PacificLight

Sustainable cities challenge

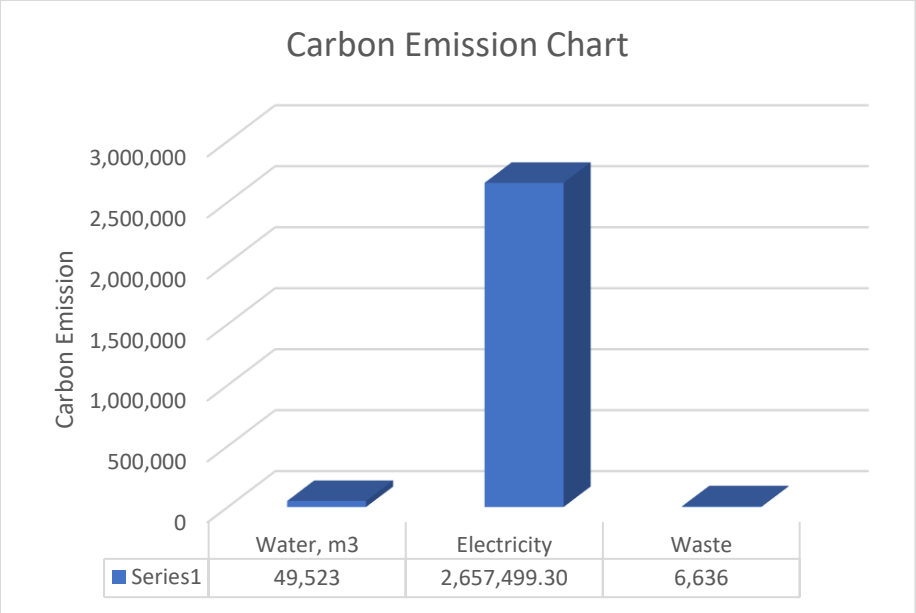
Tham Keng Cong, Muhammad Rayyan,
Gerald Peng, Ho Jun Hao
Temasek Polytechnic

15 July 2024

Contents

Carbon Emission

Carbon emissions are produced during manufacturing. This consists of carbon dioxide, methane, and nitrous oxide, and hydrofluorocarbons that causes the earth's atmosphere to warm, resulting in changes to the climate that we are already starting to see today.



Based on the values given about the building's electricity, water, and waste generated and consumed…

Electricity consumption

Total consumption: 6,372,900 kWh
Grid Emission Factor: 0.417 kgCO2/kWh
Electricity Carbon Emission: 2,657,499.3 kgCO2

Water consumption

Total consumption: 69,360 kL,
Factor: 0.714 kgCO2e/m3
Water Consumption Carbon Emission: 49,523.04 kgCO2

Waste generated

Total incinerated waste: 473,190 kg
Recycled wastage: 512,623 kg
Waste generated Carbon Emission (Recyclable Waste Disposal): 1,481 KgCO2eq
Waste generated Carbon Emission (Incinerated Waste Disposal): 5,155 KgCO2eq

Consumption Source

Largest consumption for electricity

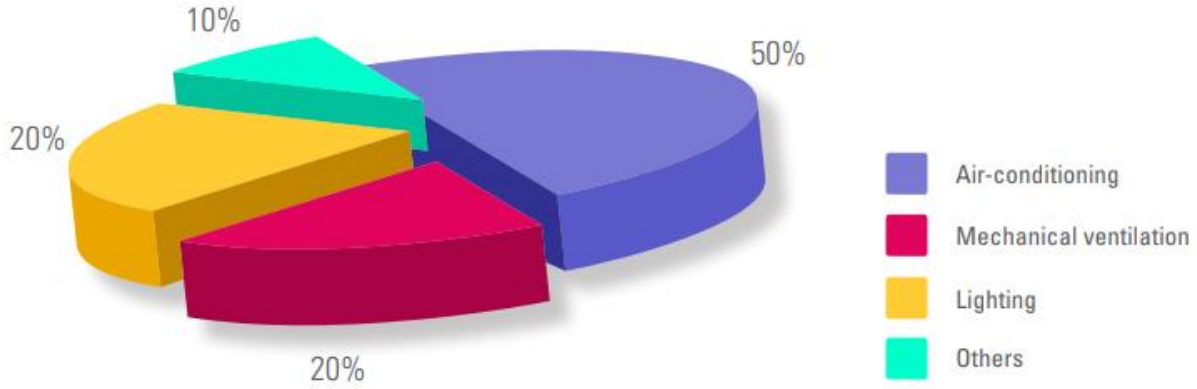


Figure 1: Breakdown of energy consumption within a building[1]

The picture shows an estimated percentage of different energy consumption in a building that shows Air-conditioning consumes 50%, Mechanical ventilation 20%, Lighting 20%, and others 10%.

Based on our calculation tenants use about 31% more energy than landlords. This is because the tenants take up more area in the mall and requires more energy to display their products whilst most of the energy usage from landlord is from air-conditioning.

According to the National Climate Change Secretariat energy consumed by heating, ventilation and air-conditioning take up to 50.1%, lighting and mechanical ventilating using 20% each of the total energy consumption in a building.

Trade Category (in descending order of GRI)	By NLA	By GRI[10]
Food & Beverage	28.9%	37.3%
Beauty & Healthcare	11.5%	13.8%
Fashion & Accessories	9.9%	11.8%
Sundry & Services	8.4%	9.5%
Supermarket & Grocers	15.4%	9.5%
Education	6.8%	3.4%
Jewellery & Watches	1.3%	3.2%
Electrical & Electronics	5.5%	3.2%
Books, Music, Arts & Craft, Hobbies	4.6%	2.8%
Information & Technology	3.3%	2.4%
Homeware & Furnishing	2.4%	2.3%
Leisure & Entertainment	2.0%	0.8%
Vacant	0.0%	0.0%
Total	**100.0%**	**100.0%**

During our research on the overall building. We know that cooling a space requires more energy than heating it. Thus, the malls supermarket has piqued my interest. As the most common **energy consumers in the supermarket are the lighting and chillers.** Supermarkets **use chillers constantly** to maintain the freshness of their inventory, which results in a **continuous energy consumption.** Additionally, the supermarket takes up the **biggest space (15.4%** of the total area), meaning that more space is needed for chilling the merchandise.

Description	Pathway 2 - LPB Targets (W/m2)			SS 530
	Gold^{PLUS} EE >50%	Platinum EE ≥55%	SLE EE ≥60%	Reference Lighting Power Budget (W/m^2)
Retail - Supermarket, vehicle, sporting goods, stationary, hardware, others (Total)	*15*	*11*	*8*	*20*

Based on SS530 Reference Lighting Power Budget (W/m2) = 20W/m2

Operating hours: 8am - 10pm (14hrs plus 1hr)

Area 15.4% of 21614 = 3328.56m2

Lighting Power Consumption=3328.56×20= 66.5712kW

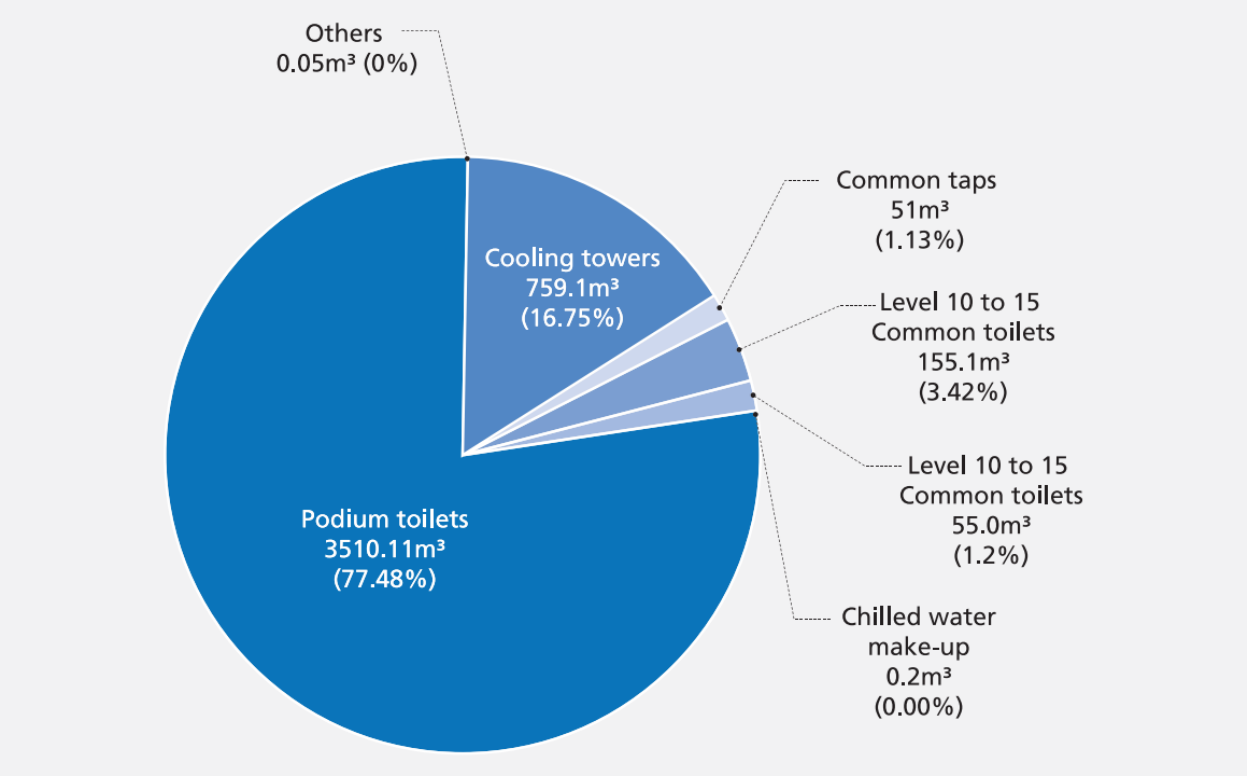
Total energy consumption: 66.5712kW x 15hrs/day x 31days = 30955.61kWh

Percentage of total= (30955.61/1062150) x 100= 2.91%

According to statistics from the Hougang mall's entire energy consumption, the supermarket uses, on average, 2.91% of the building's total energy consumption, which is significant for only calculating the lighting power for that store.

Largest consumption for water

Within the 6 months the amount of water used by landlords is about 16% more than tenant, this is because building owners are the ones responsible for handling public toilets and air-conditioning. Common usage of water in the building are for plumbing, cooling tower, toilets and many more.



As shown in the graph, toilets are known to affect most of the water consumption in a building with around 80% consumption. Therefore, our focus will be on toilets such as its basins, toilet bowls etc.

Largest consumption for waste

Carbon emitted for disposing non-recyclable is 5,155 KgCO2eq. NEA has a list of non-recyclable items with low recycling rates:

Materials with low recycling rate (2021)

2022 Waste Statistics and Overall Recycling Rate Table

Waste type	Total Generated ('000 tonnes)	Total Recycled ('000 tonnes)	Recycling Rate	Total Disposed ('000 tonnes)
Ferrous metal	1,338	1,331	99%	7
Paper/Cardboard	1,064	394	37%	671
Construction & Demolition	1,424	1,419	99%	5
Plastics	1,001	57	6%	944
Food	813	146	18%	667
Horticultural	221	188	85%	32
Wood	419	298	71%	121
Ash & sludge	241	27	11%	213
Textile/Leather	254	5	2%	249
Used slag	169	166	99%	2
Non-ferrous metal	92	91	98%	2
Glass	73	11	14%	63
Scrap tyres	26	25	95%	1
Others (stones, ceramics, etc.)	249	30	N.A. [1]	219
Total	7,385	4,188	57%	3,197

Plastics	6%
Ash & sludge	9%
Textile and leather	4%
Glass	13%
Others (stones, ceramic etc.)	8%

With this data, plastic is a major contributor to non-recyclable waste with 1,001 tonnes of plastics are generated but only 6% of it is recycled. Therefore, plastic is the largest combusted waste of 94% of its generated amount.

According to Singapore Environment Council,

> results still show that 67% of people are most likely use plastic bags to bag and dispose of general waste. As such initiatives to ban or tax plastic bags in Singapore are unlikely to be well-received by people owing to their dependency on this behaviour.

To pinpoint some areas that use large quantities of plastic bags; NTUC and other retail shops that give out plastic bags. This is because majority of the population going to the supermarket 3 to 5 times in a week and requesting between 1 and 5 plastic bags per shopping trip.

Target and Solutions

Our goal is to include improvements that sets an agreement between landlord and tenant to set out environmental objectives on how the building can be improved. Hence, we would like to implement both landlord and tenant energy efficient strategies.

Our focus for the targets and solutions is to cover the passive, active, smart, and renewable strategies for electricity (AC), water (Toilet), waste (Plastic) consumptions for the building.
This consists of…

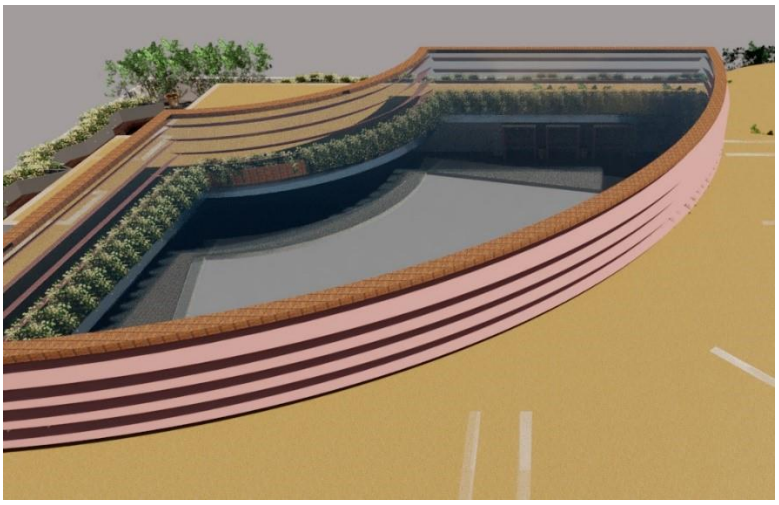
Electricity:
Passive Displacement Ventilation, PDV (Active Strategy)
Photovoltaic Technology (Renewable Strategy)

Water:
Rainwater Harvesting (Renewable Strategy)
Water efficient fittings (Passive Strategy)

Waste:
Smart Recycling Bin (Smart strategy)
Extended Producer Responsibility, EPR (Passive Strategy)

Electricity (Solution)

Louvres (Passive Strategy)



From phase 1, adding Louvers can effectively manage airflow and **promote natural ventilation**, the louvers maintain the look of the indoor space while pushing hot air out of the building through natural convection. **Reducing the need of having chillers to cool the area**. Thus, **reducing electrical consumption.**

> Additionally, electric lighting accounts for 35% to 50% of the total electrical energy consumption in commercial buildings. By generating waste heat, lighting also adds to the loads imposed on a building's mechanical cooling equipment. The energy savings from reduced electric lighting through the use of daylighting strategies can directly reduce building cooling energy usage by an additional 10% to 20%. Consequently, for many institutional and commercial buildings, total energy costs can be reduced by as much as one-third through the optimal integration of daylighting strategies.

With more natural lighting in the building. It reduces the need of lighting near the surrounding area of the atrium. From the above information it has proven that louvers can help to reduce building's waste heat generated from lighting by an additional 10% to 20%.

Solutions

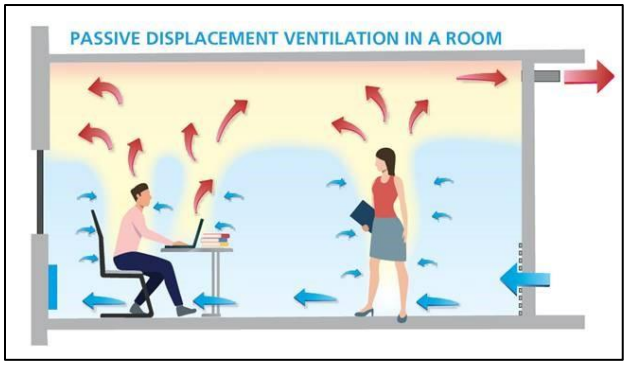
With Total Electrical consumption: 6,372,900 kWh

10% saved of electricity: 637,290kWh.

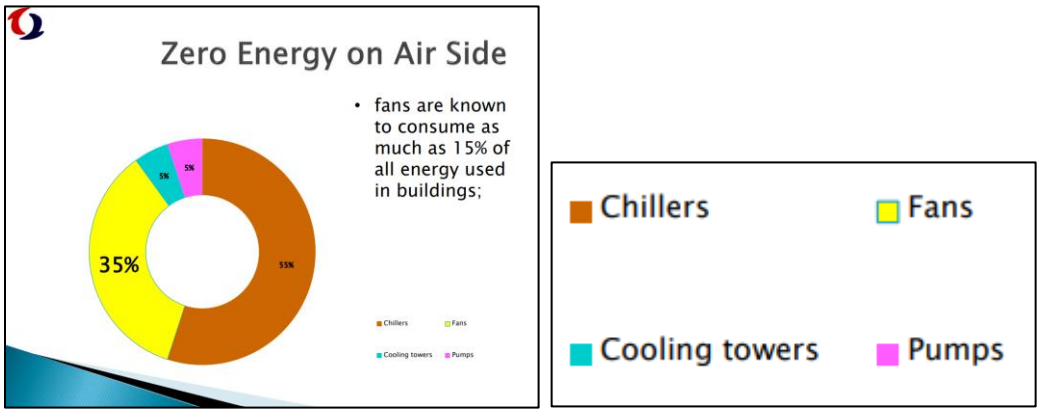
Current total electricity after adding louvers: 5,735,610kWh.

Assuming the worst possible outcome which is saving only 10% of Electrical consumption. The result is still quite significant, **saving up to 637,290kWh worth of electricity, 265,749.93 kgCO2 carbon emission.**

Passive Displacement Ventilation, PDV (Active Strategy)



PDV reduces the need of mechanical fans, dust getting stuck on ducts, and condensation. Thus, reducing the need for common maintenance problems, as well as energy saving.



According to SLEB, mechanical fans consume as much as 15% of all energy used in buildings as implemented in NTU The Hive. We can implement PDV to tenant area such as the tuition centre or library.

Solutions

Assuming we implement PDV for 100% of tenant area, that means that we can save 15% energy consumption for tenant area.

Total electricity consumption: 6,372,900 kWh
Tenant electricity consumption: 4,178,000 kWh

After calculating the savings for tenant area, it adds up to 626,700kWh, 261,333.9kgCO2

Which means we can save up to 9.8% of the total electricity consumption by implementing PDV.

Photovoltaic Technology (Renewable Strategy)

REC ALPHα

Model Number	**REC365AA**
STC Rating	365.0
PTC Rating	346.9
Open Circuit Voltage (V)	44.6
Short Circuit Current (A)	10.19
Panel Efficiency	20.9%
Frame Color	Black
Power Tolerance	-0/+5 Watts
Weight (lbs)	43.0
Area (sq. ft.)	18.8
Length (in)	67.8
Width (in)	40.0
Height (in)	1.2

Assuming we use a REC Solar panel that produces about 365Wp.

365Wp	9 hours of sunlight	3.285kWh
3.285kWh	181 days (6 months sept -Jan)	594.585kWh

Assuming the building uses 100 solar panel, it can produce 59,458.5kWh.

Total building energy consumption: 6,372,900 kWh

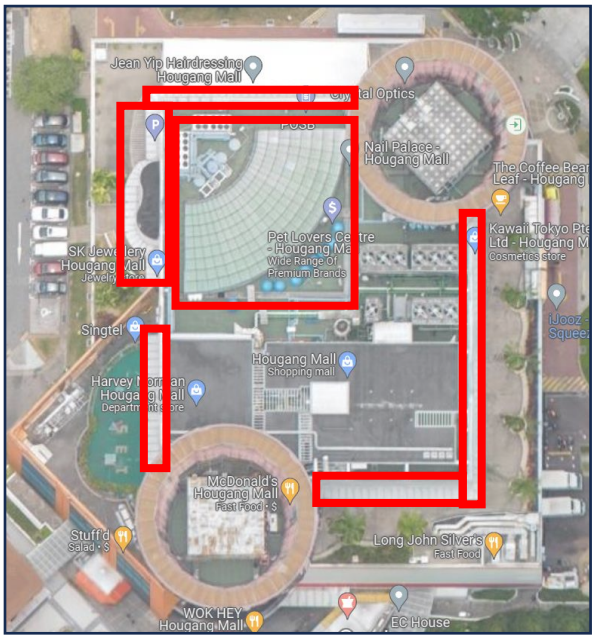
59,458kWh of 6,372,900 kWh would approximately come up to 0.93% every 6 months/ 1.87% a year.

59.485kWh x 0.417kgCO2/ kWh (Grid Emission Factor) = 24.8kgCO2

This value can vary depending on the type of solar panel chosen, as well as the number of solar panels used on the building.

Solutions

Photovoltaic Skylight



Skylight in Hougang Mall and surrounding shading devices on the rooftop area to be replaced by photovoltaic glass manufactured by Onyx Solar. Area of glass to be replaced by photovoltaic glass is 515.25 m².

Month	E_d	E_m	H_d	H_m
January	351.86	10,907.68	4.55	140.95
February	385.33	10,789.28	5.00	139.90
March	366.76	11,369.51	4.80	148.73
April	380.05	11,401.47	4.97	149.14
May	358.93	11,126.77	4.67	144.90
June	343.52	10,305.45	4.47	134.15
July	355.95	11,034.35	4.63	143.66
August	348.05	10,789.69	4.51	139.75
September	350.41	10,512.43	4.57	136.99
October	343.90	10,660.76	4.48	138.84
November	326.21	9,786.21	4.23	126.89
December	318.44	9,871.78	4.12	127.62
Yearly average	352.45	10,712.95	4.58	139.29
Total for year		**128,555.38**		**1,671.52**

Using the calculator provided by Onyx Solar, for 515.25 m² of Monocrystalline Photovoltaic Glass, it is estimated that the installation produces around 128555.38 kWh of electricity annually. We will then take this estimated value and calculate the following:

- Costs Saved Annually
- Amount to Invest for Installation
- Return on Investment
- Payback Period
- Percentage of Consumption reduced in 6 months

By multiplying the electricity generated from the photovoltaic installation by the electricity tariff, annual cost savings can be determined.

Costs saved annually = 128555.38 kWh x $0.3257 = $41870.49

Electricity generated (Sep – Feb) = 62528.14 kWh

Costs saved (Sep-Feb) = 62528.14 kWh x $0.3257 = $20383.00

RETURN ON INVESTMENT

	GLASS CONFIGURATION	AVERAGE REDUCTION OF ENERGY DEMAND (EUR/SQM)	AMOUNT TO INVEST (EUR/SQM)	AMOUNT TO INVEST AFTER INCENTIVES (EUR/SQM)	ROI %	PAYBACK PERIOD years	IRR %	TIMES THE INVESTMENT times	
		Average reduction of energy demand per square meter of Glass from energy generation and the HVAC savings in 30 years	Investment needed to add Photovoltaic Properties to each SQM of Glass and the Cost for the Balance of System	Investment after applying federal incentives for solar photovoltaics	Return on investment in 30 years: (profit-investment/investment)	Time required for the return on the investment	Internal Rate of Return: average annual return during the first 30 years of the investment	Number of times that the amount invested is received during the invesment period of 30 years (Average Reduction of Energy Demand /Investment)	
ONYX SOLAR LOW-E PV GLASS	1 Clear glass + 12mm air chamber + clear glass	← Without Onyx Solar Glass there is no additional reduction in energy demand, so no Return on the Investment is received							
	2 Monocrystalline silicon photovoltaic cells with a transparency degree of 38% + 1/2" air chamber + clear glass	**3.071,18 €**	**73,58 €**	**61,07 €**	**4929%**	**< 1**	**142%***	**50**	✓ BEST CHOICE
	3 Monocrystalline silicon photovoltaic cells with a transparency degree of 38% + 1/2" argon chamber + low-e glass	2.996,52 €	85,58 €	71,03 €	4119%	< 1	121%	42	
	4 Monocrystalline silicon photovoltaic cells with a transparency degree of 15% + 1/2" air chamber + clear glass	3.928,46 €	113,18 €	93,94 €	4082%	< 1	114%	42	
	5 Monocrystalline silicon photovoltaic cells with a transparency degree of 15% + 1/2" argon chamber + low-e glass	668,25 €	125,18 €	103,90 €	543%	< 3	43%	6	

* IRR at: 5 YEARS: 140% · 10 YEARS: 142% · 20 YEARS: 142% · 30 YEARS: 142%

9

According to Onyx Solar's specification sheet for their monocrystalline panels, the amount to invest, disregarding government incentives and installation costs, purely relying on the cost of the panels itself per m², would be 73.58 €/m², which converts over to approximately 107.50 SGD/m². Calculation of the amount for initial investment is shown below:

Amount to invest = 515.25 m² x $107.50 = $55389.38

If the average annual costs saved is same throughout 10 years and the Electricity Tariff does not change, we can calculate the estimated Return on Investment of the photovoltaic installation based on the first 10 years as well as the estimated payback period of the installation.

Return on Investment (1st 10 years) =

{[($41870.49 x 10) - $55389.38] / $55389.38} x 100

= 655.9%

Payback period = $55389.38 / $41870.49

= 1.3 years

1 year 4 months

To calculate the percentage reduction in electricity consumption, we will take the electricity produced from the photovoltaic glass for 6 months, starting from September to February, which tallies up to 62528.14 kWh.

Energy Saved (%) = (62528.14 kWh / 6372900 kWh) x 100

= 0.98%

Carbon Emissions Reduced (Sep-Feb) = 62528.14kWh x 0.417 kgCO2/kWh

= 26074.23kgCO2

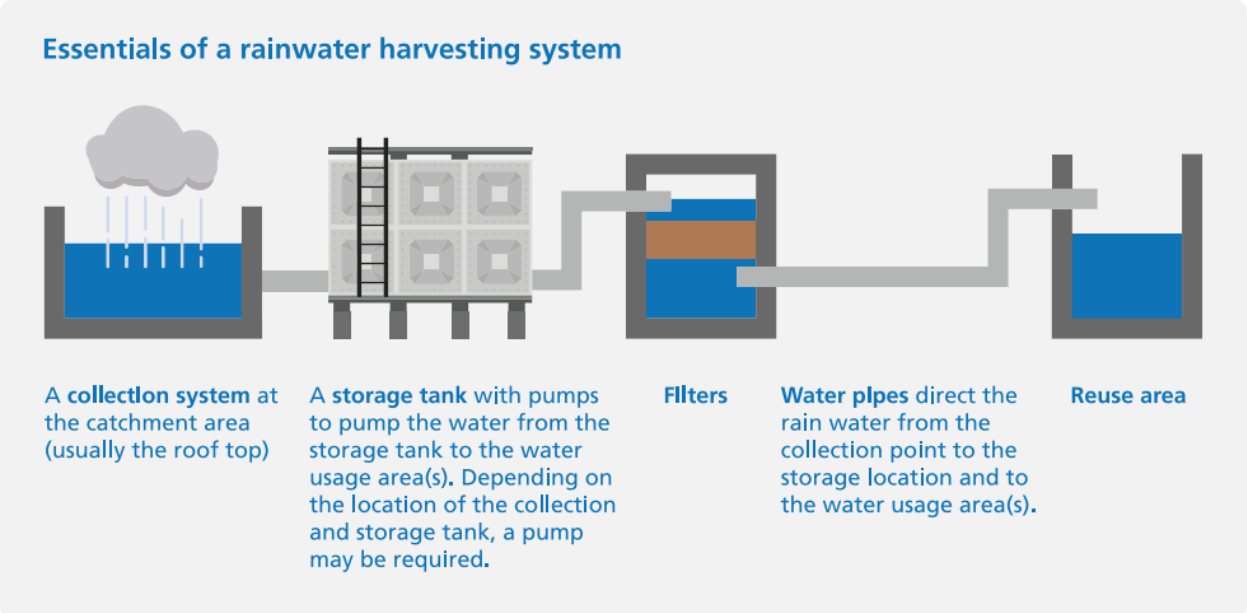
Percentage of emissions reduced (Sep-Feb)

= (26074.23 / 2657499.3) x 100

= 0.98%

Water

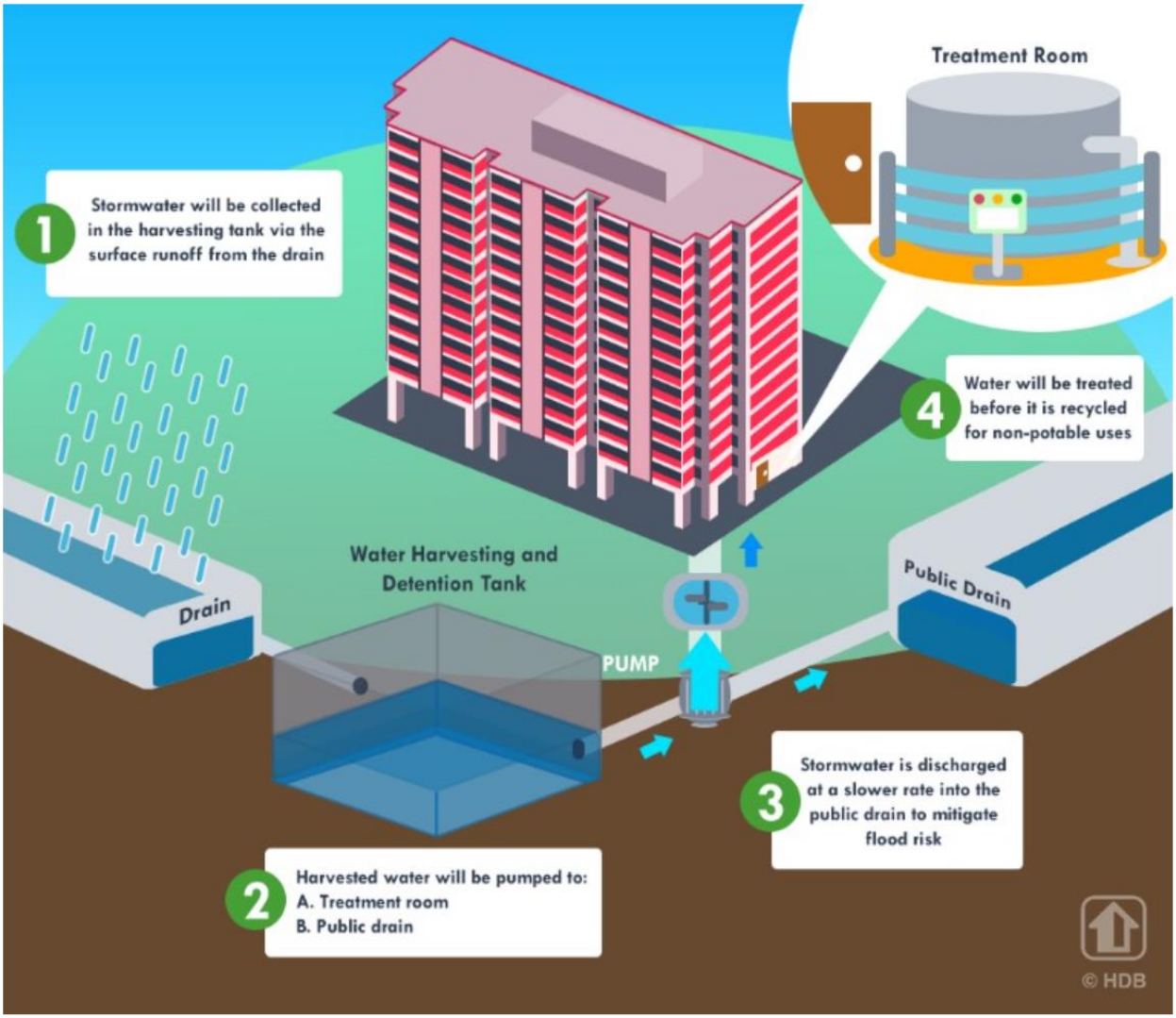
Passive Strategy (Rainwater Harvesting)



By collecting rainwater, buildings can reduce their reliance on the public water supply, leading to cost savings on water bills. Additionally, harvested rainwater can be used for non-potable purposes such as irrigation, flushing toilets, and cleaning, thereby

conserving precious freshwater resources. This sustainable practice also helps in reducing stormwater runoff, which can alleviate pressure on drainage systems during heavy rainfall.

HDB



Schematic of how the UrbanWater Harvesting System works. [Credit: HDB]

According to HDB, BTO estates in Yishun and Jurong to be installed with Urban Water Harvesting Systems (UWHS) can expect to save up to 50% of water usage for non-potable purposes. The system's rainwater harvesting capability and water detention capacity allows for 1 UWHS to harvest from and dispense water to as many as 12 residential blocks. It is estimated that about 15 UWHSs will be installed across the areas mentioned, potentially reaping water savings of about 17,500m3 per year, or the average yearly consumption of potable water of over 85 units of 4-room HDB flats.

Solution

Water [kL]			
Water Consumption - Tenant area - kL			
Sep-23	4930		Total water tenant
Oct-23	4910		29180
Nov-23	4750		
Dec-23	4700		
Jan-24	4820		
Feb-24	5070		
Water Consumption - Landlord area - Domestic Water - kL			
Sep-23	7240		Total water landlord
Oct-23	7200		40180
Nov-23	6630		
Dec-23	6880		
Jan-24	5410		
Feb-24	6820		
Total water consumption -kL	69360		

Assuming we install 1 UWHS to Hougang Mall, we will take the expected water usage savings value of 50% annually per system into consideration. Since the data for water consumption only covers 6 months, we will assume that the annual water consumption would be twice of 6 months, which would be 138720L, and the water savings value would be assumed to be 25% for 6 months. The rainwater harvested will be used for non-potable purposes like cleaning and irrigation.

Water Saved (6 months) = 138720kL x 25% = 34680kL

Carbon Emissions Reduced = 34860kL x 0.714 kgCO2e/m3 = 24890.04kgCO2

Percentage of Carbon Emissions Reduced
= [(24890.04kgCO2) / (49,523.04 kgCO2)] x 100
= 50.25%

Besides harvesting rainwater to reduce water usage, we can also collect the cooling tower condensate produced to use for non-potable purposes. In support of Car-Lite, a portion of the carpark can be used to accommodate water tanks that will be used to store harvested rainwater and cooling tower condensate.

Passive Strategy (Water Efficient Fittings)

The retail portion of MBFC, Marina Bay Link Mall, and all three buildings have several water-efficient features and practices in place. Water leak detection and monitoring systems, water-efficient toilet fixtures, and signs with contact details posted in each restroom to facilitate prompt leak or faulty fitting reporting and repair are some of these. Furthermore, condensate water from the air conditioning system at MBFC Tower 3 is recycled for use in irrigation, cleaning, and fountains, saving approximately 3,000 cubic meters of water annually.

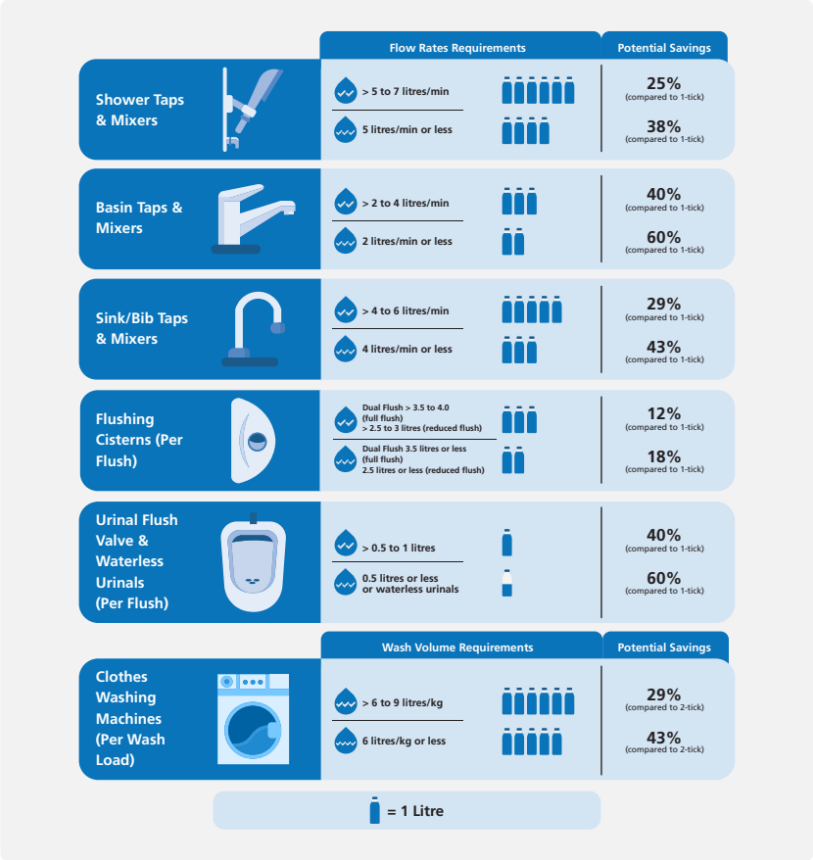
Solution

Water Efficient Flow Rates

Area of Usage	Water Efficient Flow Rate / Flush Volume
Basin tap and mixer	2 litres/min (Public / Staff toilets) 4 litres/min (Other areas)
Sink / kitchen tap and mixer	6 litres/min
Shower tap & mixer and showerhead	7 litres/min
Bib tap and mixer	6 litres/min
Urinal	0.5 and 1.0 litre of water per flush for ≤ 300 mm and > 300 mm size urinals respectively
Flushing Cistern	Dual-flush flushing cistern (For all new developments and existing premises undergoing A&A/renovation works from July 2009)

PUB
Water for All : Conserve, Value, Enjoy

Businesses, industries, schools, and buildings are encouraged to implement water-efficient practices under the PUB's Water Efficient Building Certification Scheme. Organizations who use water-efficient strategies on their property are certified by this program. Recipients of qualifying awards under this program are acknowledged as the top achievers in their respective industries.



We can install water efficient fittings all throughout Hougang Mall based on the recommended water efficient flowrates provided by PUB. By replacing existing Basin taps and mixers with water efficient ones as per PUB’s recommended list, there is a potential to save upwards of 40% of water usage within a building. The savings will specifically apply to the common taps portion of water usage, which is 1.13% of the total water consumption.

Water Saved (6 months) = (69360kL x 1.13%) x 40% = 313.51kL

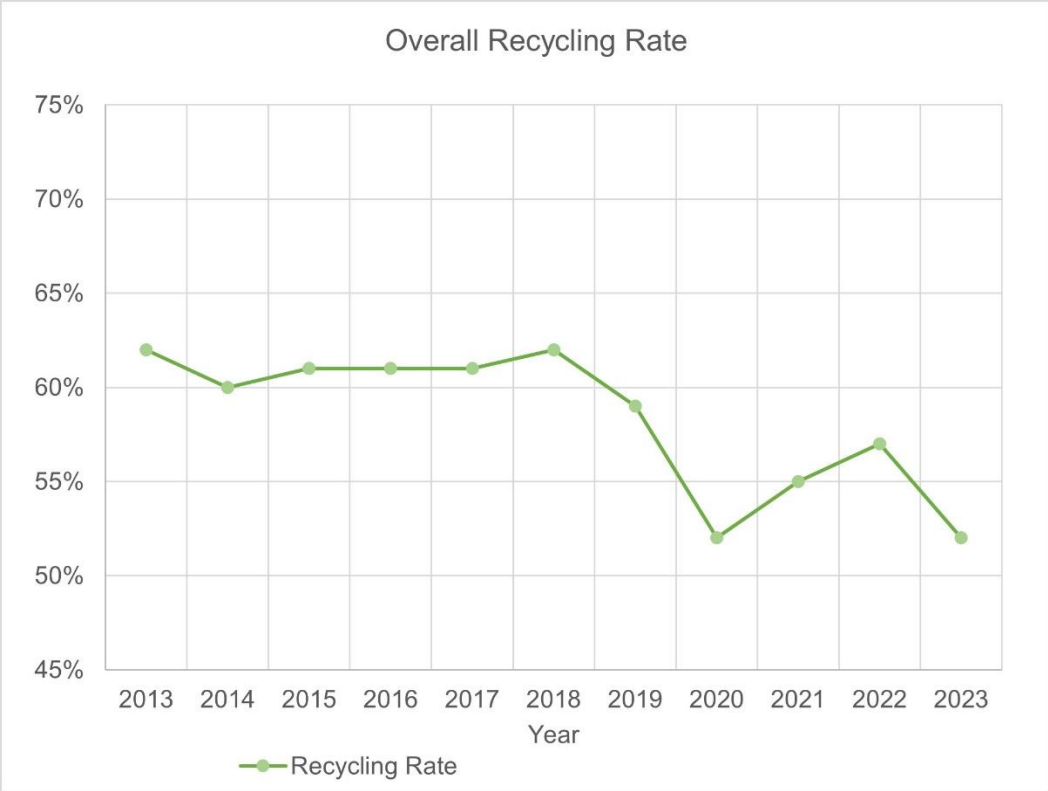
Carbon Emissions Reduced = 313.52kL x 0.714 kgCO2e/m3 = 223.85kgCO2

Percentage of emissions reduced = (223.85kgCO2 / 49523.04kgCO2) x 100 = 0.45%

Waste

Waste Control

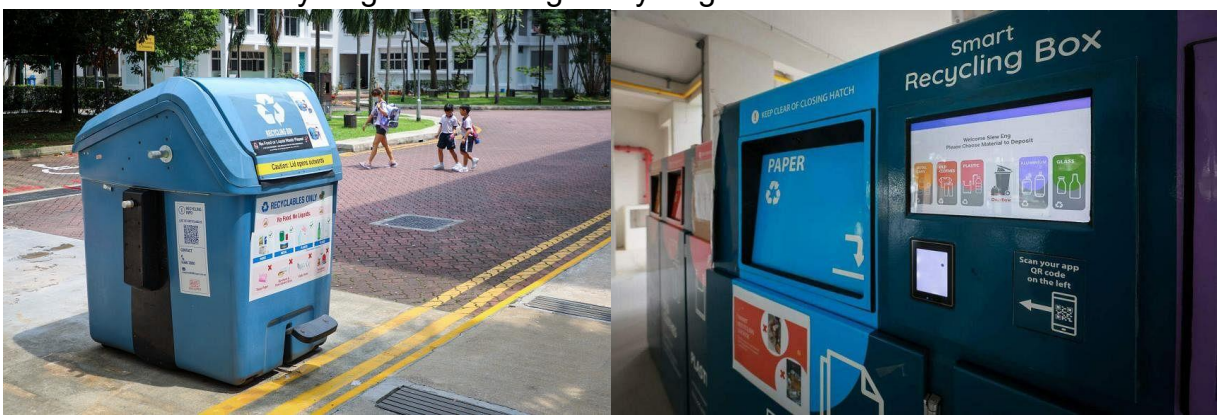
Currently with the 52% of 2023 recycling rates efforts must be increased to reach NEA's recycling target which is 80% by 2030, in 2022 the recycling results is 72% with the hope to see a linear increase to reach their goal. However, in 2023 there was a decrease in recycling rate to about 52%.



Hence the recycling efforts must be doubled for 2024 to reach the goal of 73% minimally.

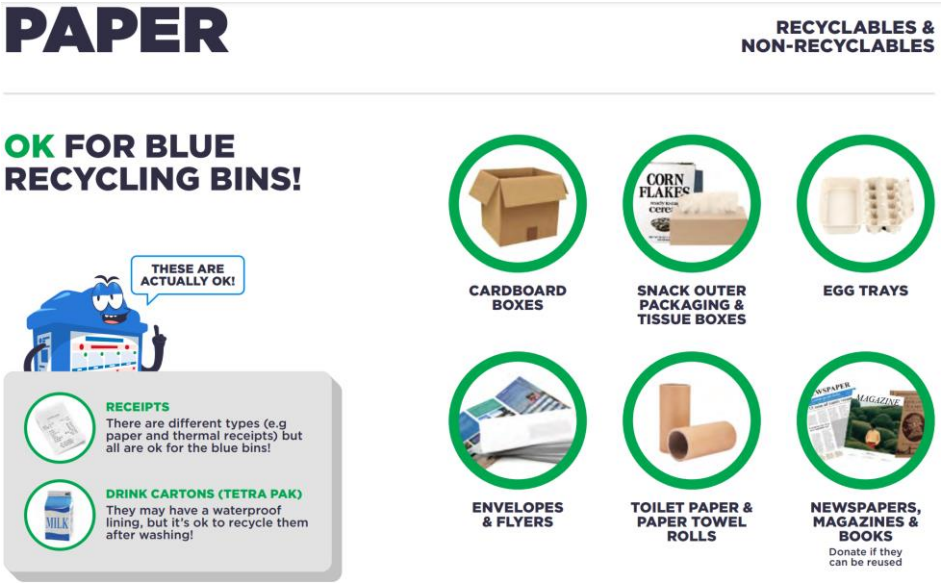
Waste Management

Addition of smart recycling box and large recycling bin:



The smart recycling box provides incentive points for FairPrice vouchers to those who recycle that can be used.
It can be located near the escalator from the basement to make use of human traffic to encourage and promote the habit of recycling to the mall's tenants and shoppers.

Case study: The Straits Time
According to a survey of 2,180 respondents conducted by NEA, these recycling bins and box made commuters more aware of the common items that can be deposited into it. In addition to the new bins, a campaign which features Bloobin, a blue recycling mascot, includes an online game and short videos showing how recycling can be incorporated into everyday activities such as buying takeaways and making online purchases.



These efforts are made to encourage the habit of recycling to the community and can also be implemented to Hougang mall.

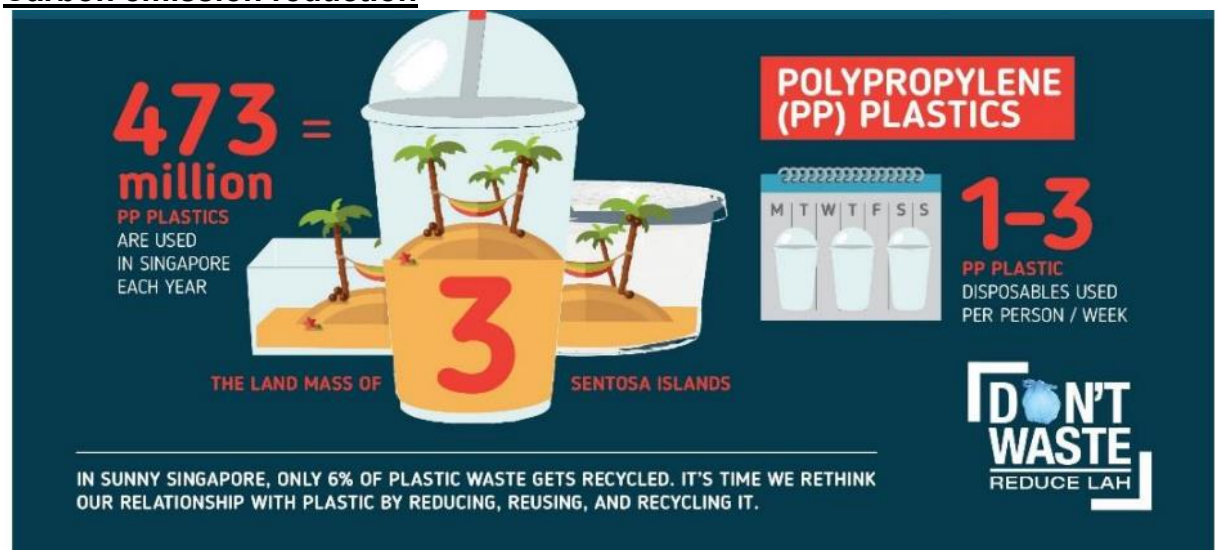
To improve the existing recycling efforts Extended Producer Responsibility (EPR) can be introduced for end-of-life circle of their products and create fruitful environmental, social, and economic effects. The entire EPR process is managed following government regulations, from post-consumer take back to waste segregation and recycling. Considering this complicated process's tremendous environmental and legal responsibility, it is not difficult to understand how vital an efficient application is, but also rare. Fortunately, EPR solution facilitates every little detail about the chain of custody.

With EPR it can:
• Reduce waste generation starting from single-use plastics and packaging
• Increase recycling, reusing, and recovery of waste rates worldwide.

With the reduction of plastic production, it can also reduce the amount of carbon emission. LAVIT is a beverage company, and their goal is to improve the water quality that people are consuming. According to LAVIT:

> consumption. Each of those bottles takes about 4 million joules of energy to create, and every ton of this plastic that is produced creates three tons of CO_2.

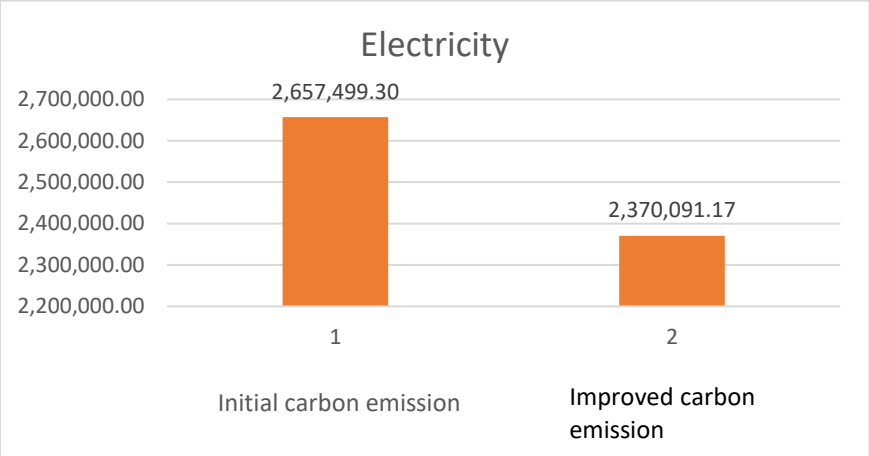
Carbon emission reduction



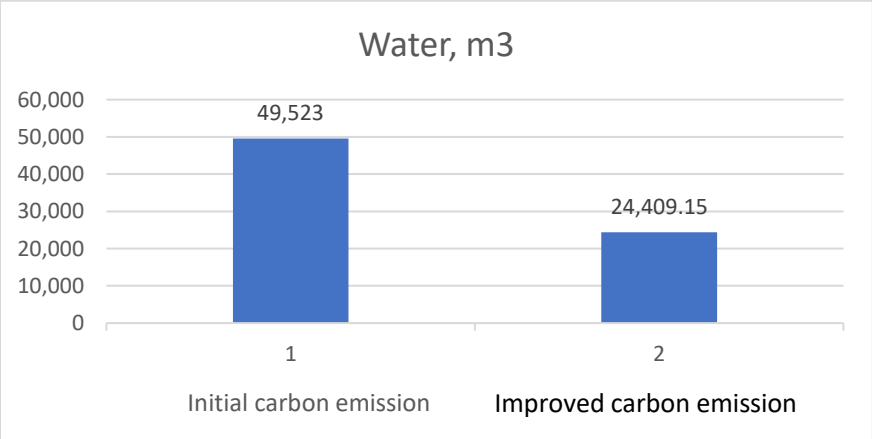
3 pp plastic is disposed a week, so in 6 months it will add up to 78 per person.
On average, a bottle weighs 23.83g.
1 person disposes about 1,858.74g (1.85kg) of plastic bottle.
Every ton of plastic produces 3 tons to CO_2 so per kg of plastic is 3kg of CO_2
Hence, the carbon emission per person is about 5.5kgCO_2 (1.85 x 3)
This results in a carbon emission of 5.5 kgCO_2 per person

Finalise savings

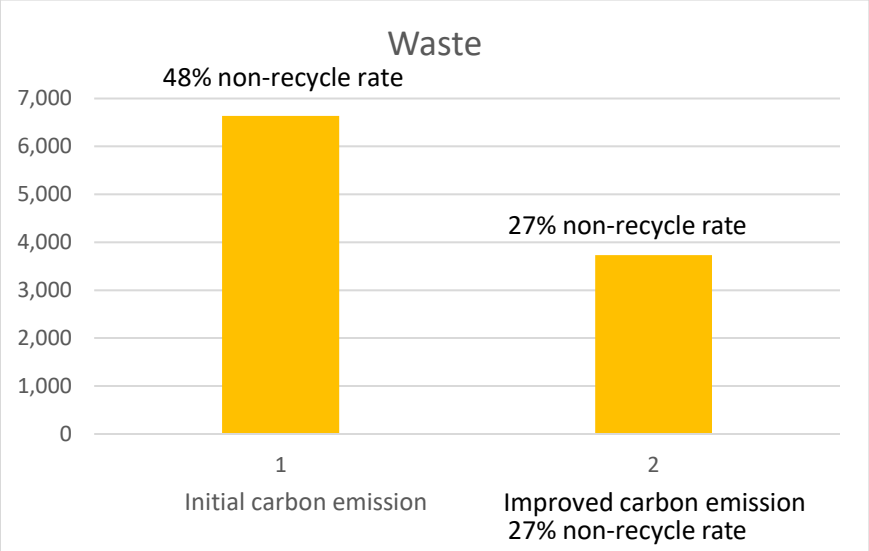
Electricity:



Water:

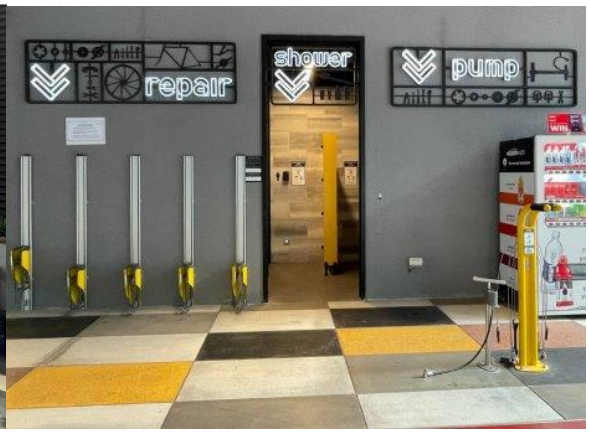


Waste:



Community Engagement

Mitigating Carbon Footprint (Permanent)



Hougang Mall being built in the 90s, does not have much convenient "Car-Lite" mobility options for users to reach the mall. leading the mall's car parks and car usage to rise.

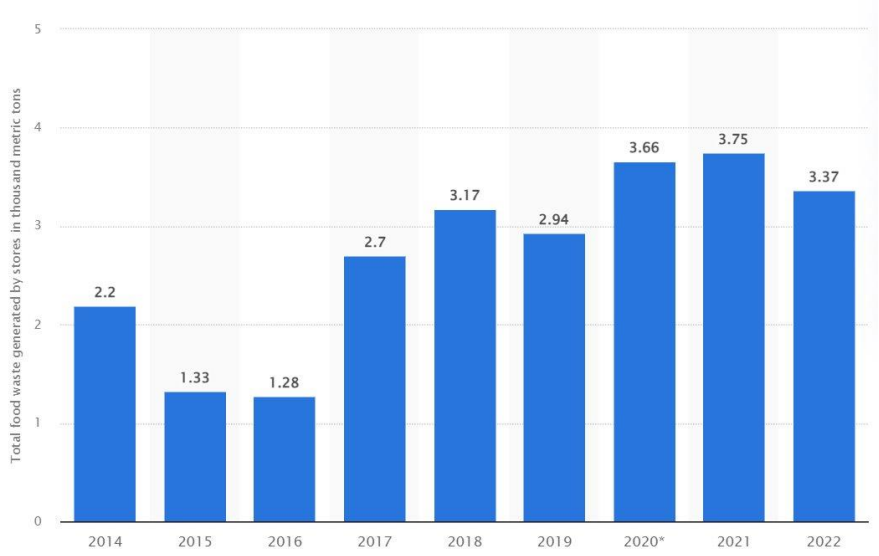
Now, where there are more "Car-Lite" mobility options like bus and MRT stations,

We can **convert** the basement parking lot into a **bicycle parking area and add more essential amenities**. By enhancing the available public transportation choices, this l**essens the need for private vehicles**.

With bicycle parking spaces now accessible, more features like a **shower room and a bike maintaining facility** can be added. As a result, it serves as a reminder to users that they can **lower their daily carbon emissions by simply choosing a different mode of transportation**. With bicycles producing only **33 grams** of carbon footprint per mile, saving up to **97.5% compared to buses.**

Aligns with the mall's goal of reducing private transport usage and environmental impact.

Mitigating Food waste & Carbon Footprint (Permanent)



According to the latest statistics gathered in Singapore, food wastage has become a significant problem in recent years. With **3.75 thousand metric tons of food wasted in 2021**, it peaked at the top of the chart. Using a 3,000 metric ton average as a guide, each kilogram of food waste corresponds to 2.5 kilograms of CO2 emissions. Therefore, **3,000 food waste is equivalent to 7,500 metric tons of CO2 emissions.**

To educate the public about managing food waste, FairPrice and F&B establishments can work with SG Food Rescuers. Only approximately 1**6% of food waste is recycled**, even though reports indicate that half of it—primarily rice, noodles, and bread—could have been avoided. We can drastically **cut waste** by putting in place **Community Fridges and Racks** to gather unsaleable fruit and vegetables from suppliers and donate them to people in need. We Singaporeans experience a **stronger sense of belonging** as more of them become knowledgeable and educated. **Joining SG Food Rescuers** and making a positive impact on society is more common among educated and well-informed Singaporeans.

Mitigating Plastic Waste (Permanant)

To **increase inclusivity and enjoyment,** The idea of a carnival game using recyclable materials like **plastic bottles and a basketball scoring system** sounds quite enjoyable. Players are encouraged to compete to hurl recyclable goods to score the most points. In return, they can **get some discounted coupons** for shopping within the mall.

An alternative, more straightforward method would be to use London's Ballot Bin concept, in which participants drop cigarettes into voting pins to determine which response to the above question they believe is the best. This has been shown to minimize litter caused by cigarettes by **up to 73%**. So, we're **aiming for comparable outcomes** using materials that can be recycled, like plastic bottles.

Mitigating Waste and water (Permanant)

With fast fashion is becoming more and more popular, retail outlets, like clothes retailers, frequently have between **10% and 40% of clothing that is unsaleable**. One cotton shirt can **require up to 2,700 litters of water** to produce, despite cotton being one of the most environmentally friendly natural fibres and a popular fabric used in apparel. An **upcycling program** called "ReBag Workshop: Bring a Shirt, Take Home a Bag" can be introduced to address this problem and promote sustainability. Bringing their **unwanted or unsold shirts** to this class will help participants **turn them into reusable bags**, which will motivate participants to be creative and environmentally conscious while cutting down on waste.

Conclusion

Reductions in Electricity Consumption:

We reduced CO2 emissions by nearly 553 thousand kg by implementing Photovoltaic Technology (Renewable Strategy) and Passive Displacement Ventilation (Active Strategy). Roughly 20.8% of the building's total CO2 emissions are accounted for by this reduction.

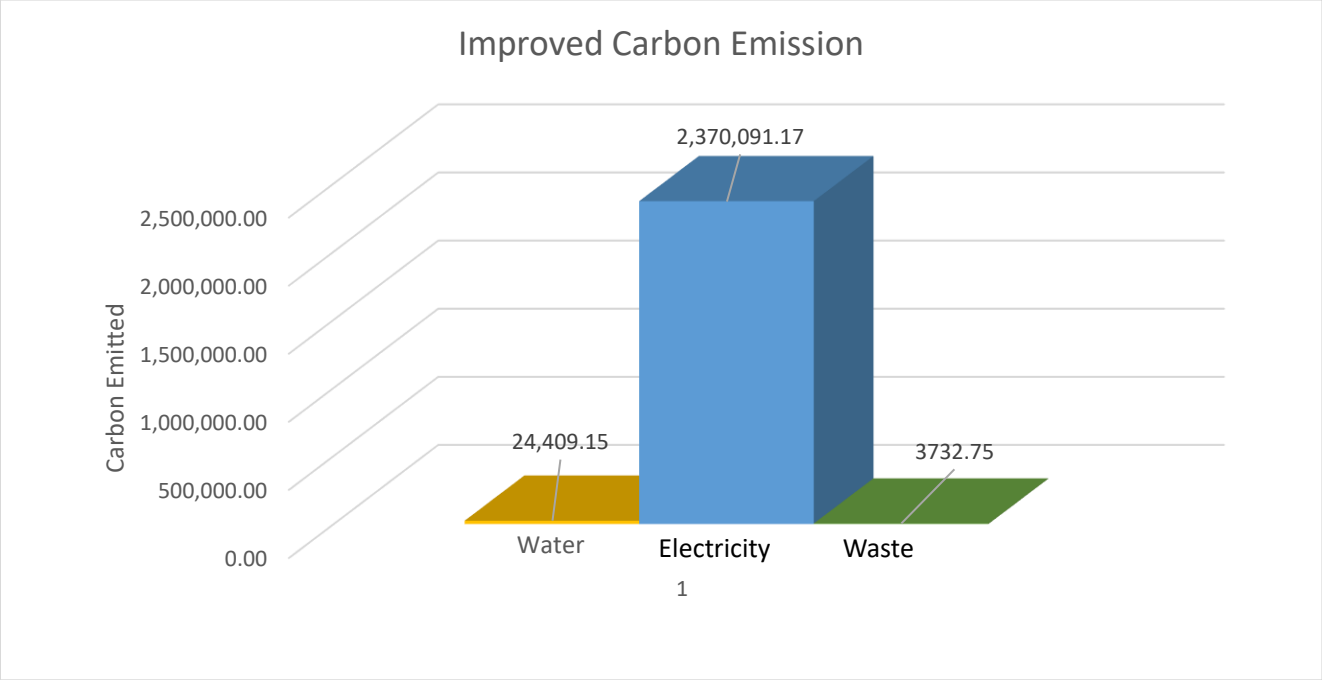
Reductions in Water Usage:

We installed a Rainwater Harvesting System (Passive Strategy) and Smart Energy (Water Efficient Fitting) to reduce CO2 emissions from water use by 25 thousand kg. With almost the half of what we saved for the overall building with 50.7%

Reducing Waste Usage:

by the application of waste management and control techniques. It reduces CO2 emissions by 11 kg overall. Each person can save up to 5.5 kg of CO2 if they adhere to the trash regulation, which will significantly help our building's overall sustainability goals.

Through our comprehensive approach to sustainability, CO2 emissions have been reduced substantially, with 553 thousand kg of electricity and 25 thousand kg of water and 11kg of waste savings. By implementing these strategies, we demonstrate the effectiveness of our sustainability efforts and lay the foundation for future sustainability initiatives.



References

Rainwater Harvesting

http://www.rainwaterharvesting.org/international/singapore.htm
https://www.hdb.gov.sg/about-us/news-and-publications/press-releases/28032022-Greener-More-Sustainable-Homes

https://www.mbfc.com.sg/marina-bay-financial-centre/awards/

https://www.mbfc.com.sg/sustainability/

https://www.hdb.gov.sg/cs/infoweb/about-us/our-role/smart-and-sustainable-living/Green-Towns-Progamme

Waste

https://www.wastecare.com/usefulinfo/PET-Plastic-Water-Soda-Bottles-Bale-Weights.htm#:~:text=PET%20%2D%20Plastic%20Water%20%2F%20Soda%20Bottles,Weights%2C%20Size%20and%20Recycling%20Equipment&text=Note%3A%201%20of%20the%2020,PET%20bottles%20to%20the%20pound.

https://www.todayonline.com/big-read/big-read-countries-wage-war-plastics-jury-still-out-how-best-tackle-problem

https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling

Water Efficient Fittings

https://www.pub.gov.sg/-/media/Images/Feature/Content-Pages/Public/Singapore-Water-Loop/Water-Conversation/Resources-on-Water-Efficiency-Measures/Water_Efficiency_Buildings_v2.pdf

https://www.pub.gov.sg/Public/WaterLoop/Water-Conservation/Awards-and-Certifications/Water-Efficient-Building-Certification

Lighting

https://www.rayzeek.com/blog/do-motion-sensor-light-switches-save-energy#:~:text=They%20work%20by%20automatically%20turning,%25%20~%2060%25%20energy%20savings.

https://www.brite.sg/post/brite-motion-detection-lighting-singapore-solution-for-rising-electricity-

tariffs#:~:text=Benefits%20of%20Using%20Brite's%20Motion,our%20customised%20energy%20saving%20proposals

https://www1.bca.gov.sg/

Solar Panel

https://www.onyxsolardownloads.com/ROI/CRYSTALLINE/ASIA/ROI_CRYSTALLINE_SKYLIGHT_SINGAPORE.pdf

https://onyxsolar.com/photovoltaic-estimation-tool

https://www.solarelectricsupply.com/rec365aa-365w-rec-alpha-solar-panel

Grid Emission Factor

https://www.ema.gov.sg/resources/singapore-energy-statistics/chapter2

https://www.spgroup.com.sg/our-services/utilities/tariff-information

https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf

https://www1.bca.gov.sg/buildsg/sustainability/regulatory-requirements-for-existing-buildings/bca-building-energy-benchmarking-and-disclosure

PDV

https://www.sleb.sg/UserFiles/Resource/Slides%20Library/Super%20Low%20Energy%20Training%20Workshop/Natflow%20Pte%20Ltd%20-%20Apr%202019%20-%20PDV%20_for%20circulation_.pdf

Target & Solution (Green Lease)

https://en.savills.co.kr/services/sustainability-and-esg-services/green-lease.aspx

Waste and recycling

https://evreka.co/solutions/epr-management/
https://www.nea.gov.sg/media/news/news/index/waste-generation-and-recycling-rates-increased-in-2022-as-economic-activity-picked-up
https://sec.org.sg/pdf/reports/new-plastic-economy.pdf
https://www.straitstimes.com/singapore/smart-recycling-boxes-and-lockers-for-another-83-locations-in-s-pore-by-january#:~:text=SINGAPORE%20%E2%80%93%20A%20system%20that%20uses,the%20contamination%20rate%20of%20recyclables.
https://www.straitstimes.com/singapore/environment/more-households-recycle-in-2023-than-in-2021-nea-survey
https://www.nea.gov.sg/docs/default-source/our-services/waste-management/list-of-items-that-are-recyclable-and-not.pdf
https://www.drinklavit.com/blog/plastic-isnt-green#:~:text=A%20typical%20one%2Dliter%20plastic,creates%20three%20tons%20of%20CO2.
https://www.nea.gov.sg/docs/default-source/asr/nea-ar-fy22.pdf

Community Engagement Mitigating Carbon Footprint (Permanent)

https://www.capitaland.com/sg/malls/funan/en/concierge/amenities/Cycling_Path.html

https://www.future.green/futureblog/save-carbon-biking#:~:text=Reducing%20Carbon%20Emissions,of%20CO2%20per%20mile%20traveled.

https://www.carbonindependent.org/20.html#:~:text=The%20typical%20bus%20produces%20about,quoted%20by%20Goodall%20%5B7%5D).

Community Engagement Mitigating Food waste & Carbon Footprint (Permanant)

https://www.statista.com/statistics/1060538/ntuc-fairprice-co-op-total-food-waste-generated-by-stores/#:~:text=In%20financial%20year%202022%2C%20National,largest%20supermarket%20chain%20in%20Singapore.

https://www.sg101.gov.sg/resources/connexionsg/foodwaste/

Community Engagement Mitigating Plastic Waste (Permanant)

https://ballotbin.co.uk/

Community Engagement Mitigating Waste and Water (Permanant)

https://www.roadrunnerwm.com/blog/textile-waste-environmental-crisis

https://www.gogreen.gov.sg/rebag-workshop-bring-a-shirt-take-home-a-bag/