Final Submission of Proposals

For

Sustainability Cities Challenge 2024

On

Hougang Mall

Registration Number: IHL021

By

Stansen Ang
Kanchelskis Chiew
Mohamed Aarif Bin Tippu Sultan

Singapore Polytechnic

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1. Introduction of Hougang Mall

Hougang Mall boasts a net lettable area of 13,393 square metres and accommodates over 12.7 million shoppers annually.

The mall also has a Green Mark Platinum certification for existing non-residential buildings. Despite its status as a relatively older building, the mall has undergone extensive retrofitting and upgrades to enhance its energy and carbon efficiency.

One notable initiative includes the retrofitting of the cooling system to improve energy efficiency, resulting in a projected 34.4% increase in operational efficiency and annual energy savings of 1,000,000 kWh. Additionally, the installation of LED lighting in common areas is expected to further reduce energy consumption by 100,000 kWh annually. These efforts have collectively led to Hougang Mall successfully lowering its carbon footprint by 395 tonnes of CO2e and reducing energy consumption by 968,000 kWh.

2. Background of Report

Against this backdrop, the objective of this sustainability challenges report from our group is to reimagine and retrofit Hougang Mall, integrating sustainable principles into its architecture and landscaping, via addressing three key areas as follows:

a. Intensify the use of renewable energy through the harnessing of solar-photovoltaic panels

The mall is missing out on the opportunity to harness renewable energy sources from their available space on the rooftop. Solar panels can be installed on the rooftop to harness solar energy, reducing the mall's reliance on non-renewable energy sources.

b. Improving efficiency of air-conditioning with hybrid cooling, and

The mall experiences limited air circulation due to its atrium design as well as the corridors within enclosed space. Implementing fans for air circulation could improve comfort and reduce the need for excessive air conditioning.

c. Facilitate eco-friendly waste management, that can shape a greener and more sustainable future for the mall and its surrounding community.

The mall experiences a need for waste management methods that are more efficient and require minimal effort to manage. By introducing artificial intelligence and Internet of Things (IoT) into their waste management, operations are more efficient. Furthermore, a community centred approach towards waste management can engage Hougang Mall's users in joining in the effort towards waste reduction.

Figure 1: Hougang Mall, An Iconic Building in The Northeast District of Singapore

2.1 Background Information on The Need for Our Sustainability Proposals

Hougang Mall serves as a bustling hub for commerce, leisure, and community engagement, attracting a significant footfall of visitors daily. However, the operation of such a large-scale facility demands substantial energy consumption, primarily sourced from conventional fossil fuels. Recognizing the environmental implications of its energy practices, Hougang Mall can seek to enhance its sustainability credentials by implementing innovative solutions that prioritise energy efficiency and environmental stewardship.

2.2 Total Building Performance Addressed

Idea	Mandate	Physio	Psycho	Socio	Econ
Solar Panel	Energy Efficiency	Utilises Unused Roof Space	-	-	Saves Cost
Hybrid Cooling	Thermal Energy Efficiency	Improved Comfort	-	**-**	Saves Cost
Eco-Friendly Waste Management	Waste Management	**-**	Enhances Bond of The Community	Community Involvement in Recycling	Increased Sustainability

3. Proposal 1 - Harnessing Solar Photovoltaic Energy

3.1 Introduction & Benefits of Solar Panels and Solar Energy

The extensive rooftop of Hougang Mall presents a prime opportunity for the installation of solar panels, an initiative that could revolutionise its energy consumption dynamics. By harnessing the potential of solar energy, Hougang Mall could not only mitigate its environmental impact but also reap a myriad of benefits, ranging from cost savings to enhanced sustainability efforts.

The following reasons outline the benefits Hougang Mall can reap:

1. Cost Savings: Embracing solar energy allows establishments like Hougang Mall to reduce their reliance on traditional grid electricity, thereby lowering operational expenses associated with utility bills. Once the initial investment in solar panel installation is recouped, the electricity generated from solar becomes essentially free, leading to substantial long-term cost savings.

2. Environmental Sustainability: Solar energy is a clean, renewable resource that produces minimal greenhouse gas emissions and pollution compared to conventional fossil fuels. By transitioning to solar power, Hougang Mall can significantly reduce its carbon footprint, contributing to environmental sustainability and combating climate change.

3. Energy Independence: Installing solar panels empowers Hougang Mall to generate its own electricity on-site, reducing dependence on external energy sources and the volatility of utility prices. This increased energy independence provides greater stability and resilience against fluctuations in energy markets.

4. Promotion of Green Image: Adopting solar energy aligns with the growing consumer preference for environmentally responsible businesses. By visibly demonstrating its commitment to sustainability through solar panel installation, Hougang Mall can enhance its brand reputation and attract eco-conscious customers and tenants.

5. Long-Term Investment: Solar panels have a long lifespan and require minimal maintenance, making them a sound long-term investment for Hougang Mall. Additionally, advancements in solar technology continue to improve efficiency and decrease costs, ensuring that the benefits of solar energy will only increase over time.

6. Aligning with National Goals: The Minister for Sustainability and the Environment has highlighted Singapore's commitment to reaching a solar power deployment target of at least 2,000 megawatt-peak by 2030. Solar energy will play a significant role in Singapore's energy mix, with projections suggesting that it could meet about 10 percent of the country's projected electricity demand in 2050. Moreover, Singapore has committed to achieving net zero emissions by 2050 as part of its long-term low-emissions development strategy. By investing in solar photovoltaic technology, the mall actively participates in Singapore's journey.

3.2 Feasibility Study

This section provides our rationale as to why Hougang Mall is a prime place to install solar panels.

3.2.1 Evaluation of local climate conditions and their impact on solar energy production.

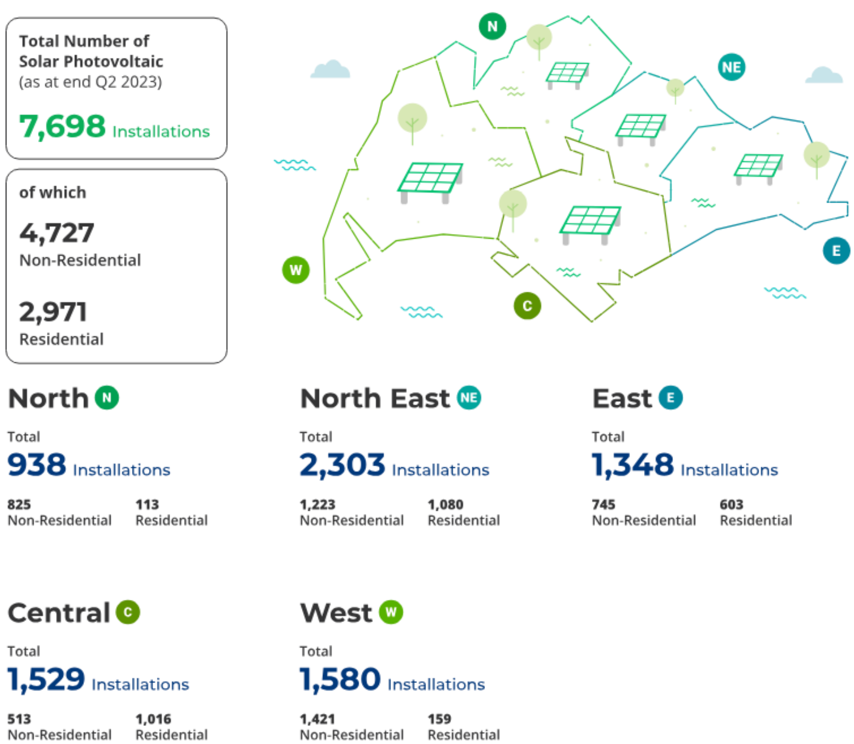

Figure 2: Solar Installations by Planning Region (https://www.ema.gov.sg/resources/singapore-energy-statistics/chapter6#solar-pv-installations, 2023)

Hougang Mall is in the **North-East Region** of Singapore and thus is one of the most suitable locations to implement solar panels to harness solar energy.

Singapore's tropical climate provides favourable conditions for solar energy production. With abundant sunshine throughout the year and minimal seasonal variations, the local climate is conducive to efficient solar panel operation. However, admittedly periodic rainfall and cloud cover may temporarily reduce energy generation levels. Nevertheless, advanced solar panel technology, coupled with efficient system design, can mitigate the impact of such weather conditions on overall energy production.

Looking into the microscale of the vicinity of Hougang Mall, little photovoltaic technology has been implemented. Macroscale-wise, more residential buildings along Kovan/ Ang Mo Kio have been commissioned for rooftop solar panelling systems under the Solarnova programme launched in 2024. The programme aims to produce and generate an estimated 420 GWh of solar energy annually, amounting to 5% of Singapore’s total energy consumption. As of Quarter 2 2023, North-East boasts the highest number of photovoltaic installations amongst the planning regions, showing it has and can be done.

High sunlight exposure in its geolocation, ideal rooftop configuration and space for the installation of solar battery farm, minimum disruption to the use of rooftop space.

Figure 3: Overhead View of Empty Spaces

Figure 4: Rooftop View of Hougang Mall

Figure 5: Zoomed In Area for Installation of Solar Panels

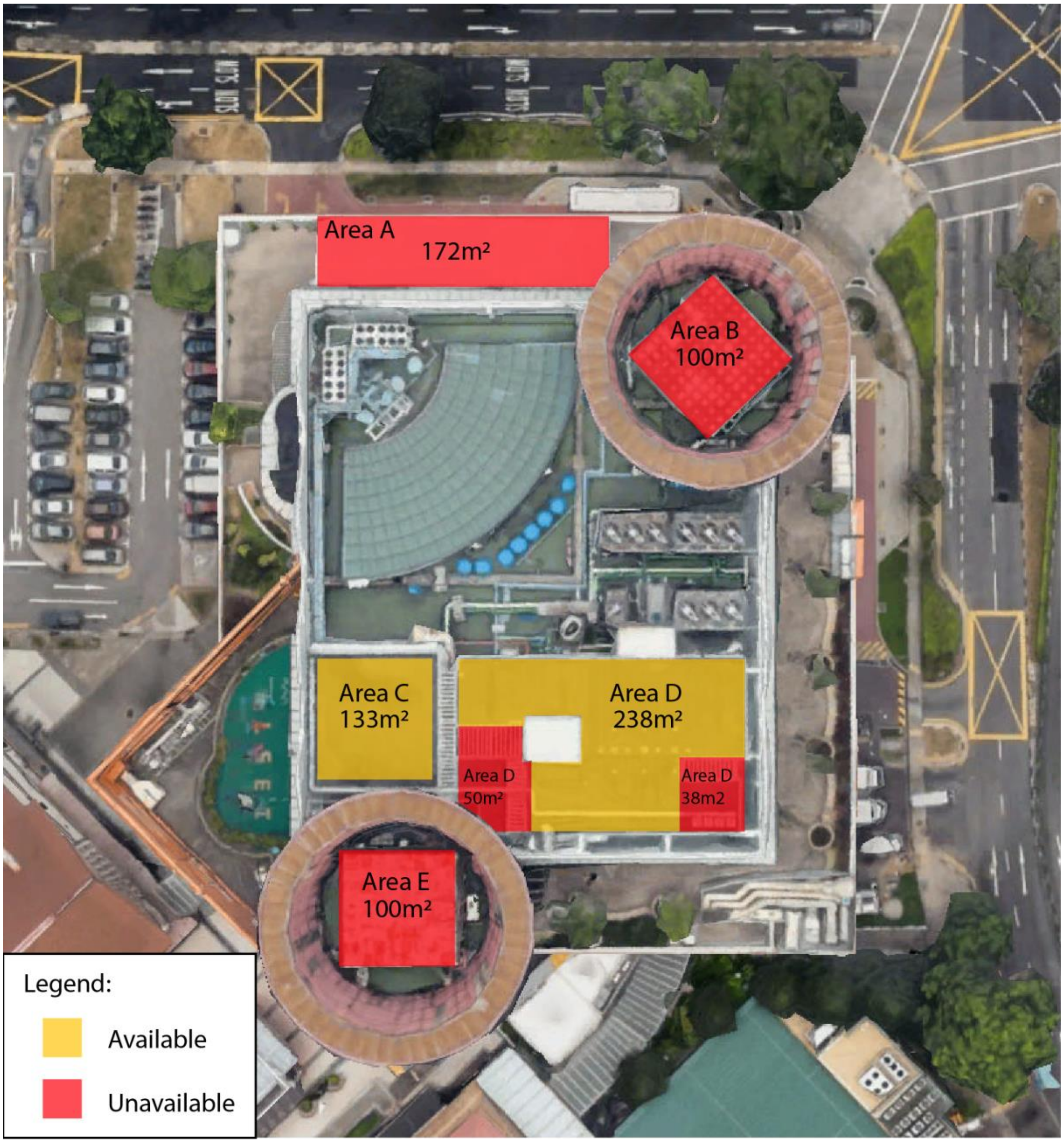

Figure 6: Areas Of Proposed Rooftop for Installing Solar Panels
Source: Modified From Google Maps

Utilising a map area computing software (map developer area finder) the total estimated area available for installation of solar panels on the roof of Hougang Mall is 371m2. 80% of it would be 296m2. These proposed areas include the space needed for maintenance access and the various engineering and electrical elements needed to power and maintain the solar panels.

Name	Area	Remarks
Area A	**172**	Condenser Unit Storage Area
Area B	**100**	Domestic Worker Tank/ Sprinkler Tank
Area C	**133**	Simple Supporting Structure over the roof
Area D	**238**	Simple Supporting Structure over the roof
Area E	**100**	Domestic Worker Tank/ Sprinkler Tank

Table 1: Considerations for Solar Panels Installation

3.2.2 Analysis of the Surrounding Characteristics of Hougang Mall

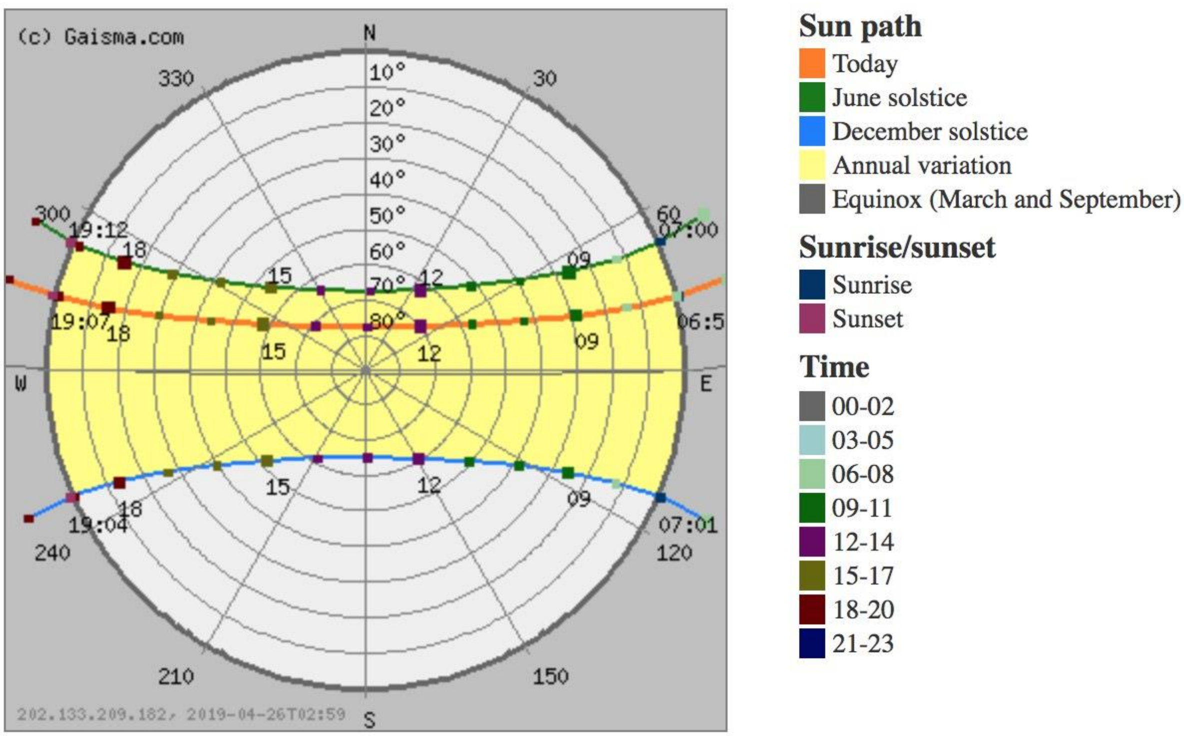

Figure 7: Sun Path (https://www.gaisma.com/en/location/singapore.html)

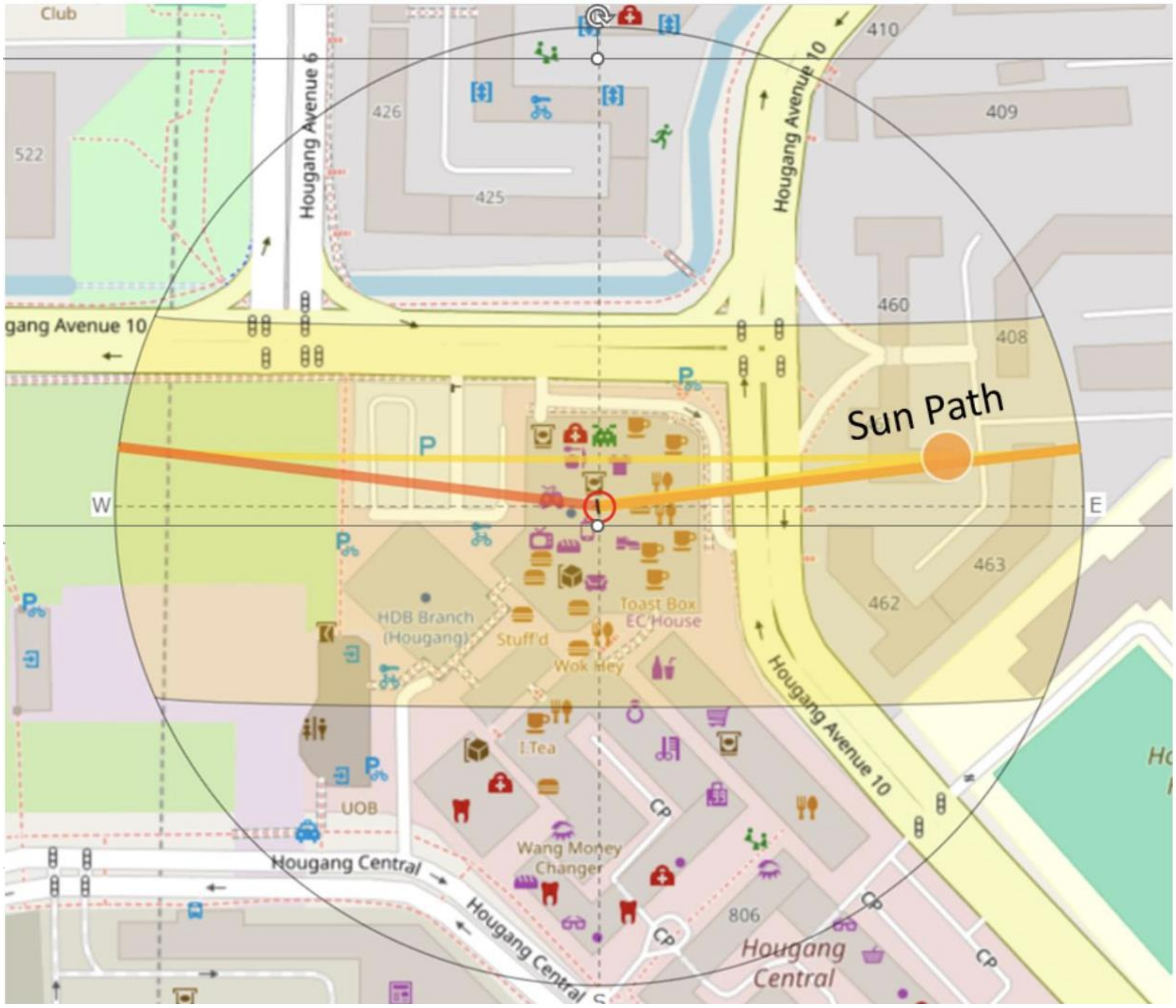

Figure 8: Sun Path
(https://www.suncalc.org/#/1.3742,103.8869,19/2024.05.01/23:48/1/0)

The maximum sunshade would be from the following HDB building 463 in which the shade starts from early morning 8 am and clears up at 12 pm. The shadow cast affects mainly the bottom right square of the proposed solar panels. From 12 pm to 6 pm, no further shadow will be cast on the roof of Hougang Mall especially during its peak at 12 pm making it suitable for solar panel installation.

Figure 9: Side View Comparing the Height of the Nearest Building to Hougang Mall

Table 2: Potential Shadows Cast from Taller HDB Blocks Surrounding Hougang Mall Overtime.
(https://shademap.app/@1.37256,103.89367,17.48684z,1712965200629t,0b,0p,0m)

Based on an assessment of Hougang Mall's sun path, blocks 460, 461, and 462 to the east of the mall would potentially cast shadows on the rooftop where solar panels are installed. The quantity of solar energy that the panels receive throughout the morning hours of 8 a.m. to 12 p.m. will be impacted by these shadows. Since the heights of the adjacent buildings to the west of Hougang Mall are relatively shorter, the shadow cast will be reduced from noon onward, allowing the solar panels to collect and generate the maximum amount of solar energy.

Additionally, installing solar panels on the rooftop of Hougang Mall offers the advantage of minimal disruption to daily operations. Unlike ground-mounted solar installations, which may require land clearing or alterations to existing infrastructure, rooftop solar panels can be seamlessly integrated into the existing building structure. This minimizes the need for additional space and mitigates any potential disruptions to parking areas or pedestrian traffic.

Furthermore, rooftop solar installations are less susceptible to vandalism or theft compared to ground-mounted systems, enhancing security and peace of mind for the mall management. Overall, the rooftop location provides an ideal opportunity to harness solar energy while minimizing disruption to the mall's operations and aesthetics.

3.2.3 Assessment of The Suitability of The Rooftop for Solar Panel Installation

The rooftop at Level 6 of Hougang Mall provides an ideal space for solar panel installation. Initial assessments indicate that the orientation of the rooftop allows for maximum exposure to sunlight throughout the day, optimising energy generation potential. Minimal shading from surrounding structures ensures that much of the rooftop area receives ample sunlight. However, structural integrity assessments are to be conducted to confirm that the rooftop can support the weight of solar panel arrays.

The mounting structure will be carefully designed to optimize solar exposure and ensure the efficient capture of sunlight throughout the day. This may involve utilizing fixed tilt mounting systems to orient the panels at an optimal angle relative to the sun's path, maximizing energy generation potential. Additionally, considerations will be made to minimize shading from surrounding structures and maximize the use of available space to accommodate as many panels as feasible.

3.2.4 Analysis of Potential Energy Generation Capacity

The available rooftop space at Hougang Mall offers significant potential for solar panel installation. Preliminary calculations suggest that approximately **296 square meters** of space can be utilized for installing the solar panels, allowing for the installation of a substantial array. Based on this available space and considering the average solar irradiance levels in Singapore, the estimated energy generation capacity of the proposed solar panel system is approximately **35030 Kilowatt-hours per year**.

3.2.5 Hougang Mall's Energy Usage

With reference to the BCA Building Energy Benchmarking Report (Statistics and Figures) 2023, the average energy use intensity for large retail malls was 275 kWh/m2. Under BCA, large retail malls refer to office Buildings and Retail Buildings of GFA ≥15,000 m², in which Hougang Mall boasts 21,626 m². (BCA)

Energy Consumption = EUI * GFA	Energy Generated = Available Rooftop Area * Solar Irradiance * Panel Efficiency * Time Period
Energy Consumption	Tenant – 8,356,000 kWh Landlord – 4,389,800 kWh Total – 12,745,800 kWh
One Solar Panel Area	97.91/66 = 1.4834848485m2
Area available for Solar Panels Installation attained from **3.2.3**	80% x (133+238) ~ 296
Number of Panels for Hougang Mall	296/1.483 ~ 200 Panels
Annual kWh Generated from Solar Panels	11560/66 * 200 = 35,030 kWh
Percentage of Hougang Malls Energy Usage that can be covered by Solar Energy	35,030/12,745,800 = 0.27%

Table 3: Hougang Mall Energy Usage Table

When calculating the total area required for solar panels, only 80% of the available space were allocated for the panels themselves. This decision accounts for the necessary support structures and walkways that facilitate maintenance and access. By doing so, we ensure that there is adequate room for essential infrastructure, safety, and operational efficiency. The remaining space accommodates any unforeseen adjustments or expansions, thereby optimizing the overall functionality and durability of the solar panel installation.

3.2.6 Comparison of Malls Solar Panels Statistics

As compared to City Square (97.91m2), JCube (300m2) and Bugis Junction (1000m2), the area identified on the rooftop is adequate and feasible for installing solar panels in Hougang Mall. Todayonline

Venue	Hougang Mall (Potentially)	Junction 8	JCube	City Square
Solar Panels Number	200	1000	202	66
Area of Solar Panels Metre Squares	296	1000	300	97.91
Annual Power Generated kWh	35,030	200,000	60,477	11,560

Table 4: Comparisons of Solar Panels' Outputs with 3 Other Shopping Malls

3.2.7 Hougang Mall Annual Greenhouse Gas Emission

Item	Electricity consumption in Tenant Area x Emission Factor	Greenhouse Gas Emission
Sep-23	693,900 x 0.4168 kg CO2/kWh	289,218 Kg CO2
Oct-23	724,600 x 0.4168 kg CO2/kWh	302,013 Kg CO2
Nov-23	694,600 x 0.4168 kg CO2/kWh	289,509 Kg CO2
Dec-23	713,800 x 0.4168 kg CO2/kWh	297,512 Kg CO2
Jan-24	696,000 x 0.4168 kg CO2/kWh	290,093 Kg CO2
Feb-24	655,100 x 0.4168 kg CO2/kWh	273,046 Kg CO2
Total for Tenant 6 Months	-	1,741,391 Kg CO2
Annual Tenant Greenhouse Gas Emission	**1,741,391 x 2**	**3,482,782 Kg CO2**

Annual Landlord Greenhouse Gas Emission	**914,935 x 2**	**1,829,870 Kg CO2**
Hougang Mall Annual Greenhouse Gas Emission	**1,829,870 + 3,482,782 Kg CO2**	**5,312,652 Kg CO2**
Reduction of Greenhouse Gas Emission with Solar Panels	**35,030 x 0.4168 kg CO2/kWh**	**~14,600**

Table 5: Hougang Mall Annual Carbon Emission

Source: EMA

3.2.8 Types of Solar-Panels that can be used

1. **Ballasted racking systems** are non-penetrative mounting solutions that rely on weighted ballasts to secure the solar panels to the roof surface. These frames are ideal for flat roofs and are adjustable to accommodate various roof configurations. Ballasted racking systems are popular for rooftop solar installations because they minimize the need for roof penetrations, reducing the risk of water leakage and structural damage.

Figure 10: Ballasted Racking Systems
Source: *https://modernize.com/homeowner-resources/solar/solar-ballast*

2. **Rail-Based Racking Systems** consist of aluminium rails that are attached to the roof structure using mounting brackets. Solar panels are then attached to the rails using clamps, allowing for easy installation and maintenance. Rail-based systems are versatile and can be adjusted to accommodate the slope and orientation of the roof. They are suitable for both flat and sloped roofs.

Figure 11: Rail-Based Racking Systems
Source: *https://www.polarracking.com/rooftop-solar-mounting-system/rail-based-solar-racking/*

3.2.9 Advisory Note for Solar Panel Installations

It is recommended to adopt a 10 to 15-degree tilt angle of the panel to the horizontal plane. This range of tilt angles optimises the performance of solar panels by maximising energy harvest. Panels installed at less than 10 degrees may lose performance as rain trapped by the panel frame could cause dirt to be deposited on the panel as it evaporates. Tilting beyond 20 degrees also reduces the absorption of overhead equatorial sunshine.

The following guide is recommended by BCA with regards to the licences for installation of solar photovoltaic systems on rooftops.

No.	Design and Installation Checklist	Check Box
1	Set your budget and select a location.	☐
2	Determine the energy requirement and estimate the size of the system.	☐
3	Perform a site survey for space needed, and access for maintenance.	☐
4	Engage a licensed electrical worker ("LEW") if your proposed solar PV system: i) is to be connected to the electrical installation within the premises of the building; and /or ii) to be connected and operated in parallel to the power grid. The appointed LEW will be responsible for the design and implementation of the connection of your solar PV system to the electrical installation and/or power grid.	☐
5	Select a PV module type and mounting method.	☐
6	Select inverter to match PV array: i) Number of inverters needed; ii) Select inverter type; and iii) Location of inverters (accessible for inspection and maintenance).	☐
7	Finalise the mounting system.	☐
8	Ensure there are fixing and mounting points available.	☐
9	Ensure the structure for mounting is safe: i) Additional loading by solar PV system is considered; ii) Wind loading is considered; and iii) Waterproofing is not compromised during installation.	☐
10	Ensure solar access: i) Ensure location to be mounted will get maximum exposure to sunlight; and ii) Choose a location that is not shaded.	☐

Figure 12: Solar Photovoltaic System Installation Checklist
Source: BCA Advisory on Solar Panels Guidelines
Reference:(https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/handbook_for_solar_pv_systems.pdf)

4. Proposal 2 - Improving Efficiency of Air-Conditioning with Hybrid Cooling

4.1 Area Identified for Sustainability Improvement

It is paramount to maintain a pleasant environment for visitors and occupants of Hougang Mall. It is a known fact that air movement can play a vital role for occupant's comfort, particularly in large atrium spaces and corridors.

Green Mark 2021 by BCA emphasizes hybrid cooling systems to improve energy performance and sustainability which involves raising HVAC temperature setpoints and using ceiling fans to enhance thermal comfort. Higher setpoint temperatures in fan-integrated AC systems save energy compared to the conventional 23-25°C range recommended by SS 553 (2016).

Thus, HVLS fans can be installed at the ceilings of corridors to enhance air circulation.

Given that the Hougang Mall has a conical shaped atrium, destratification fans can be installed under the skylight of Hougang Mall with suitable additional structure. This can prevent the buildup of hot and stagnant air at the upper levels of the mall.

Moreover, this enhanced air movement provides a cooling effect that allows for a thermostat set point increase of 2 to 3°C without sacrificing comfort. This adjustment can lead to a significant 20% reduction in energy expenses by effectively reducing the air-conditioning load. Currently, the air conditioning system at Hougang Mall is set to around 24°C, which can theoretically be increased to 26°C with proper testing and adjustments.

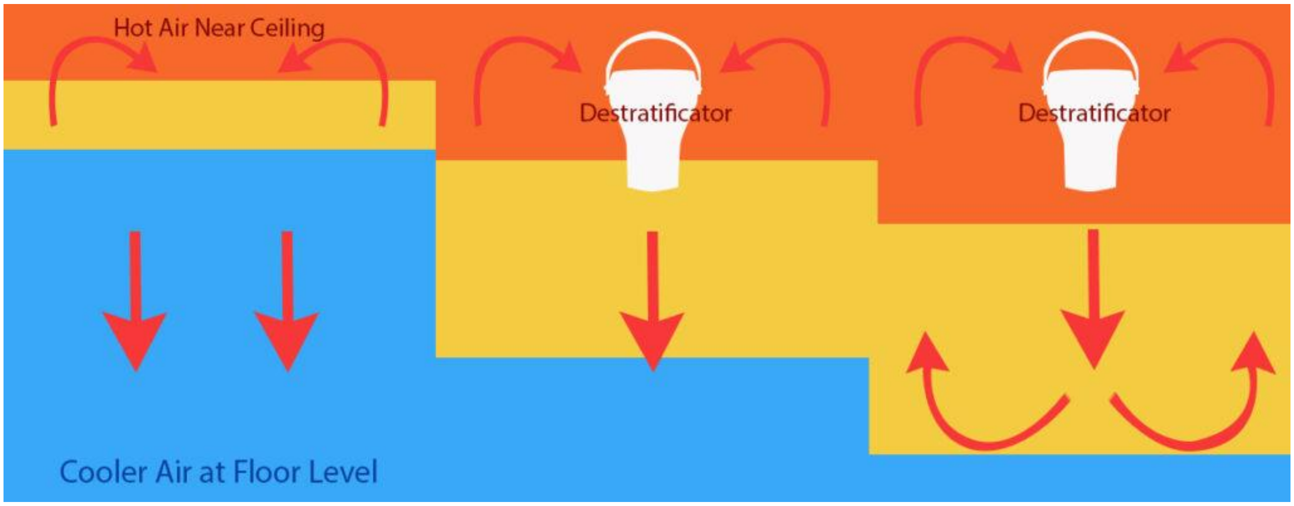

Figure 13: Fans Improve Indoor Air Quality by Circulating Hot Air at the Ceiling

Air naturally stratifies due to temperature differences, causing warm air to rise and cooler air to sink, creating layers of different temperatures. This stratification poses challenges in HVAC design, impacting thermal comfort and indoor air quality.

Destratification mixes the air to combat stratification. By recirculating air, destratification fans break up the layers, pushing warm air down to the floor.

4.2 Proposed Solutions

To address this need, the proposed solution entails the utilisation of HVLS Fans in every retail level's corridor to achieve optimal airflow and ventilation.

Figure 14: Picture of HVLS Fans in Mall

The ceiling height of each level in Hougang Mall is 3m, which is ideal for installing HVLS fans, as their optimal height is between 2.7 to 3.2m.

A rod can be added to adjust the fan's height for better airflow if needed.

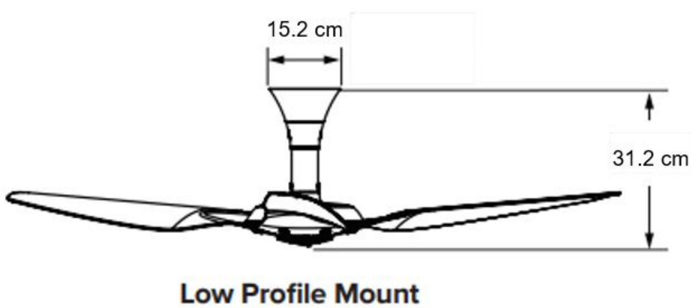

Figure 15: Dimensions of HVLS Fan

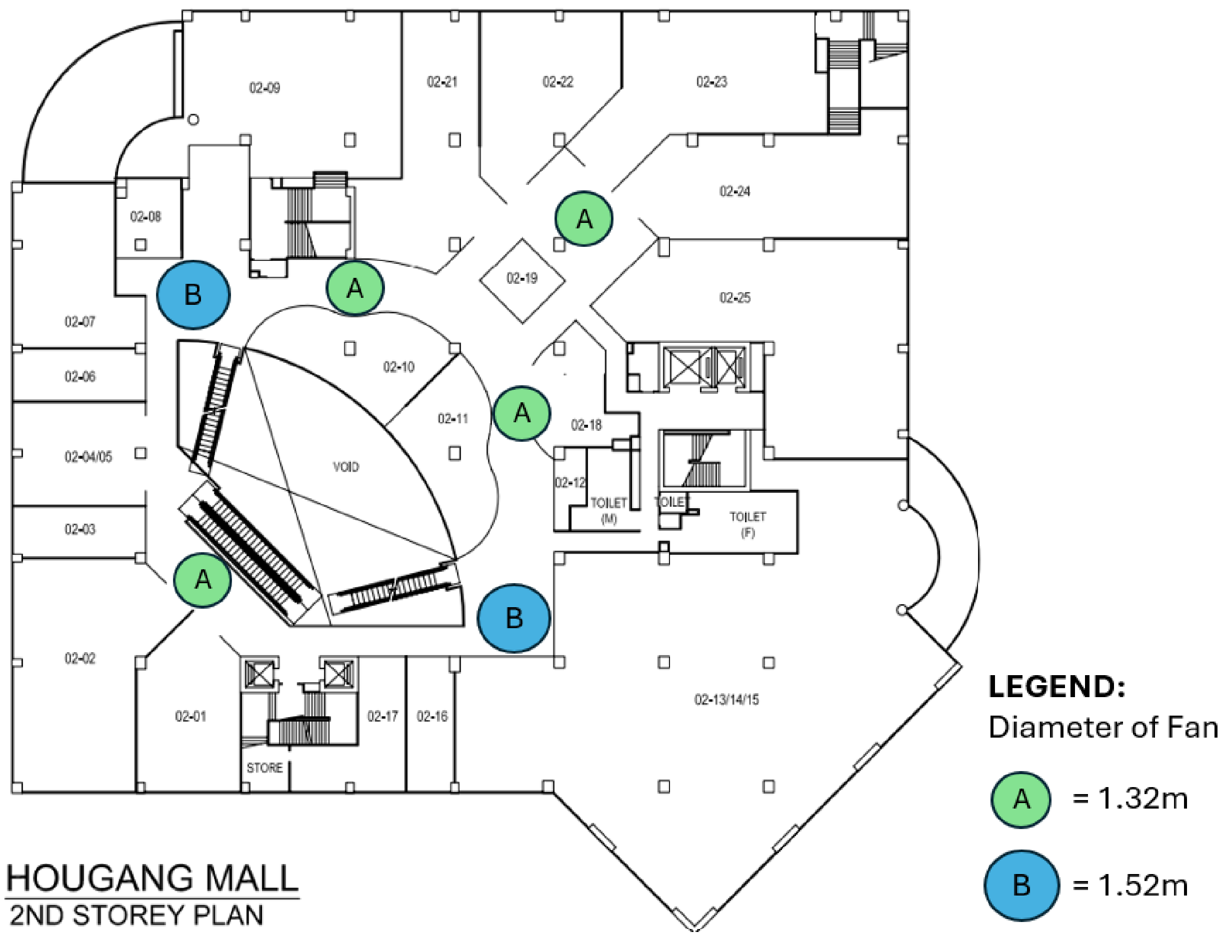

Figure 16: Proposal of Areas for HVLS Fan Installation

A 1.32m fan has a max speed of 177 RPM and airflow of minimally 427 to a maximum of 5,172 CFM.

In each retail level corridor of the mall, it's recommended to install fans in central and strategic areas to maximise air movement.

Smaller fans are placed along the corridors where they provide adequate airflow without being obstructive, as these areas are narrower and see more foot traffic. In contrast, larger fans are strategically placed in the top left and bottom right corners of wider areas to enhance air circulation, as these corners often experience less effective airflow and require the greater capacity of larger fans.

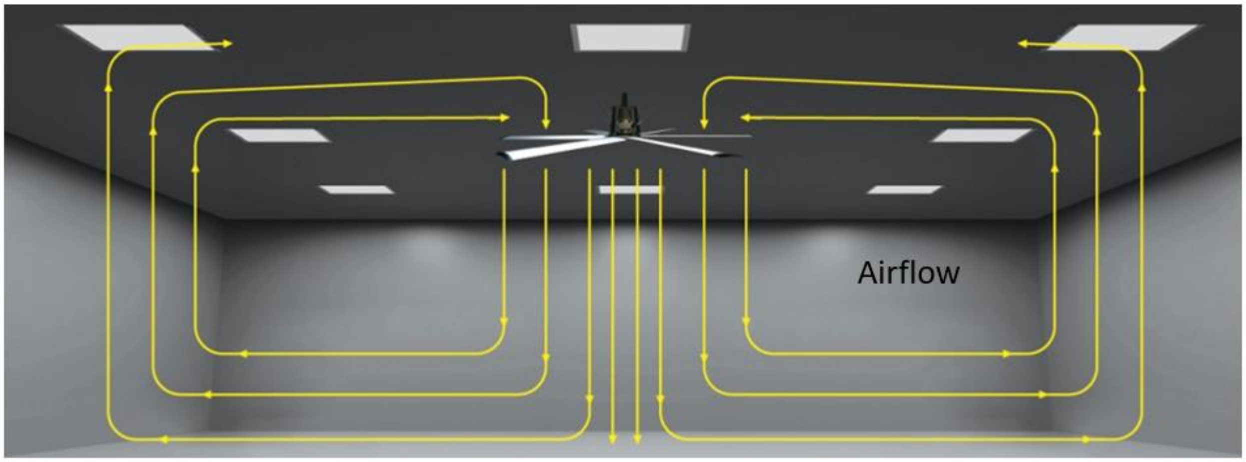

Figure 17: Working Principle of HVLS Fan

The fan's function is to move air, promoting faster evaporation for a cooling effect. HVLS fans push large volumes of air from the ceiling down to the floor. This air then spreads horizontally until it meets a wall or obstacle, where it then redirects upwards and sideways. When the air rises, it is pushed down again by the HVLS fan, creating continuous airflow throughout the space.

Another proposed solution is the usage of destratification fans under the skylight.

Figure 18: Hougang Mall Atrium Space

The destratification fans feature a unique nozzle design and stator system that delivers a focused column of air from the ceiling to the floor. Unlike traditional axial fans, which lose airflow velocity due to radial spreading, the fixed blade stator below the fan converts rotational energy into a linear motion, creating a tight and efficient air column. This design, combined with a slightly tapered nozzle that increases exit speed, maximizes the effectiveness of the air throw.

Figure 19: Smoke Test Showing Airflow of Destratification Fan

As shown in the figure, the destratification fan outperforms a regular ceiling fan in air circulation. Unlike a standard ceiling fan that lets smoke accumulate at the ceiling, the destratification fan pushes the smoke down to the floor and then disperses it upward. The smoke test shows that the fan can evenly distribute air consistently to improve comfort in the mall.

4.3 Feasibility and Implementation

Distance	Airflow Speed	Coverage Area	Explanation
20 ft	4.34 m/s	Small	Strong airflow but covers a small area.
40 ft	2.13 m/s	Medium	Airflow strength decreases, covering a larger area.
70 ft	1.09 m/s	Larger	Airflow speed continues to decrease, with a larger coverage area.
100 ft	0.69 m/s	Largest	Weakest airflow with the largest coverage area.

Figure 20: Airflow and Area Coverage of Destratification Fan

As the distance from the fan increases, the airflow speed decreases. This happens because the air stream spreads out and loses its intensity as it travels farther from the fan. As the distance from the fan increases, the coverage area increases. While the fan covers a larger space at greater distances, the strength of the airflow decreases.

It has a potential lifespan of 10 years.

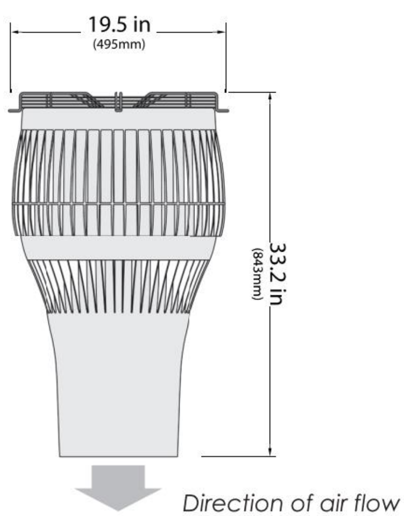

Figure 21: Dimensions of Destratification Fan

With ample space under the skylight for installation, the fan's compact design will blend well with the mall's aesthetics.

It is likely that steel beams are used in Hougang Mall, which are designed to support significant weights. It is likely that a 20 kg load, such as a single destratification fan for 1 beam, is well within their capacity to support.

4.3.1 Phased Installation and Timeline

Phase 1: Initial Installation and Testing

The objective of Phase 1 is to test the effectiveness of destratification fans and HVLS fans. Destratification fans will be installed under the skylight on the top floor to address temperature stratification, while HVLS fans will be installed on the ceiling of the first floor's corridor to enhance air circulation. This phase will last for 3 months. During this time, temperature consistency and energy consumption will be monitored, and feedback will be collected from visitors and occupants.

Phase 2: Expansion Based on Results

If Phase 1 proves successful, Phase 2 will focus on expanding fan installation. More HVLS fans can be installed from the second floor to the fourth floor, and additional destratification fans can be placed under the skylight on the top floor. Phase 2 is expected to last around 3-6 months. The need for additional fans on other floors will be determined based on the analysis of data from Phase 1.

4.3.2 Operational Strategy

The fans will be operated only during the mall's operating hours from 10 AM to 10 PM. Specifically, fans will be switched on during peak periods, such as 12 PM - 2 PM and 5 PM – 8 PM. During off-peak hours, fans can be turned off or operated at lower speeds to save energy.

Occupants accustomed to conventional cooling may take up to 3 months to adapt to a hybrid cooling system with warmer temperatures and higher air speeds. Changes in temperature setpoints should be gradual and based on occupant feedback. The adaptation process should incorporate thermal comfort analyses and practical feedback loops.

For example, increase the setpoint from 24°C to 25°C, maintain it for 2 weeks, then increase to 26°C. If dissatisfaction arises, adjust incrementally, such as lowering it to 25.5°C before raising it back to 26°C after adaptation.

4.3.3 Annual Greenhouse Gas Calculation for Landlord Area

Date	**Electricity consumption in Landlord Area x Emission Factor**	**Greenhouse Gas Emission**
Sep-23	373,200 x 0.4168 kg CO2/kWh	155,550 Kg CO2
Oct-23	384,000 x 0.4168 kg CO2/kWh	160,051 Kg CO2
Nov-23	361,500 x 0.4168 kg CO2/kWh	150,673 Kg CO2
Dec-23	367,900 x 0.4168 kg CO2/kWh	153,341 Kg CO2
Jan-24	366,000 x 0.4168 kg CO2/kWh	152,549 Kg CO2
Feb-24	342,300 x 0.4168 kg CO2/kWh	142,671 Kg CO2
Total	-	**914,835 Kg CO2**

Table 6: Carbon Emission for Landlord Area Over Last 6 Months

Electricity consumption - Landlord Area (kWh)

Electricity grid emission factor = 0.4168 kg CO2/kWh

Source of Largest consumption of electricity and their consumption patterns

The largest consumption of electricity originates from air-conditioning with an estimated 50% of total electricity consumed in the mall. Consumption patterns for electricity usage likely peaks during the hottest parts of the day and during periods of high foot traffic, such as late morning to early evening and on weekends. Special events and holidays can also lead to temporary spikes in electricity usage.

Efficiency improvement percentage for electricity and the carbon reduction target

In the carbon emissions calculation, it is assumed that air conditioning represents 50% of the total electricity consumption. The 6-month electricity consumption values are doubled to represent a full year's worth of data. This step effectively cancels out in the final carbon emissions calculations.

914,835 x 80% = 731,868 kg CO2/kWh

The annual carbon reduction target is 182,967 kg CO2, which is 20% of the carbon emissions produced from electricity consumption for air-conditioning for landlord area.

The overall efficiency improvement percentage for total electricity consumption is 10%.

4.3.4 Cost Analysis

Considering that the electricity tariff from the SP Group is 32.57 cents/kWh for residential buildings, and Hougang Mall is a commercial building which consumes a large amount of energy, a competitive price would be around 25 cents/kWh.

	Initial Cost	Operating Cost (monthly)
6 HVLS fans	$2000 each	0.015kW x 10h x 30 days x $0.25/kWh x 6 = **$6.75**
4 Destratification fans	$1000 each	0.39kW x 10h x 30 days x $0.25/kWh x 4 = **$117**
Total costs	**$16000**	**$123.75**

Table 7: Installation and Operating Cost for Fans

4.4 Potential Benefits to Enhance Sustainability

The destratification fan RPM is 1690 with dB(A) around 40 with a weight of 20kg.

Destratification fans are easy to maintain because they do not require frequent adjustments. They have a long lifespan, which means that once they have been installed and set up correctly, regular maintenance is not necessary.

EC motors are a great option for maximum efficiency and controllability. EC fans maintain higher efficiency across the entire speed range when compared to traditional AC motors.

Balance Temperatures – Gentle air mixing is used to control room temperature.

NPBI or PHI equipped fans – Reduced pollutants and pathogens for cleaner indoor air.

Save energy and money – Destratification constantly mixes the air to help facility managers provide more comfortable working environments and save energy by up to 30%.

Improve room comfort for employees and customers – By equalizing air temperature, fans can reduce costs and raise overall comfort levels in buildings.

4.5 Case References

Based on a study which surveyed a total of 35 occupants on thermal comfort and satisfaction over a 11-week period, setting a higher air conditioning temperature with elevated air-movement produced by ceiling fans does not compromise thermal satisfaction. In fact, the results show an improvement in comfort acceptability from 55% to 77% by raising the set-point temperature from 24 °C to 26.5 °C. By increasing the temperature set point and supplementing this with elevated air-movement, a cooling energy savings of 32% was also achieved.

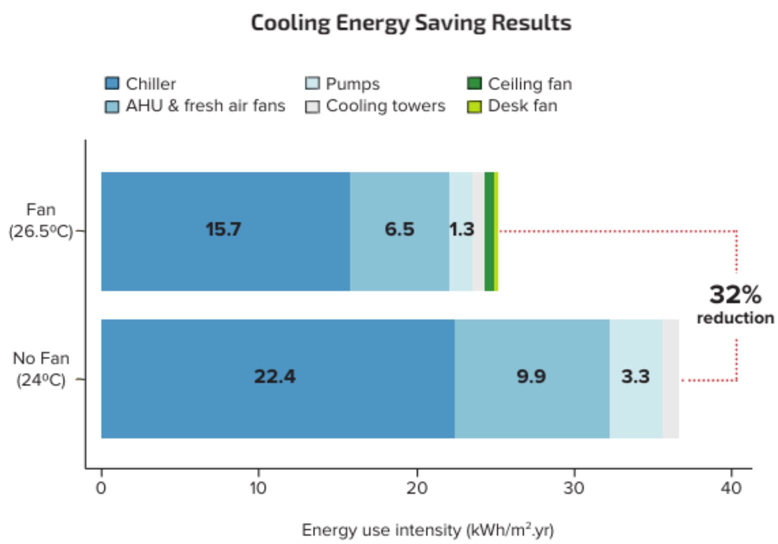

Figure 22: Reduction in Energy Usage using Fans

Source: BCA

We have found a case study using hybrid cooling at ZEB Plus @ BCA Braddell Campus.

The Hybrid Cooling System allows indoor air temperature to be increased and provides greater air movement with ceiling fans as needed. The Hybrid Cooling System can provide substantial energy savings. Energy analysis for tropical buildings has shown that up to 45% in cooling energy savings can be achieved by increasing the cooling temperature setpoint from 24 °C to 27°C.

Through test bedding at ZEB Plus, changing the setpoint temperature from 24°C to 27°C with the introduction of ceiling fans has increased occupant satisfaction from 60% to 90%. The best cognitive performance was obtained at 26°C. In this smart building, 27 ceiling fans have been installed while the air temperature is set at a minimum of 26°C.

Additionally, each work desk has a desk fan for personalised comfort.

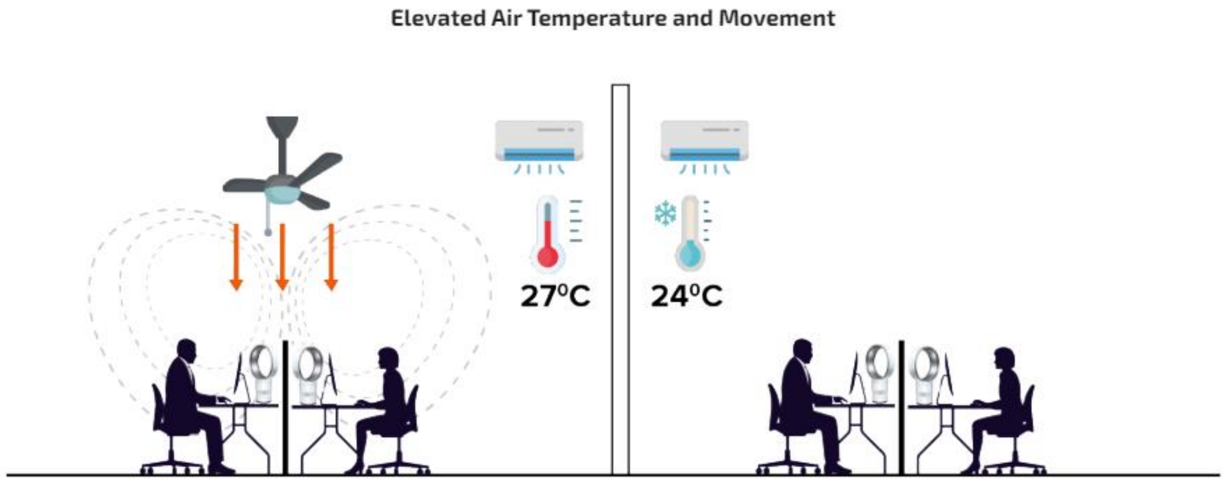

Figure 23: Hybrid Cooling with Fans Increase Thermostat Temperature

Rock Lititz Studios, a premier 52,000 sq. ft. production-rehearsal facility in USA, hosts some of the world's top rock bands and requires precise temperature control amid its complex setup of steel girders, lighting rigs, and camera equipment.

Challenge: The expansive size and presence of sensitive sound equipment demanded an HVAC solution that could provide effective air distribution without disrupting audio quality. Additionally, the intricate lattice of wires and structural steel required a system that could operate efficiently without physical interference.

Solution: The fans were positioned 90 feet above the floor to achieve optimal air destratification. These fans deliver a gentle yet effective airflow across the facility without interfering with the acoustics or physical setup.

Results: The installation dramatically improved air circulation, maintaining consistent temperatures and ensuring quiet operation, crucial for not affecting the sound systems. The fans' design also avoids disruption to the established system of wires and girders.

Figure 24: Destratification Fans Installed under Ceiling

5. Proposal 3 - Eco Friendly Waste Management

5.1 Food Waste - Compost Digester

As part of the efforts to reduce food waste, Hougang Mall encouraged their F&B vendors to sell their remaining food of the day at a lower price in the last hour of business. They have also encouraged customers to purchase food after 8pm with an incentive of receiving a $5 gift card to spend at malls owned by Frasers Property.

Figure 24: Poster To Help Mitigate Food Waste

However, despite their efforts, the issue of food wastage is still present. To mitigate the food wastage at Hougang Mall, it is recommended to implement a food waste – compost digester.

Food scraps and other organic waste are broken down into simpler materials by a food digester. This is often accomplished via aerobic or anaerobic digestion, in which the organic material is broken down by microbes.

It is recommended to implement a food digester that can digest food waste into compost via a similar biological process but in a heated, accelerated environment using facultative bacteria, primarily from the Bacilli class (Bio-Safety Level 1), as the main microbial agents. These bacteria can use dissolved oxygen, oxygen from food materials, system input water, or air circulation to survive and function effectively.

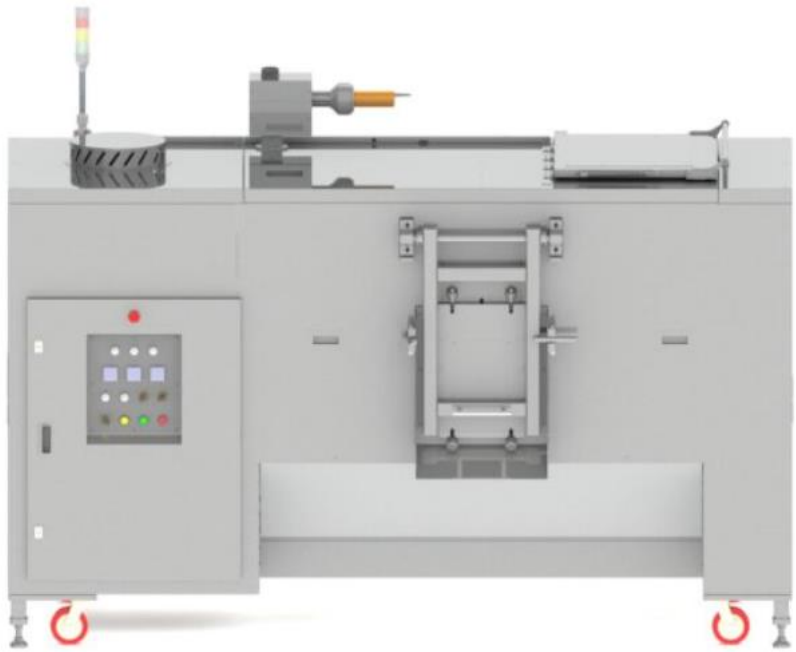

Figure 25: Food Waste – Compost Digester

5.1.1 How It Works

Firstly, food waste will have to be segregated from general waste. After which, the food waste can be deposited into the food digester and commence the digestion process. The food digester's innovative technology enables an automated and odourless process.

Using microbes in a controlled heated environment, food waste is converted into nutrient-rich compost in under 24 hours, achieving a 50-70% reduction in food waste weight and volume.

The controlled heating ensures microbes are active in digestion while eliminating harmful bacteria present in the input food waste. The quality of the compost produced by the food digester varies depending on the type of food waste used.

5.1.2 Advantages of Food Waste - Compost Digester

1. The system can convert between 25 kilograms and 1 ton of food waste into compost each day.
2. Food waste can be converted into 30 to 40% of its initial volume within 24 hours.
3. Food waste, containing roughly 50-80% moisture, is combined with microbes in the system, requiring replenishment every three months.
4. The entire process is efficient, clean, highly automated, and user-friendly, utilising a straightforward PLC control system.

The digester can also be customised according to the mall’s needs by including these add-ons:

1. A bin lifter
2. A load cell that can record the weight of each dump and track cumulative weight data daily, weekly, monthly, and yearly to comply with regulatory and funding requirements.
3. A built-in grinder that can handle bones and seafood shells in addition to standard food waste.
4. Options are available for storing food waste tonnage either locally or viewing it online. The data can then be uploaded to a Cloud portal for remote access.

5.1.3 Feasibility and Implementation

Hougang Mall can implement the usage of a food waste - compost digester by making it compulsory for all F&B outlets to segregate their food waste from general waste. It is recommended for the housekeeping team of the mall to have a food waste collection bin to prevent any other type of waste going into the digester.

After business hours, employees of the F&B outlets can throw their food waste into the bin provided by the mall. Housekeeping team is to ensure integrity of the waste before inserting it into the digester. After which, the digestion process can commence. After the 24-hour process, the housekeeping team can retrieve the compost from the discharge drawer and collect it into a designated tank.

The compost derived from the digestion process can be used to support Hougang Mall’s “Eco Fun @ Hougang Mall” programme by spreading awareness on how food waste can be recycled into compost. By doing so, the mall could inspire its community to practise composting. The compost from the digester can also be used for the landscape surrounding the mall.

Figure 26: Eco Fun @ Hougang Mall

To ensure the capacity will be able to handle Hougang Mall's daily food waste output, the calculation below is carried out:

	Calculation	Total
Estimated food waste output per month	80990 kg x 37.3%	30,210 kg
Estimated food waste output daily	30,210 kg / 30	1007 kg

Table 8: Estimated Food Waste Output by Hougang Mall

As shown above, based on the estimated highest level of food waste produced by Hougang Mall, the digester will not be able to handle the extra 7 kg. This could be due to multiple tenants in the mall disposing a high level of food waste. To reduce the amount of food waste produced, the food waste collection bin can be a smart bin. This smart bin can be placed at the bin centre as well.

Figure 27: Smart Food Waste Bin

The bin uses an IoT sensor to ascertain the volumes of food waste within. This information can be used by the management to track the source of food waste and implement control measures later to reduce them. The tracking of records allows the management to identify those food vendors that generate the most food waste, analyse and help the vendors to take proper actions to manage their food wastage.

To encourage the F&B vendors in the mall to reduce their food waste, it is recommended to provide them with an incentive scheme such as providing a quota for free disposal of food waste for each vendor. Those vendors that have more food waste than the quota will pay a premium. Those that have less food waste will get an incentive such as monetary benefits.

By doing so, Hougang Mall will be able to reduce food waste whilst enticing its vendors to participate in the efforts to be a more sustainable building.

5.1.4 Annual Greenhouse Gas Reduction Calculation

Based on NEA's calculations, 11% of total waste generated in 2023 consisted of food waste. Therefore, the calculation of the total amount of food waste that is part of total waste generated in Hougang Mall is based on that.

Date	Total Amount of Food Waste	Greenhouse Gas Emission of Recyclable Food Waste (Emission Factor for Waste = 0.76kg CO2/Kg)	Reduction of Greenhouse Gas Emission
Sep –23	76810 x 37.3% = 28,650.13 kg	28,650.13 x 0.76 kg CO2/Kg	21,774.1 kg CO2
Oct –23	80990 kg x 37.3% = 30,209.27 kg	30,209.27 x 0.76 kg CO2/Kg	22,959.05 kg CO2
Nov –23	77460 kg x 37.3% = 28,892.58 kg	28,892.58 x 0.76 kg CO2/Kg	21,958.36 kg CO2
Dec –23	79480 kg x 37.3% = 29,646.04 kg	29, 646.04 x 0.76 kg CO2/Kg	22,531 kg CO2
Jan –24	79800 kg x 37.3% = 29,765.4 kg	29,765.4 x 0.76 kg CO2/Kg	22,621.7 kg CO2
Feb –24	78650 kg x 37.3% = 29,336.45 kg	29,336.45 x 0.76 kg CO2/Kg	22,295.7 kg CO2
Estimated GHG reduction total for 6 months			134, 139.91 kg CO2
Estimated GHG total reduction for 1 year			268,279.82 kg CO2
Percentage in total reduction of GHG for 1 year			25.4%

Table 9: Estimated Greenhouse Gas Reduction

5.1.5 Cost Analysis

Assuming that a competitive electricity tariff cost is around 25 cents / kWh, and the daily electricity consumption of a food waste – compost digester is about 30kWh:

	Estimated Initial cost	Estimated Operating Cost
Food Waste – Compost Digester	$35,000	30 kWh x 24h x 30 days x $0.25 = $5400
Smart Food Waste Bin	$3250	0.1kWh x 12h x 30 days x $0.25 = $9

Table 10: Installation and Operating Cost for Food Waste – Compost Digester and Smart Food Waste Bin

5.1.6 Case Reference

The Grand Hyatt hotel, located near Orchard Road in Singapore, has introduced a waste management approach that saves them $100,000 annually by repurposing food waste. The food digester processes up to 500 kg of food waste daily, which is then utilised for the hotel's landscaping needs.

Beyond saving on waste disposal costs, operational expenses, and manpower, the hotel's effort also contributes to reducing its environmental impact by eliminating food waste from incineration processes.

Implementing a food waste compost digester demonstrates the benefits for the building and supports Singapore's goal to reduce daily per capita food waste sent to Semakau Landfill by 30% by 2030.

5.2 Automated Recycling Bin

Based on NEA's Waste Statistics and Overall Recycling report, Singapore's overall recycling rate has decreased from 62 percent to 52 percent over the past decade (2013 - 2023). As such, it is more crucial now to promote recycling habits and practices to the community.

To encourage the community surrounding Hougang Mall to partake in recycling, it is recommended to implement an automated recycling bin that has the artificial intelligence to auto-sort waste by scanning the item and inserting it into the bin allocated for that waste.

Key features to look out for the automated recycling bin would be waste sorting via automation, automatic compression, and digital display and app.The automatic compression refers to the compactor within the bin activating when fill level hits the predetermined level, therefore providing 8 times more space for waste.

Digital display serves its purpose by indicating the fill level in each bin for the public's knowledge whilst the app sends real-time data to the house-keeping team. Furthermore, features like automated compacting and sorting simplify the recycling process and save labour costs and human intervention requirements. Additionally, monitoring and evaluating recycling data offers insightful information about usage trends that facilitates resource allocation and decision-making.

5.2.1 How It Works

The first step is to scan a QR code for user identification purposes that will be shown on the digital screen. After which, the user will be able to put their recyclables into the bin one by one so that the bin can auto-sort the waste.

Once they are done, the user can select the “End Cycle” button that will be shown on the digital screen. This will allow them to see the total weight of the recyclables recycled.

To enhance the recycling process, the automated recycling bin comes with an anti-viral coating with Ultraviolet-C light to disinfect the recyclables. This process occurs after the recycle waste has been auto sorted into the specific bin.

Should any of the allocated bins within be filled, the user-friendly fill level detector will display on the screen that it is unable to collect that specific recyclable material.

Once the fill level detector has been triggered, it activates the smart compressor within the bin to make the recyclable material more compact to allow space for more material to go into the bin. This function, however, is only limited to the plastics and paper bins.

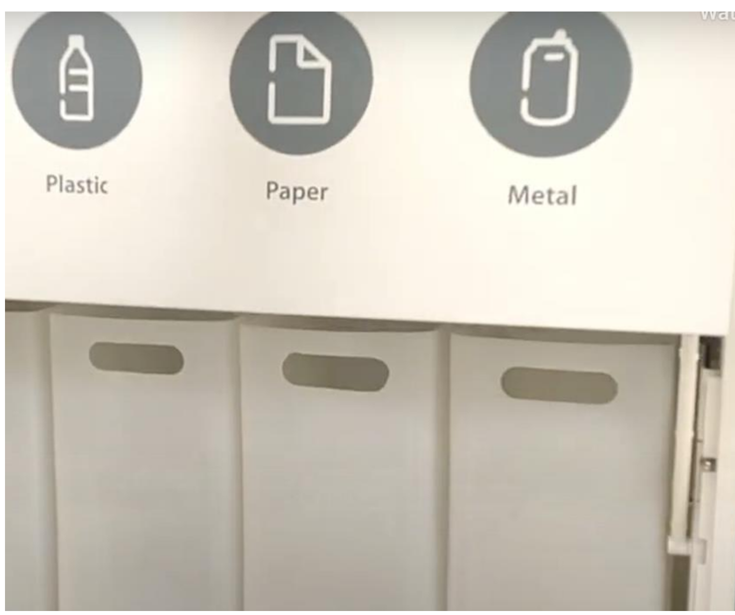

Figure 28: Inside of The Automated Recycling Bin

5.2.2 Advantages of Automated Recycling Bin

1. No need for pre-sorting
2. Customise your collection schedule according to fill level
3. Sleek design that complements any environment
4. Data stored in the cloud
5. Generate reports through an app

5.2.3 Feasibility and Implementation

It is recommended to implement the automated recycling bin in an area with higher foot traffic and accessible to the community. Such an ideal location would be the area where there are letterboxes near the entrance of the mall closest to Hougang Mrt Station.

This location is recommended as letterboxes contain a high amount of paper waste that usually ends up being disposed into the general waste bin. By implementing an automated recycling bin there, it can encourage the users to bring along their recyclable wastes to dispose it there.

The ideal duration to view the effectiveness of the automated recycling bin will be 6 months. Based on the data collected by the bin, should there be a significant increase in the amount of recyclable material being recycled over the course of 6 months, Hougang Mall could expand the implementation of automated recycling bins inside the mall as well.

Figure 29: Area Where the Automated Recycling Bin Can Be Installed

To further encourage the community to recycle, there could be a reward system put in place. For example, the user can be given a certain amount of recyclable waste such as 500 grams to be recycled per week. By doing so, the user gets to collect points rewarded in the FRx App at the end of the week if they achieve the goal.

To achieve the connection between the amount of waste put into the automated recycling bin by the user and the FRx App, the user identification system via the QR Code on the digital screen of the bin can be used. Given that data is already being collected based on who is disposing how much of recyclable material, that data can be used to gauge how much each user is already recycling and challenge them to recycle more after each month.

The accumulated points can be used at the end of each month to either redeem shopping vouchers or freebies from the customer service. This is a good way to encourage users to be consistent in their recycling as per Singapore's culture, people will do anything to get freebies.

5.2.4 Cost Analysis

	Estimated Initial Cost	Estimated Operating Costs
Automated Recycling Bin	$7500	1.7 kWh x 24 x 30 days x $0.25

		= $306

Table 11: Installation and Operating Costs of An Automated Recycling Bin

5.2.5 Case References

A trial in Bishan and Sin Ming, Singapore, using smart boxes for recycling has reduced contamination rates to just 5%, far below the national average of 40%. Started by 800 Super in April 2022, the trial collects various recyclables like paper, plastic, aluminium, metal cans, old clothing, and glass, awarding points to residents for proper sorting. Ten smart boxes were installed, though only five have been operational since the trial began. These boxes separate materials into different compartments, unlike the usual single blue bins. Residents use an app to register and scan a QR code at the smart boxes before depositing recyclables, earning points redeemable for supermarket vouchers. This system ensures 95% of collected materials are recyclable. Each location collects an average of 600 kg of recyclables monthly, with points awarded based on the type and weight of materials.

This has shown that implementing smart recycling bins such as an automated recycling bin is able to encourage the community to recycle more.

6. Conclusion

This submission outlines 3 different proposals with recommendations to enhance the sustainability of Hougang Mall.

Firstly, installation of solar photovoltaic panels on the rooftop of the mall to help reduce energy usage.

Secondly, to adopt hybrid cooling by installing HVLS fans at the ceilings of the corridors of the mall to improve air circulation thereby providing the necessary thermal comfort with a reduction of air-conditioning energy usage.

The last proposal is to further improve the waste management systems at Hougang Mall by installing a food waste – compost digester that is supported by a smart food waste bin, and an automated recycling bin to engage the community in active recycling.

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