October might indicate increased waste generation
due to the factors below;

Foot Traffic: Higher foot traffic, particularly during peak shopping seasons, likely contributes to increased waste generation and incineration energy consumption.

Special Events/Promotions: Sales events, holidays, and promotions can lead to temporary spikes in consumption.

Operational Changes: Changes in operational hours, waste management practices, or new tenants can impact the amount of waste generated.
The relatively stable consumption from December to January suggests consistent waste generation during the holiday season and post-holiday period.

Total Carbon Emission: **12726089.8964175 CO2e** (waste and electricity)

Reporting Period	2023-2024	Septemer to Feburary										
Description	Category	Amount	Unit	EF (CO2)	kgCO2e	EF (CH4)	GWP	kgCH4	EF (N2O)	GWP	kgN2O	Total (tCO2e)
Direct Emissions												
WASTE												
Sep-23	1	76810	Kg	21.2808	1634578.80386							1634.57880
Oct-23	1	80990	Kg	21.2808	1723532.57811							1723.53258
Nov-23	1	77460	Kg	21.2808	1648411.32857							1648.41133
Dec-23	1	79480	Kg	21.2808	1691398.55919							1691.39856
Jan-24	1	79800	Kg	21.2808	1698208.41750							1698.20842
Feb-24	1	78650	Kg	21.2808	1673735.48918							1673.73549
ELECTRICITY												
Sep-23	1	373200	kWh	0.4168	155549.760000							155.54976
Oct-23	1	384000	kWh	0.4168	160051.200000							160.05120
Nov-23	1	361500	kWh	0.4168	150673.200000							150.67320
Dec-23	1	367900	kWh	0.4168	153340.720000							153.34072
Jan-24	1	366000	kWh	0.4168	152548.800000							152.54880
Feb-24	1	342300	kWh	0.4168	142670.640000							142.67064
Total Direct Emissions (tCO2e)					10984699.4964175000							10984.6994964175

Description	Category	Amount	Unit	EF (CO2)	kgCO2e	EF (CH4)	GWP	kgCH4	EF (N2O)	GWP	kgN2O	Total (tCO2e)
Indirect Emissions												
ELECTRICITY												
Sep-23	2	693900	kWh	0.4168	289217.520000							289.2175200000
Oct-23	2	724600	kWh	0.4168	302013.280000							302.0132800000
Nov-23	2	694600	kWh	0.4168	289509.280000							289.5092800000
Dec-23	2	713800	kWh	0.4168	297511.840000							297.5118400000
Jan-24	2	696000	kWh	0.4168	290092.800000							290.0928000000
Feb-24	2	655100	kWh	0.4168	273045.680000							273.0456800000
Total Indirect Emissions (tCO2e)					1741390.4000000000							1741.3904000000
Total Emissions (tCO2e)					12726089.8964175000							12726.0898964175

Figure 7

Analysis:

Electricity (direct + indirect): (2656.22472)

Grid Emission Factor

The Operating Margin (OM) Grid Emission Factor (GEF) measures the average CO_2 emissions emitted per unit of net electricity generation in the system by all grid-connected power units. The OM GEF includes generation technologies from main power producers (e.g. combined cycle power plants, waste-to-energy) and autoproducers* (e.g. embedded co-generation plants and solar).

The Build Margin (BM) Emission Factor refers to the average CO_2 emissions emitted per unit of net electricity generation by the most recently built power units. Singapore's BM emission factor trends lower than the OM emission factor as the most recently built power plants are generally more efficient as compared to the older plants.

Singapore's average OM GEF rose slightly from 0.4085 kg CO_2/kWh** in 2021 to 0.4168 kg CO_2/kWh in 2022. This was largely due to an increase in diesel consumption as natural gas markets worldwide tightened in 2022.

Figure 8

Upon our research, we've managed to find the latest grid emission factor [1] used to calculate the electricity generation, which is 0.4618 kg CO_2/kWh (2022). Hence using the GEF from 2022, we multiplied the Hougang Mall's electricity consumption by the given GEF to come out with the total electricity consumption of 2656.22472 kWh.

Waste: (10069.86518 tCO_2e)

Upon our research, we've managed to find the latest Greenhouse Gas emission conversion factors (2023)[2] which are used by UK and international organizations to report on 2023 greenhouse gas emissions.

			Re-use	Open-loop	Closed-loop	Combustion	Composting	Landfill	Anaerobic digestion
Activity	Waste type	Unit	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e
Refuse	Household residual waste	tonnes				21.281		497.045	
	Organic: food and drink waste	tonnes				21.281	8.912	700.210	8.912
	Organic: garden waste	tonnes				21.281	8.912	646.607	8.912
	Organic: mixed food and garden waste	tonnes				21.281	8.912	655.987	8.912
	Commercial and industrial waste	tonnes				21.281		520.335	

Figure 9

With reference to the waste type commercial and industrial waste, the emission conversion factor for waste combustion is 21.281 CO_2. Hence using the latest conversion factor for waste, we multiplied the waste combusted for Hougang Mall by the conversion factor to come out with the total carbon emission for waste.

Energy Efficiency:

1) **Aircon Setpoint to 25 Degree Celsius (°C)** *- energy reduction implementation*
   By setting the building aircon temperature by 1 degree higher could have an carbon emission/reduction efficiency of 10%. Based on research from CNA[3] Temasek Polytechnic has also taken similar steps in its attempt to improve energy efficiency as shown .

Figure 10

2) **Implementation of Solar Panels**

   a) **Rooftop | [Rooftop Photovoltaics (PV)]** *- renewable energy implementation*

   Upon conducting the site visit of Hougang Mall, we have noticed that this building's wide rooftop surface on Level 5 allows for some application for sustainability enhancements. Given that the site visit was conducted near noon at around 11 - 12pm SG time, there was a good way to gauge the direction and the intensity of sunlight and having solar panels installed to utilize this energy tapping potential.

   As we had limited access to the rooftop level, we utilized Google Map's Satellite image to obtain the layout and facilities present on the rooftop.

(The map data is recent as it's based on 2024 as shown in the bottom right)

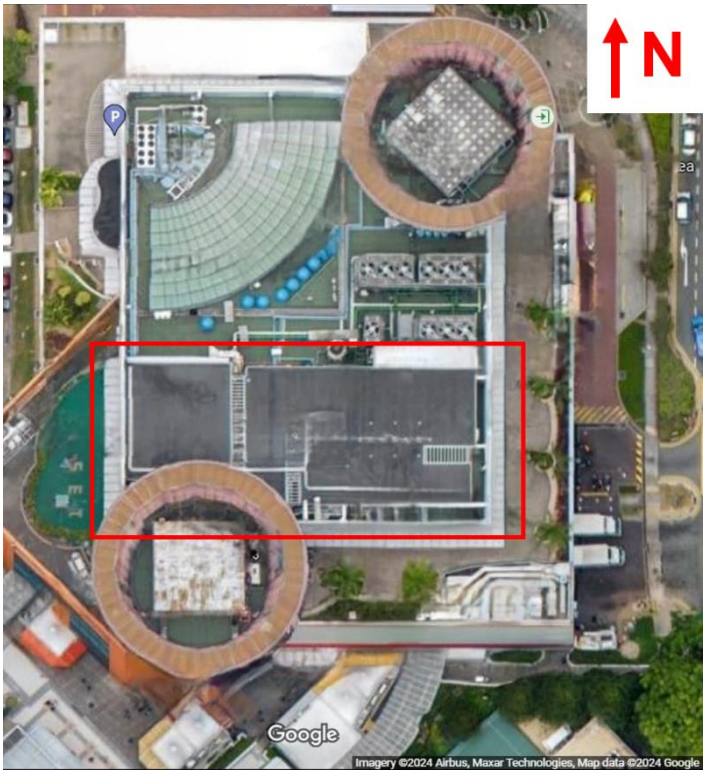


Figure 11

Figure 12

Focusing on the red box from Figure 4, zoomed in picture in Figure 5, we noticed that there is ample space for some solar panels to be installed to help reduce energy consumption. Installation in this area is suggested to utilize this open roof space.

Figure 13

Figure 14

Figure 7 above is a rough idea on how the installation of solar panels will be carried out.

Some factors considered were the direction of the sun and the allocated movement space. As the sun rises from the east and sets in the west, this position is most ideal due to little sunlight obstructions nearby. While the allocated movement space will not hinder maintenance and cleaning of the panels.

Temasek Polytechnic's roof contained solar panels that help with energy consumption along with many modern buildings; hence we plan to implement this idea onto the roofs of Hougang Mall. Below are some real-life examples taken of the solar panel implementation in Temasek Polytechnic.

Figure 15

Figure 16

According to research done, **Monocrystalline** + **Monofacial** type solar panels would be ideal as it utilizes better efficiency for a smaller space, given that Hougang Mall's rooftop space is limited, installation of more efficient solar panels will allow the mall to benefit in the long run. This makes it a considerable action plan to pursue in asset enhancement.

Reasons for this specific implementation:

Monocrystalline:

Perform well despite extreme temperatures making it ideal for intended application outdoors (higher surface temperature), longer lifespan, higher efficiency making it space efficient.

Monofacial:

Only the front surface of the solar panel will absorb sunlight, ideal for intended application where the underside of panel will be blocked by Level 5's exterior wall/rooftop floor surface

Required Solar Panels:

Required Solar Panel PV Type:	Technology:
Monocrystalline	Monofacial (one sided)

Solar Panel Specifications:

The brand of SUNEV has a range of Monocrystalline solar panels, one of which has been identified and indicated below.

Given that only a singular surface is needed for this installation purpose, a Monofacial *(single-sided)* PV, in which only the front side can generate electricity, will be sufficient for required operations. Browsing through all the Monocrystalline types of Solar utilizing a Monofacial systems, three considerable models have been chosen for this proposal. Their details are specified below.

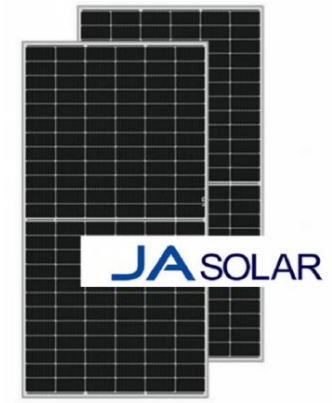
Model 1: pros ~ *High efficiency, larger surface area*

Figure 17

Name:	Canadian N-Type TOPCon Monofacial Module
Power Range:	570 - 600W
Max. Efficiency:	23.2%
Dimension: *L*W*H*	2278*1134*30mm
Weight:	27.6kg

Model 2: *pros ~ Smaller dimension, lighter weight*

	Name:	JA Solar Panel N-Type Bifacial Double Glass High Eff. Mono Module
	Power Range:	415 - 435W
	Max. Efficiency:	22.3%
	Dimension: *L*W*H*	1722*1134*30mm

 *Figure 18*	**Weight:**	20.8kg

Model 3: pros ~ Highest Power Output, Excellent Power Generation

 *Figure 19*	**Name:**	SunEvo Risen Half Cell Mono PV Panels
	Power Range:	605W - 630W
	Max. Efficiency:	22.5%
	Dimension: *L*W*H*	2465*1134*30mm
	Weight:	33.5kg

Available Rooftop Dimension/Space

As we were unable to gain access to the roof throughout this project, improvisation was required to gain measurements to determine the required/feasible dimensions.

Utilizing the “Measure” map feature under Google map tools, I was able to obtain a rough available distance for the roof surface to install the solar PV.

Measure

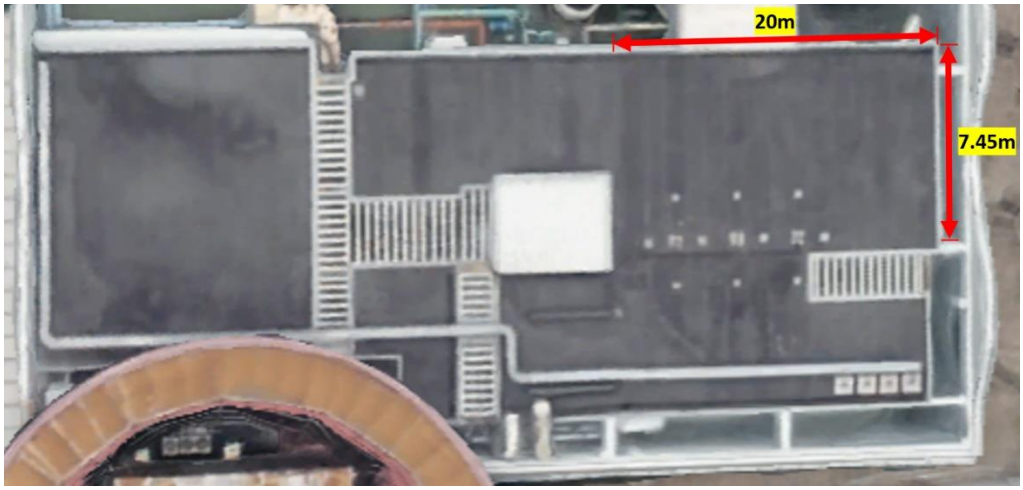


Figure 20

Given the length for the roof surface where we plan to install the solar panels is approximately 7.45m, and with a 1.2m being allocated to facilitate mobility. Resulting in 6.25m of available space being allocated for movement.

Model 1:

If model 1 is chosen, 2 PV panels can be installed vertically and 10 horizontally taking into consideration walking spaces between the mounted panels.

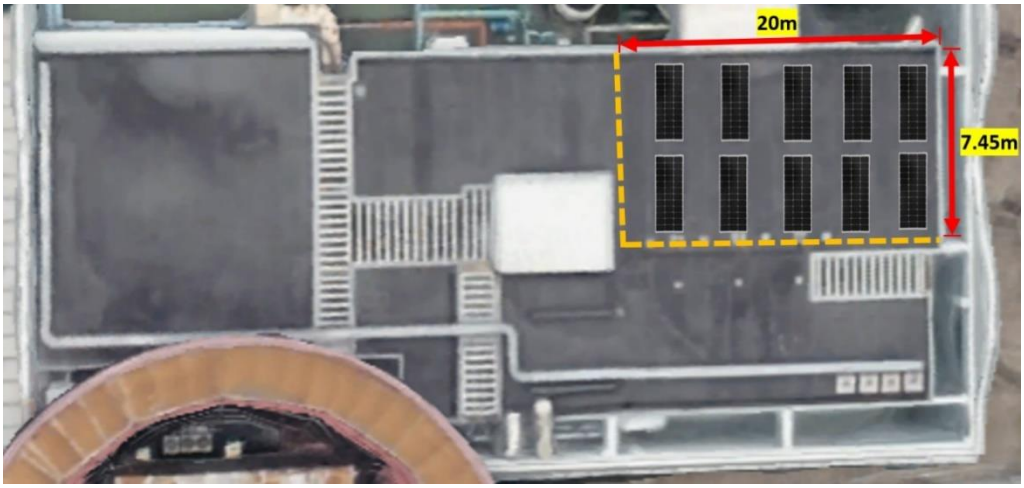


Figure 21

Model 2:
If model 2 is chosen, 3 PV panels can be installed vertically & 10 horizontally taking into consideration walking spaces between the mounted panels this option is viable should more solar panels be preferred.

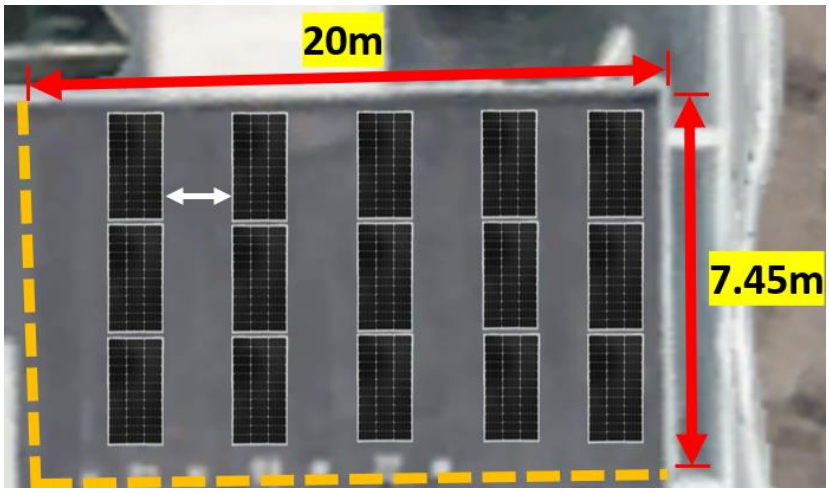


Figure 22

b) **Vertical Solar Panels on Roof Side Walls**
- renewable energy implementation

Another alternative location for solar panels installation, is on the side wall indicated below. Through our site visit, we have identified this white wall at level 5's EAST and WEST facades only as an ideal location due to the sun orientation.

East View:

Figure 23

West view:

Figure 24

Measuring the length of the roof wall using Google Maps has returned with **32.72m** (rounded down to 32m) on the East Façade.

For the West Facade, Due to a blockage preventing solar panels from being installed at that location, (indicated with a red box) the facade will be split into 2 areas.

Figure 25

ZONE A. **7.01m** (rounded down to 7m) & ZONE B. **25.61** (rounded down to 25m)

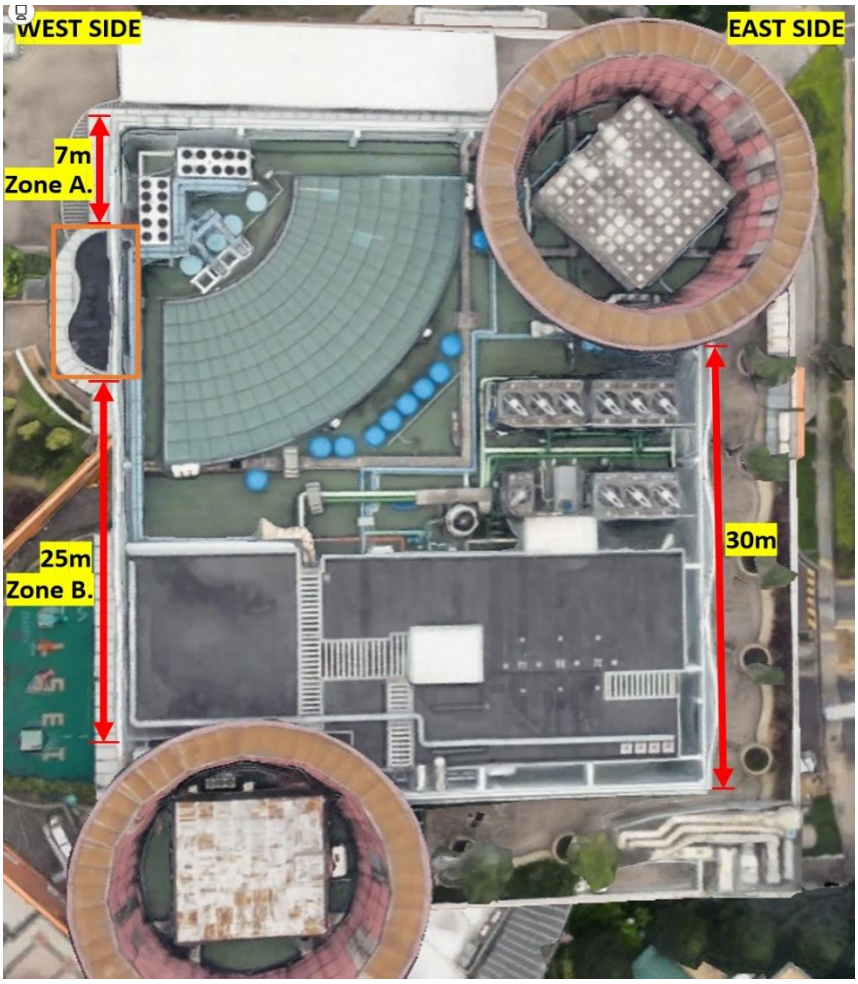


Figure 26

Model 1: [Canadian N-Type TOPCon Monofacial Module]
East Side: 14 PV Panels can be installed
West Side (Zone A): 3 PV Panels
West Side (Zone B): 10 PV Panels

Model 2: [JA Solar Panel N-Type Bifacial Double Glass High Eff. Mono Module]
East Side: 18 PV Panels can be installed
West Side (Zone A): 4 PV Panels
West Side (Zone B): 14 PV Panels

Model 3: [SunEvo Risen Half Cell Mono PV Panels]

not considered for vertical applications

Its heavy weight of 33.5kg was deemed a safety risk when side mounted.

Efficiency Improvement Percentage:
With the 3 different Solar PV types, their indicated power range was multiplied by the 2022 Efficiency Factor of 0.4168 [1] to determine how effective are our proposed implementations in reducing Carbon Emissions Savings (CO_2).

After comparing the different types of solar panel, MODEL 3 is recommended due to the high efficiency potential

~~**Model 1: [Canadian N-Type TOPCon Monofacial Module]**~~
~~*(power range of 570W - 600W)*~~

~~570 × 0.4168 = 237.576~~
~~600 × 0.4168 = 250.08~~

~~Carbon Emissions Savings (CO2):~~
~~Amount of CO2 Reduced: **237.576 W to 250.08 W (PER PANEL)**~~

~~**Model 2:**~~
~~**[JA Solar Panel N-Type Bifacial Double Glass High Eff. Mono Module]**~~
~~*(power range of 415W - 435W)*~~

~~415 × 0.4168 = 172.972~~
~~435 × 0.4168 = 181.308~~

~~Carbon Emissions Savings (CO2):~~
~~Amount of CO2 Reduced: **172.972 W to 181.308 W (PER PANEL)**~~

Model 3: [SunEvo Risen Half Cell Mono PV Panels]
(power range of 605W - 630W)

630 W × 6 Hrs × 182 Days × 49 = 33710040 W/h
33710.04 = 33710 KW/h

33710 × 0.4168 = 14050.328
14050.328 = 14050

14050 ÷ 1000 = 14.060 (tCO2e)
Reduction = 14
Consumption = 2656 x 100%
Saving = 4050 ÷ 2656 x 100% = 0.5%

Carbon Emissions Savings (CO2):
Amount of CO2 Reduced: **0.5%**

3) **Solar Tubes/Sun Tunnels** - *energy reduction implementation*

Solar tubes, also known as sun tunnels, for illumination of level 5 area inside the mall -> through channeling of outside daylight into the mall. It provides a natural, cost-effective way to naturally illuminate dark interior spaces without using electricity. They're less expensive and easier to install, and they prevent the kind of heat loss (and gain) that comes with full-sized windows in your roof.

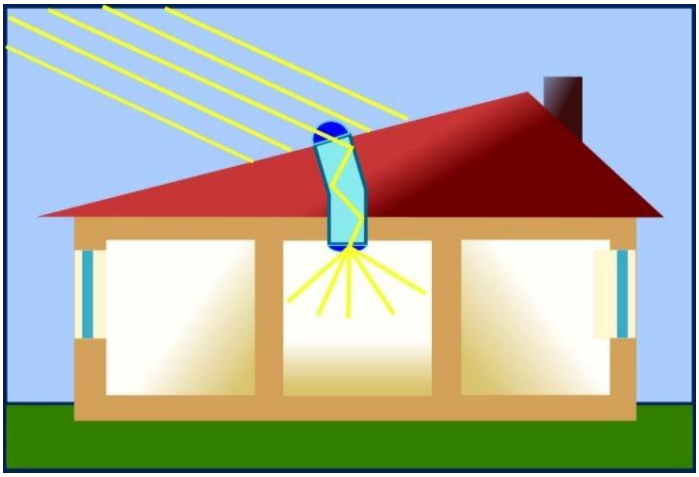


Figure 27

The Integrated Built Environment Centre (IBEC) located in Temasek Polytechnic has such fixtures. Bringing exterior light into a classroom located inside the building.

Unlike skylights, solar tubes are less invasive and allow for a more concentrated projection of natural daylight into a specific area *e.g.(room)* as lighting can be redirected.

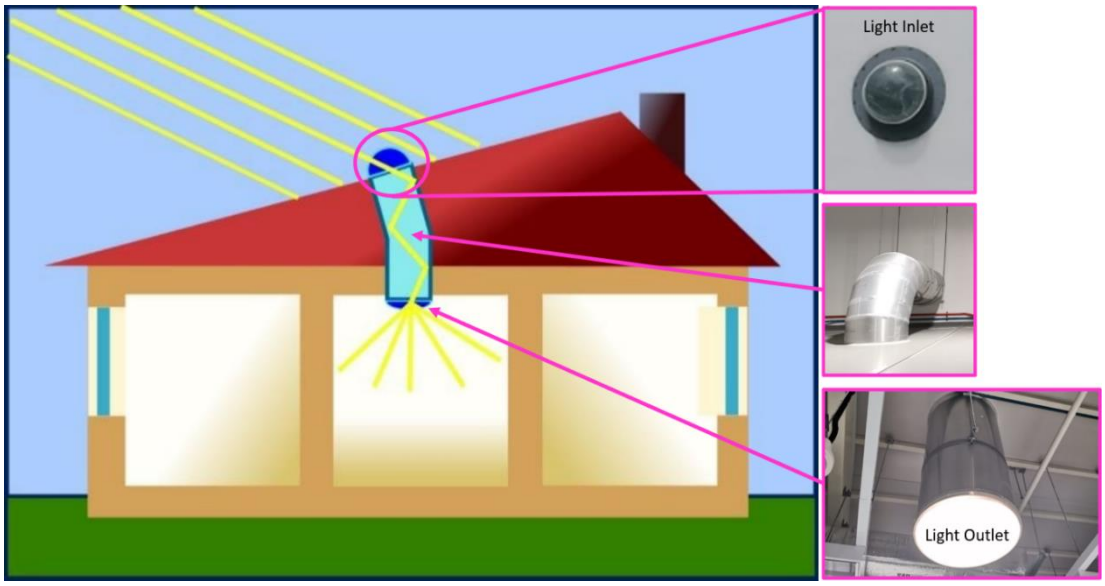


Figure 28

4) Photovoltaic Glass [Rooftop Skylight Replacement]

- renewable energy implementation

Figure 29

What is Photovoltaic Glass (PV Glass)?

It is an electricity-generating material, with the aim of capturing the sunlight and turn it into electricity. The panes are made of layers of heat-treated safety glass which can provide the same thermal and sound insulation as conventional architectural glass, not to mention the fact that they also let natural light go through in the same way as conventional glass.

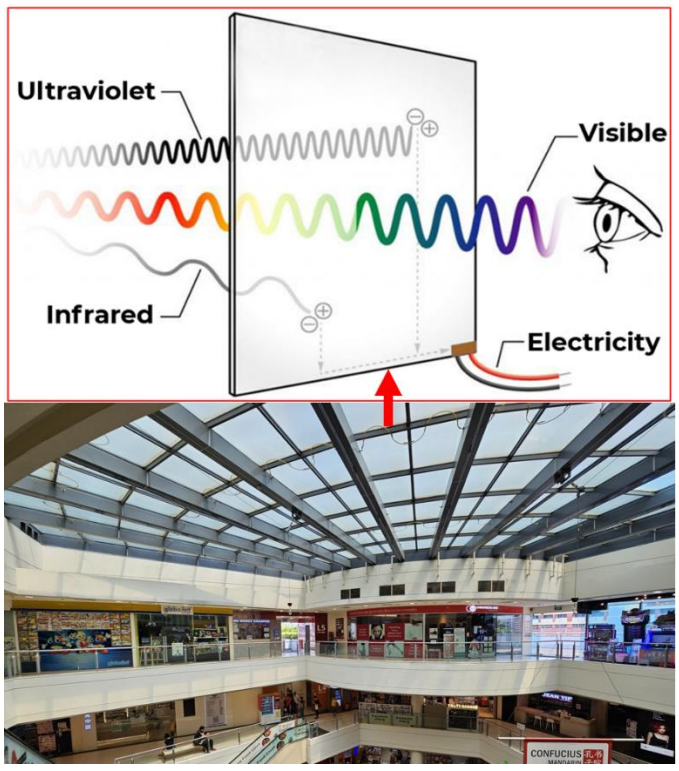


Figure 30(possible application of PV glass planes on skylight)

Through calculation of the glass planes that form the skylight, 16 vertical glass planes and 11 horizontal glass planes give an estimated dimension size of (16 x 11), therefore approximately ~ 176 Photovoltaic glass planes are required for a full improvement of skylight installation.

Benefits:
- PV Glass generates free and clean electricity using the solar energy from the sun, turning buildings into vertical power generators.
- PV Glass allows natural lighting to pass, which in this case is crucial for a skylight. It also provides thermal and sound insulation, ensuring great filtering power as 99% of UV harmful radiation and up to 95% of IR radiation can be absorbed.

5) LED Lights Alight Sensor (Smart Lighting Systems):

- renewable energy implementation

(The brightness of the lights will change according to the surroundings)

Utilizing light sensors, light dependence can be reduced, with possibilities for smart lighting systems applications.

During the site visits conducted, it has come to our attention that the mall's lighting system can be reduced due to its efficient skylight located on the ceiling of the atrium, allowing light to permeate into the building space.

Figure 31

By integrating Light Dependent Resistors (LDRs), the lighting will become more adaptive / responsive to the exterior sunlight. Below shows a picture of a light dependent resistor that is crucial for this sustainability implementation.

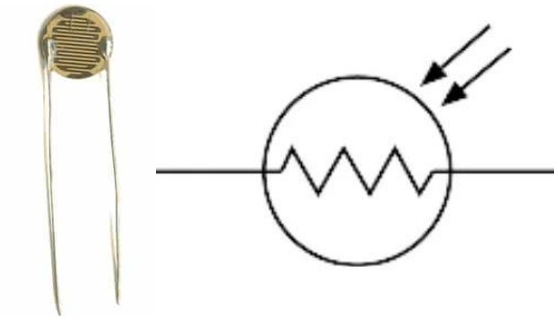


Figure 32

Some ideas of implementation are areas close to the skylight and where natural lighting oscillates daily.

Proposed Locations:	Reason:
-Level 5 (all lights)  *Figure 33*	Majority of the natural lighting illuminates the whole of level 5, allowing this application to be utilized best throughout the mall's day to day operations. Especially near afternoon periods where the sun is most effective. (11- 3pm)
-Level 1-4 (sides of floors)  *Figure 34*	Application is suggested on only the sides of these floors surrounding and overlooking the atrium, as some lighting can illuminate these areas. Following this application can also help keep this proposal **cost-effective**, **realistic,** and **efficient.**

5. **Regenerative Lifts** - *energy recovery/reduction implementation*
Turning to a more modern and sustainable approach, implementing regenerative elevators in Hougang Mall's elevator systems can allow for better energy saving.

At the site visit, we observed that the mall has 2 passenger lifts, compared to other malls in the area *(Nex, Hougang 1, Heartland Mall)* built in 1994, and recently modernized with safety features due to the high elderly commute within the mall, this can be taken a few steps further.

Based on the floor plan below, observations have been confirmed that 2 passenger elevator shafts span across all floors in the whole mall. *(Illustrated with a red box below).*

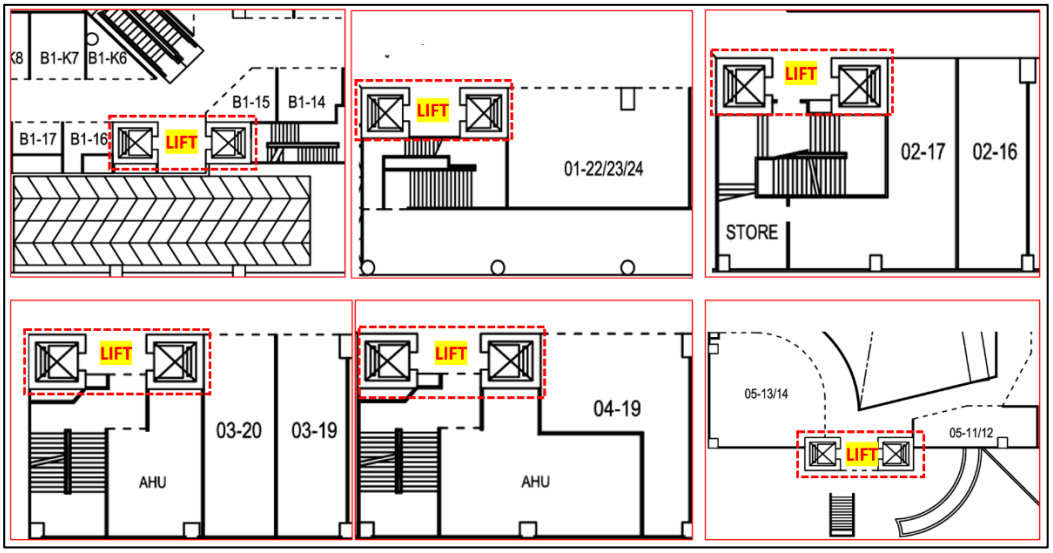


Figure 35

Given the situation with the usage frequency and internal load of the elevators in Hougang Mall, providing another avenue in which energy can be regained and used to power other electrical systems takes our idea a step further in
energy efficiency.

In other real-life applications, JEM Mall has utilized this technology in their elevators and reduced their annual energy consumption by ~ 13 GW/h [3]

Traditional Mechanic:

The lift's traditional braking resistor system, converts energy generated from the lift's downward motion into heat, increasing the building's cooling load and subsequently cooling costs and wasting energy potential.

What Are Regenerative Lifts & How Do They Work?:
The lift's traditional braking resistor will be changed into a "Line Regenerative Drive" which allows a lift with half or more passenger load to Generate Electricity through its downward motion which can be used in other areas. e.g.(lighting systems, AHU, ACMV Systems)

Figure 36

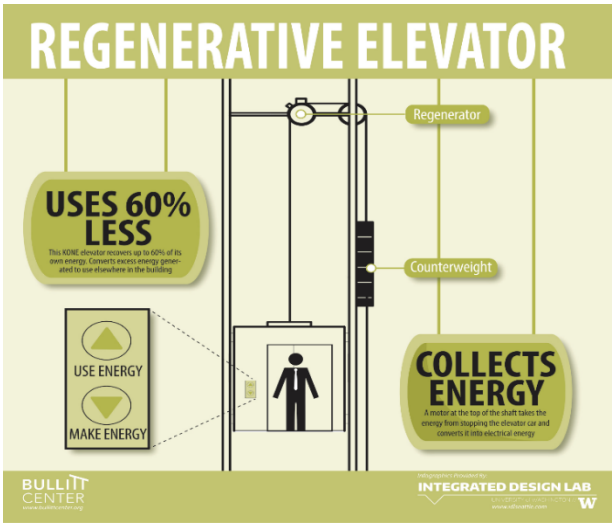


Figure 37

 *Figure 38*	**Name:**	COMBIVERT R6 LineRegen (KEBamerica)
	Function:	Energy Recovery / Energy Reduction
	Dimension: *W*H*	5.1 * 11.4
	Weight:	27.6kg

With these implementations, energy efficiency can be improved within Hougang Mall. Subsequently reducing the building's carbon footprint and help FRASERS PROPERTY achieve towards 2050 net-zero carbon goals as part of it's ESG Goals.

Greenery Integration:

1. **Implement greenery walls on the inner walls of the mall.**

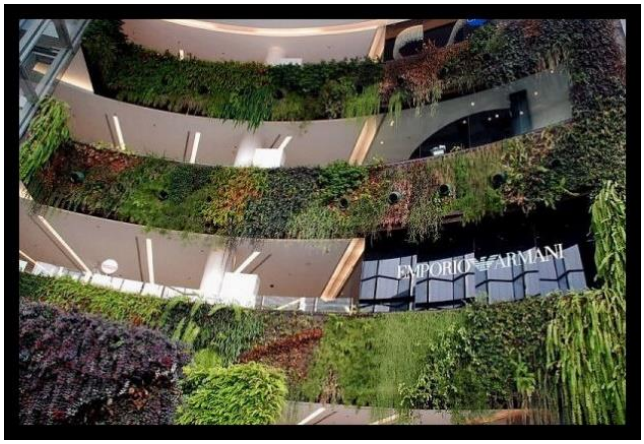


Figure 39

Above is an example of green walls in Siam Paragon Shopping Mall in Thailand.

Figure 40

Similar to Figure 36, we plan on implementing these green walls onto the floor-to-floor slab in Hougang Mall. This not only improves the malls overall interior aesthetics, but also improve the air quality in the mall.

Plant types that can be implemented:

Plant Type:	Reason:
Pothos (Epipremnum Aureum):  *Figure 41*	Pothos have trailing vines and is a popular choice for indoor spaces due to its ability to tolerate low light and infrequent watering. It also grows well in hanging baskets, making it suitable for vertical spaces
Spider Plant (Chlorophytum Comosum):  *Figure 42*	Spider plants are known for their arching leaves and unique appearance. They can adapt to various light conditions and purify air to bring freshness to the walls.
Snake Plant (Sansevieria Trifasciata):  *Figure 43*	Snake plants have valuable architecture and can purify air. They are extremely resilient and can tolerate low light and varying humidity levels. They come in various sizes and varieties, making them suitable for different wall spaces.
Philodendron:  *Figure 44*	Philodendrons are versatile and come with heart-shaped leaves that can adapt to different environments. They can tolerate indirect light, and infrequent watering, making them ideal for indoor walls in shopping malls.

Watering methods:

1. Misting System:

Implementation: Install a misting system with fine nozzles positioned above the planters. This system releases a fine mist of water that moistens the air around the plants without causing dripping.

Operation: Program the misting system to activate at specific intervals or during times when the mall is less crowded to avoid inconveniencing shoppers. Adjust the duration and frequency of misting based on the plant's water requirements and environmental conditions.

2. Drip Irrigation System with Moisture Sensors:

Implementation: Install a drip irrigation system behind the wall-mounted planters. Use tubing with small emitters that deliver water directly to the plant roots. Place moisture sensors in the soil of each planter to monitor moisture levels.

Operation: Set up a timer to regulate watering intervals based on the moisture readings from the sensors. When the soil becomes too dry, the system automatically activates to deliver water directly to the roots which minimize the risk of dripping.

Benefits of Green Walls:

1. Enhanced Aesthetics: Green walls give natural beauty and lush greenery to the interior spaces of the mall, creating visually appealing and inviting environments for shoppers.

2. Improved Air Quality: Green walls act as natural air purifiers, filtering out pollutants and releasing oxygen, thereby improving indoor air quality in the shopping mall. This results in a healthier and fresher environment for both customers and tenants.

3. Positive Shopping Experience: Green walls can make shopping more enjoyable and relaxing for visitors. A view of lush greenery may create positive emotions, reduce stress, and make shoppers feel more relaxed and comfortable.

4. Branding and Differentiation: Incorporating green walls into the mall's design can help it stand out from competitors and establish a unique brand image associated with sustainability and environmental awareness. This can attract eco-conscious customers and improve the mall's reputation.

2. **Vertical Moss wall**

Figure 45

Moss walls (also known as moss panels) are constructed from clusters of preserved or living moss mounted onto steel panels or backing boards. This idea can be implemented at the B1 Travelators leading to the car park to lower the temperature generated by the vehicles, with the lower temperature, the building's cooling load can be reduced.

Benefits of Moss Walls

Air Purification: Moss walls help remove toxins from the air and replace it with clean, fresh oxygen, improving air quality in the workplace.
Noise Reduction: Moss walls can help reduce noise levels, making for a quieter office environment.
Increased Productivity and Cognition: Plants, including moss walls, have been shown to improve productivity levels and cognition by up to 15%.
Improved Health and Wellbeing: Moss walls contribute to reducing stress and anxiety, enhancing the overall wellbeing of employees.

Living Walls vs. Preserved Moss Walls

Living Moss Walls

Benefits: Offer environmental and physical benefits, such as air purification.
Conditions: Thrive in low-light environments and require a certain level of humidity to prevent drying out. They do not need watering but might need occasional misting to maintain humidity levels.

Preserved Moss Walls

Benefits: Require less maintenance than living moss. They don't need hydration or a soil base, allowing for more creative arrangements.

Conditions: Similar to living moss, preserved moss should not be placed in direct sunlight, which can dry it out and bleach the color.
Limitations: Unlike living moss, preserved moss does not purify the air.

Types of Moss for Moss Walls

Can combine different types of moss or use a single type, and even integrate artificial or living plants for variety.

Implementation:

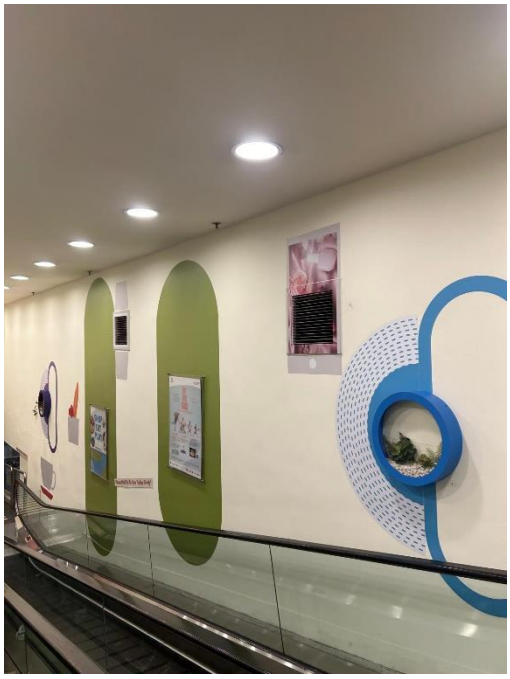


Figure 46

We plan on implementing this moss wall along the advertisement boards along the walls of the travellator connecting the basement and the carpark in the mall. These moss walls will help improve the air quality around the area as the pollutants and fuel smell from the carpark will enter the mall as customers enter the mall which makes the atmosphere there toxic and warm. With the help of the moss walls, the overall atmosphere will be cooler and free from toxins.

Installation Considerations

Moss walls can be installed on almost any wall but are **not ideal** for:
Outdoor: Exposure to outdoor light can dry out the moss.
Dry Areas: Moss walls need about 40-50% humidity to look their best.
Near Heaters or AC Vents: Heat and air conditioning can dry out the moss, damaging its appearance. Incorporating moss walls into the mall not only enhances aesthetics but also improves health and productivity, making them a valuable addition to any space.

Plant species that can be implemented:

Plant Type:	Reason:
Reindeer Moss:  *Figure 47*	It can be dyed in various colors, making it highly versatile for matching brand colors and aesthetics. Reindeer moss has a soft, spongy texture and is excellent for creating patterns and designs on moss walls.
Sheet Moss:  *Figure 48*	A popular moss species for biophilic designs because of its uniform growth pattern.
Pillow Moss:  *Figure 49*	Recognizable by its bouncy clumps, it adds a quirky, cushiony character to green walls and terrariums.
Mood Moss:  *Figure 50*	Known for its temperamental appearance, it looks lush when hydrated and weak when dry, adding a whimsical touch with its windswept look.

3. **Rooftop Garden**
    a. **Greenery Resting Place**

Figure 51

The mall can implement comfortable seating such as wooden benches and lounge chairs alongside flowers and plants that can be placed around the seats in the open space.

Materials

L-shaped Wooden Benches:

Material: Treated teak wood (for durability and weather resistance)

Dimensions: 4 meters per side, 0.5 meters wide, 0.45 meters high

Shading Structure:

Material: Powder-coated aluminum frame with UV-resistant fabric canopy

Dimensions: 5 meters x 5 meters

b. Potted Plants alongside Walls

Figure 52

Alongside the greenery resting place will be potted plants. These plants will help in reducing the amount of carbon dioxide, a significant greenhouse gas, in the air which also has an indirect cooling effect in the atmosphere. It also decreases the sun's effect on the outer walls and outdoor temperature, which means that heating and cooling the mall will require less energy, reduce the environmental impact, and save money in the long run.

Community Engagement:

- Allocate sections of the rooftop for community garden plots where participants can grow their plants of given species.
- Provide raised beds or containers, soil, compost, and basic gardening tools for participants.
- Offer gardening workshops, demonstrations, and educational programs to encourage participation and provide guidance on sustainable gardening practices.

Benefits:

- Builds community by fostering social interaction among people of all ages and backgrounds.
- Allow others to share their knowledge and skills as those who are more experienced in gardening can mentor beginners, promoting knowledge sharing and a sense of community pride.
- Improves mental and physical health by spending time outdoors and nurturing plants has proven benefits for reducing stress and promoting physical activity.

Implementation:

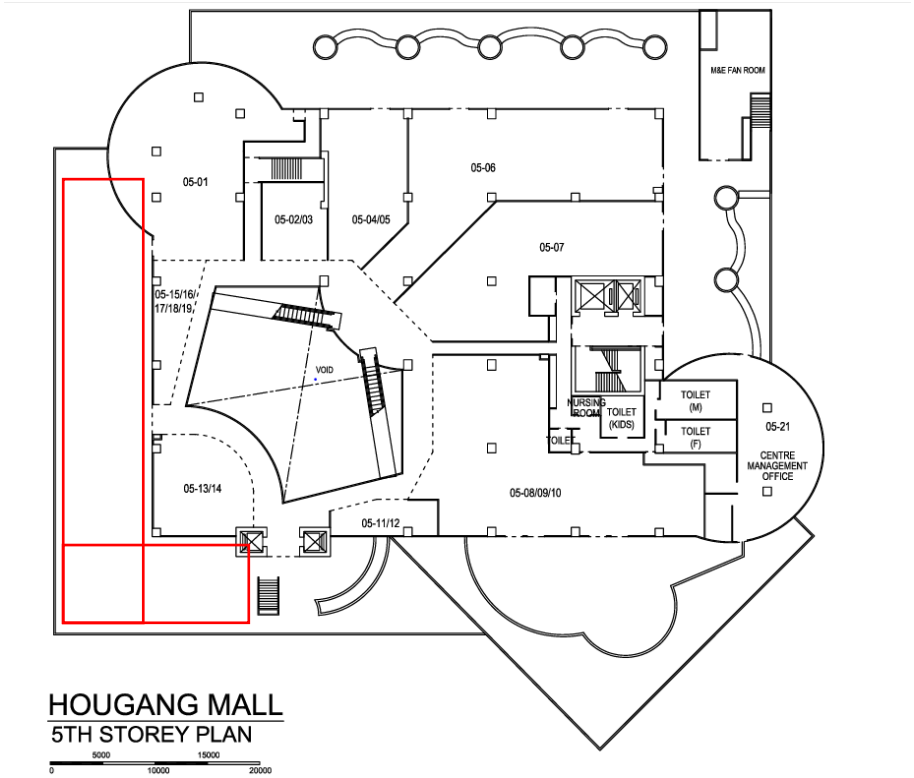


Figure 53

Figure 54

Above is the outdoor area of Level 5 of Hougang Mall, where we plan to implement the rooftop garden which consists of both the greenery resting place and the potted plants alongside the walls. This initiative will help improve the malls overall aesthetics and greenery whilst making use of the empty space.

Plant species that can be implemented:

Plant Type:	Reason:
Roses:  *Figure 55*	Roses can tolerate full sun and perform well in deep, well-draining soil, which are common conditions on rooftops. They also have wide range of colors which contribute to the aesthetics of the rooftop
Juniper:  *Figure 56*	Junipers are hardy and adaptable to various soil conditions if the soil drains well. They can also withstand the wind and exposure often found on rooftops.
Coreopsis:  *Figure 57*	Coreopsis is drought-tolerant and not picky about soil type, making it easy to maintain in the harsh conditions of a rooftop garden.
Succulents:  *Figure 58*	Succulents, such as Hen and Chicks, thrive in sunny, dry conditions and require minimal water, which suits the exposed, arid environment of a rooftop.
Marigolds:  *Figure 59*	Marigolds can grow in full sun and well-draining soil, common rooftop conditions, and their pest-deterring properties are good in an urban setting.

Waste Management:

1. **Food Composter**

Food wastage remains a huge concern in Singapore. Hence a well-structured compact design food waste composter will enhance existing waste management systems. Food composters use aerobic processes (requiring oxygen) to break down organic material. It converts waste to soil supplements in 24 hours. This process involves microorganisms breaking down food waste into compost, a stable, humus-like material. The main product is compost, which is a nutrient-rich soil amendment that can be used to enhance soil health and fertility. Compost adds organic matter, improves water retention, and provides essential nutrients for plants. This is a win-win solution as not only does it help the mall to reduce its wastage but also beneficial for the plants indoor and on the rooftop garden.

Model:

Figure 60

Above is a composting machine from ECOBOT. It is a fully automatic organic waste converter. With this, Hougang Mall can manage its waste efficiently and economically through an environmentally conscious process.

Implementation:

Figure 61

Figure 62

Figure 61 and 62 shows the loading and unloading bay located outside of Hougang Mall near the drop-off point. As it is spacious without many objects surrounding and blocking the area, we plan to implement the food composter there as it is too bulky to be placed in the mall and restaurants.

Process:

Figure 63

Step 1: Feeding of Waste
Waste passes through in-built high strength shredder. The crushed waste then enters the conversion chamber.

Step 2: The Compost Cycle Starts
A simple turn of the of the switch puts the machine into automatic conversion mode. Multiple inbuilt sensors maintain suitable temperature and moisture conditions. This process will be completed within 24 hours and the composter will then enter power saving mode.

Step 3: Remove of Soil Enricher
A tap on the touchscreen puts the machine in unloading mode. The operator will then open the outlet door where the finished soil enricher will start falling out automatically. The machine is then ready for the next batch of waste.

Benefits:

- **Improved hygiene**: By diverting food scraps from overflowing bins, food composter can contribute to a cleaner and more pleasant environment within the mall.

- **Conserving landfill waste**: Malls generate significant amounts of food waste from their food courts and restaurants. Composting this waste reduces the amount of organic material sent to landfills, which in turn decreases landfill use and the associated environmental impacts.

- **Reducing pollution**: Methane is a major GHG released by food waste deposited in landfills. Composting reduces methane emissions, thereby helping to combat climate change.

- **Soil health improvement**: Compost produced from food waste is rich in nutrients and can be used to improve soil quality in surrounding areas or

sold to agricultural enterprises. Healthy soils sequester more carbon and support robust plant growth.

2. Smart Recycling Boxes and Lockers

Figure 64

These are smart recycling boxes. The system, introduced by local waste company 800 super, collects paper, plastic, aluminum, glass, metal cans and clothing. It generates a unique QR code that a user scans at the smart boxes, before selecting the category of recyclable items. The corresponding compartment will then open. Thereafter, points will be awarded, and it can be used to exchange for FairPrice vouchers via an app. We can also award them with Frasers Points, where it can be exchanged for gifts.

Figure 65

Alongside the smart recycling boxes is a food waste recycling locker. Users can put food scraps like fruit peel and fish and meat trimmings in provided airtight containers and weigh them before placing them in the locker. The system could

cut the contamination rate of recyclables to just 10% - far lower than the national average of 40%.

Implementation:

Figure 66

This is the outside of Level 5 of Hougang Mall. We recommend implementing the recycling boxes and lockers here as there is not that much space in the mall and the outdoor area is very spacious without any obstruction. It would be placed alongside the walls under the shade as shown in Figure 59.

3. Cigarette Butts Recycling Bin

Figure 67

Cigarette butts have a significantly huge impact on the environment. Every stage of the tobacco supply chain poses serious environmental consequences, including deforestation, the use of fossil fuels and the dumping or leaking of waste products into the natural environment. The production and consumption of tobacco products also lead to significant carbon emissions, with smoking directly emitting 2.6 million tonnes of carbon dioxide annually. Each cigarette is estimated to emit about 14 grams of CO_2 throughout its cycle. On a larger scale, every year, tobacco production emits 80 million tonnes of carbon dioxide equivalent. Post consumption, cigarette butt littering represents not only a public nuisance but are exerting hazardous and toxic effects on the environment and ecosystems where they end up.

Year	Trees Cut (millions)	Land Used (hectares)	Water Used (tonnes)	CO2 Emissions (tonnes)	Cigarette Butts Littered (trillions)
2023	600	200,000	22 billion	84 million	4.5

Figure 68

Cigarette butts are one of the most polluting, discarded objects in the world, with 4.5 trillion annually. Used cigarettes that are thrown on the ground are problematic for the environment because they release toxic substances which can contaminate water, soil, and ecosystems. Only an estimated third of the cigarette butts from the 18 billion cigarettes smoked worldwide everyday end up in a rubbish or recycling bin.

Hence, this cigarette butt recycling initiative aims to stub out both litter and wastefulness. This bin ensures that cigarette butts don't end up on the streets or anywhere else, instead, are collected, recycled, and rid of toxins.

US-based recycling business TerraCycle, first sanitises the waste with gamma radiation before separating it by material type. Paper goes on to be recycled white the tobacco is composted. The plastic from cigarette filters is also turned into pellets that later go on to form the building blocks of everyday products such as outdoor furniture, storage containers etc.

Implementation:

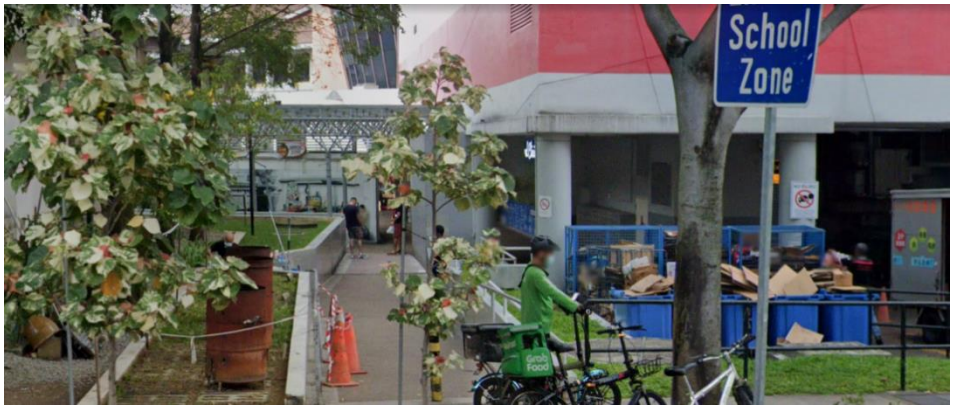


Figure 69

The first place we recommend implementing the cigarette butt recycling bin is at the smoking corner outside of Hougang Mall just right beside the loading and unloading area where people go to smoke. This bin is different from the current regularly dustbin there as only cigarette butts should be disposed in it compared to the regular dustbin where all sort of trash would be disposed. As the rate of daily smokers are high, this bin would help in the collection of all the used cigarette butts which will then be sent away to be recycled to be converted into other daily necessities.

Figure 70

The second place we recommend implementing the bin is outside Level 5 at the outdoor area near the seats. There is also a common place where people would go to have a smoke break and there is no dustbin found there. Hence, instead of randomly disposing the cigarette butt on the floor or in the plants, they can dispose it off in this cigarette butt recycling bin. This initiative not only reduces the mall's overall waste, it also gives these cigarette butts a second life.

4. Food Waste Transforming Solar Panels

Figure 71

This food waste transforming solar panels generates electricity from natural resources. It is made from fruit and vegetable waste. Due to the internal reflectance of AuREUS, the material uses naturally occurring luminescent particles which capture ultraviolet rays and then emit the energy as visible light. Combined with photovoltaic (PV) cells, they can generate solar power, even on cloudy days.

It is made from AuREUS, a material, or a technology, that allows other devices to harvest ultraviolet light and convert it into electricity. AuREUS is based on a plastic material and the particles are embedded in a flexible resin so it can be formed into different shapes. It generates electricity from natural resources.

This invention increases solar energy harvesting density tenfold[4] and opens the way for any building to become its own solar power farm by using AuREUS solar panels as its windows.

Community Engagement:

1. **Creating Circular Economies (Circular Mall):** - with reference to aeon mall
   - Co-Creating with Customers, Tenants, and Local Community Societies to Create Circular Societies
   - To achieve zero waste, we intend to build circular mall that serve as an example and hub for regional recycling economies.
   - When malls become a collection point for household waste, clothing, and other items, they provide value to the community at large. They do so by making new products from collected items and returning them to customers.
   - The event can also include a recycling workshop given by students from design/fashion courses, which can promote the importance of upcycling, giving used items a second life whilst having a change of fashion style!
   - To market this event, we can promote the mall's eco-friendly practices through signage, social media, and its website.
   - By implementing these ideas, malls can become hubs for environmental awareness and action, fostering a sense of community and attracting environmentally conscious consumers.

2. **Educational Events**
   - Workshops: Host workshops on topics like sustainable living, composting, or clothes upcycling. Partner with local environmental organizations for expertise.
   - Talks and Panels: Invite local green businesses or sustainability experts to give talks on environmental issues and solutions.
   - Educational Platform: Community gardens can be living laboratories for sustainable practices. Visitors can learn about composting, seed saving, and other techniques that minimize waste in the food cycle. This knowledge can be applied at home, further reducing household waste.

Conclusion:

In conclusion, the proposed sustainability initiatives for Hougang Mall include a comprehensive strategy for increasing energy efficiency, greenery integration, and improving waste management practices. By utilizing solar energy, implementing smart lighting systems, introducing greenery walls and rooftop gardens, and upgrading waste management infrastructure, the mall can significantly reduce its environmental impact while creating a more appealing and sustainable space for customers and tenants. These initiatives not only align with sustainability goals, but also help the mall maintain its market position and long-term viability in the Hougang area. With careful planning and execution, these measures have the potential to transform Hougang Mall into an example of urban sustainability and commitment to the environment.

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