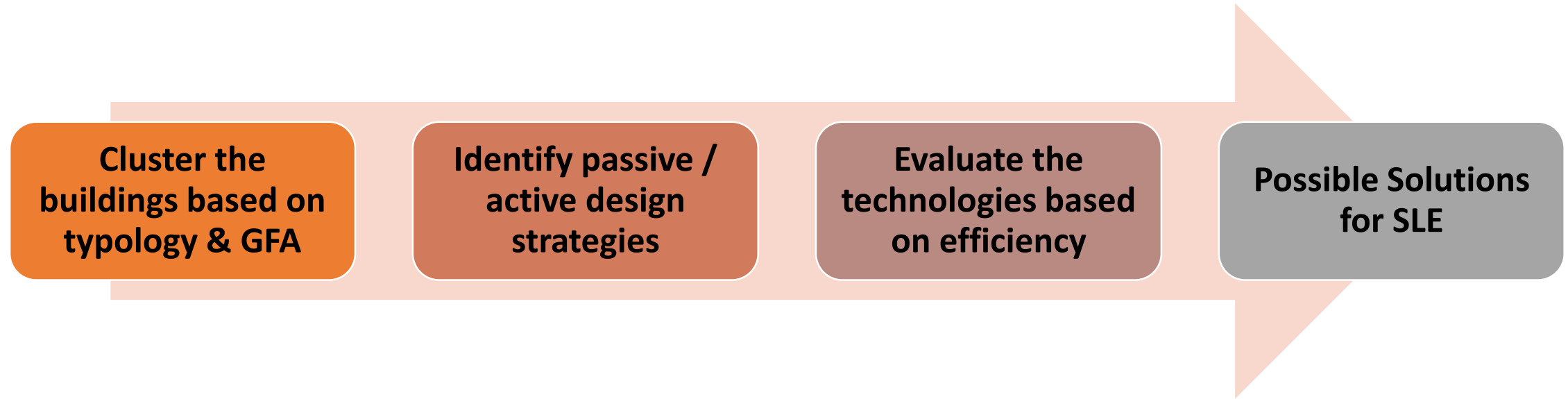


GREEN MARK SUPER LOW ENERGY SOLUTIONS PACKAGE

- To push boundaries in terms of energy efficiency and move towards a low carbon built environment, Building and Construction Authority (BCA) developed the Green Mark Super Low Energy criteria (GM SLE) in 2018.
- GM SLE is a rating tool that provides a robust framework for both new and existing (residential and non-residential) buildings and recognises projects that are on the path to net zero energy and beyond.

- BCA has created a ecosystem of supporting tools such as SLE technology Roadmap and SLEB Smart Hub to enable industry to adopt SLE buildings design. Solution Packages is one such tool which is developed based on the awarded SLE projects.
- The solutions package identifies solutions and proven SLE technologies that are available today to help the industry design and develop cost-effective SLE buildings.
- The solutions package is a live document and will be updated periodically as we have more number of GM SLE projects



How to use the Solutions Package

As a reference tool to identify;

- appropriate passive and active systems to be employed based on the **Building typology** (Institutional, Commercial, Industrial & other building types) and **GFA**.
- optimal solution range for strategies such as Façade performance, Lighting system, Air conditioning system, Renewable energy and Energy Use Intensity (EUI) along with innovative solutions to achieve Super Low Energy buildings.

Area sqm	% of Aircon area	Façade Performance	Innovative Passive Design Features (IPDF)	Lighting	Air – Conditioning System		EUI kWh/sqm/yr	Renewable Energy (RE)
					System Type & Efficiency	Innovative Technology		
5,000 to 10,000	10% to 40%	ETTV: 22 to 40 W/sqm Façade (Glass) Properties: U-Value : 1.4 to 2.5 SC : 0.25 to 0.35	1. Double Skin Façade 2. Light shelf 3. Operable louvers for Natural Ventilation	Type: LED Improvement over Baseline: 40% to 60% Control: Motion/Daylighting Sensors	Cooling System: Plant Efficiency (water cooled system): 0.50 to 0.64 kW/RT Air Side: Air Distribution Efficiency: 0.08 to 0.15 kW/RT	Hybrid Cooling System	30 to 73	On-site RE Energy Replacement: 11 to 100% (SLE to ZE)
10,000 to 20,000	15% to 60%	ETTV: 21 to 38 W/sqm Façade (Glass) Properties: U-Value &: 1.5 to 4.5 SC : 0.23 to 0.83	nil	Type: LED Improvement over Baseline: 40% to 80% Control: Motion/Daylighting Sensors	Cooling System 1.Plant Efficiency (water cooled system): 0.56 - 0.625 kW/RT 2.VRF/VRV: 0.66 kW/RT Air Side 1. Air Distribution Efficiency:0.08-0.175 kW/RT 2.FCU: 0.06 kW/RT	Passive Displacement Cooling	65 to 150	On-site RE Energy Replacement: 12 to > 100% (SLE to PE)
20,000 to 30,000	50%	ETTV: 22 W/sqm Façade (Glass) Properties: U-Value : 1.45 SC : 0.23	1.Long overhangs for east & West façade. 2. NV for common areas	Type: LED Improvement over Baseline: 50% Control: Motion/Daylighting Sensors	Cooling System Plant Efficiency (water cooled system): 0.55 kW/RT Air Side Air Distribution Efficiency: 0.169 kW/RT	Hybrid Cooling System EC FCU Fans	80.	nil
> 40,000	38%	ETTV: 37 W/sqm Façade (Glass) Properties: U-Value : 1.53 SC : 0.3	nil	Type: LED Improvement over Baseline: 50% Control: Motion/Daylighting Sensors	Cooling System Plant Efficiency (water cooled system): 0.565 kW/RT Air Side Air Distribution Efficiency: 0.128 kW/RT	PDV System Occupancy Sensor For Demand Control In Classroom	94	Energy Replacement: 100%. (ZE)

Area sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI kWh/sq/year	Renewable Energy (RE)
					System Type & Efficiency	Innovative Technology		
< 5,000	37-45%	ETTV:34-39W/sqm	nil	Type: retrofitted LED Improvement over Baseline: 40% to 50% Control: Motion Sensors	Cooling System: 1.Plant Efficiency (water cooled system): 0.56 - 0.591kW/RT 2.VRF : 0.82 kW/RT Air-side: Air Distribution Efficiency: 0.18-0.25 kW/RT	nil	30 to 171	On-site RE Energy Replacement: 100% (ZE)
5,000 to 10,000	45-60%	nil	nil	Type: retrofitted LED Improvement over Baseline: 40% to 50% Control: Motion Sensors	Cooling System: Plant Efficiency (Water Cooled system): 0.59 - 0.65 kW/RT Air-side: Air Distribution Efficiency: 0.2-0.25 kW/RT	Use of HVLS fan for atrium space	85 to 140	On-site RE Energy Replacement:14 to 100% (SLE to ZE)
10,000 to 20,000	50-90%	nil	nil	Type: retrofitted LED Improvement over Baseline: 40% to 45% Control: Motion /Daylighting sensor	Cooling System: 1.Plant Efficiency (Water Cooled System): 0.56 to 0.64 kW/RT 2. VRF - 0.67 kW/RT Air-Side: Air Distribution Efficiency: 0.068 – 0.091 kW/RT	nil	77 to 100	On-site RE Energy Replacement: 10 to 100% (SLE to ZE)
20,000 to 30,000	55-75%	Retrofitting of single to double glazed Façade (Glass) Properties: U Value: 1.6 SC : 0.30	nil	Type: retrofitted LED Improvement over Baseline: 40% to 45% Control: Motion /Daylighting sensor	Cooling System: Plant Efficiency (Water Cooled system): 0.56 to 0.69 kW/RT Air-side: Air Distribution Efficiency: 0.2-0.25 kW/RT	Hybrid cooling system	85 to 90	On-site RE Energy Replacement: 7 to 20% (SLE)
> 30,000	50-90%	nil	Sun Pipe & light shelf	Type: retrofitted LED Improvement over Baseline: 40% to 45% Control: Motion /Daylighting sensor	Cooling System: Plant Efficiency (Water Cooled System): 0.58 to 0.63 kW/RT Air-side: Air Distribution Efficiency: 0.2-0.25 kW/RT	High Speed Low Velocity Fan	70 to 93	On-site RE Energy Replacement: 10% to > 100% (SLE to PE)

Area Sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI Kwh/sqm/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
<10,000	51-76%	ETTV: 26-36 Façade (Glass) Properties: U value: 1.5-1.6 SC: 0.23-0.26	Daylight Optimization	Type: LED Improvement over Baseline : 36 to 59% Control: Motion Sensor with Smart Control System	Cooling System: Plant Efficiency (DCS/ water-cooled system):0.53-0.65 kW/RT Air-side: Air Distribution Efficiency: 0.02 - 0.15kW/RT	Passive displacement ventilation system	58 -95	On-site RE Energy Replacement: 3% - 16% (SLE)
>20,000	87%	ETTV: 35 Façade (Glass) Properties: U value: 1.6 SC: 0.26	Nil	Type: LED Improvement over Baseline : 42% Control: Occupancy and daylight sensors	Cooling System: Plant Efficiency(Water cooled) : 0.54kW/RT Air-side: Air Distribution Efficiency: 0.34kW/ton	Smart Cooling with Passive Under Floor Air Distribution System	82	On-site RE Energy Replacement: 4%(SLE)
>60,000	86%	ETTV: 38 Façade (Glass) Properties: U-Value : 1.6 SC : 0.26	Nil	Type: LED Improvement over Baseline : 50% Control: Motion Sensor	Cooling System: Plant Efficiency (water-cooled system): 0.50 kW/RT Air-Side: Air Distribution Efficiency: 0.10 kW/RT	1. Integrated control Dual Temperature Chiller system with optimized compressor impeller 2. Dual Coil Single Fan integrated High Efficiency AHU	140.57	Nil

Area sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI Kwh/sqm/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
>40,000	92%	22% of roof with greenery	Nil	Type: LED Improvement over Baseline : 70% Control: Motion Sensor	Cooling System: Plant Efficiency (Water cooled System) : 0.577 kW/RT Air-side: Air Distribution Efficiency: 0.25 kW/RT	Nil	114	On-site & REC* (ZE project*)

Area sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI Kwh/sqm/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
10,000 to 20,000	66%	ETTV: 35 W/sqm Façade (Glass) Properties: U value: 0.5 SC: 0.29	Nil	Type: LED Improvement over Baseline: 36% Control: 1.Motion/Daylighting Sensors 2.Occupancy-based sensing to moderate brightness of luminaries	Cooling System Plant Efficiency(Water cooled system) 0.55kW/RT Air-side: Air Distribution Efficiency: 0.08kW/RT	Solar Driven Digitally controlled Chiller plant. This technology operates on DC and can be powered by both solar (DC) and electricity from the grid (AC)	64	On-site RE Energy Replacement: 10% (SLE)
>100,000	1%	ETTV= 30 W/sqm Façade (Glass) Properties: U value: 2.36 SC: 0.21	Largely Naturally ventilated	Type: LED Light Improvement over Baseline : 43% Control: Motion sensor and lighting controls for daylighting optimization	Cooling System : VRF: 0.740 kW/RT Air-side: Air Distribution Efficiency :0.089 kW/RT	Nil	65.58	On-site RE Energy Replacement: 10% (SLE)

Area sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI Kwh/sqm/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
>20,000	80%	Nil	Nil	Type: LED Improvement over Baseline: 42%	Cooling System : Plant Efficiency (Water Cooled): 0.62 kW/RT Air-side: Air Distribution Efficiency:0.18 kW/RT	Nil	72	On-site RE Energy Replacement: 40% (SLE)
>40,000	48%	Nil	Nil	Type: LED Improvement over Baseline : 27%	Cooling System : Plant Efficiency (Water cooled): 0.63 kW/RT Air-side: Air Distribution Efficiency:0.25 kW/RT	Nil	115	On-site RE Energy Replacement: 25% (SLE)
>90,000	2%	Nil	Nil		Tenants own installed split units	Nil	40	On-site RE Energy Replacement: 68% (SLE)

Area Sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI Kwh/m2/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
< 5,000	20% - 40%	ETTV: 37 U-Value: 3.8 - 5.7 SC: 0.36 - 0.94	nil	Type: LED Improvement over Baseline: 50% to 60% Control: Motion/Daylighting Sensors	Cooling System: Efficiency(VRF):0.63 - 0.77 kW/RT Air Side FCU: 0.027 – 0.106 kW/RT	Nil	60 to 77	On-site RE Energy Replacement: 45 to >100% (PE)
5,000 to 10,000	10% to 25%	ETTV:28 W/sqm Façade (Glass) Properties:: U value: 5.7 SC: 0.7	1.Natural ventilation coupled with high volume low speed ceiling fans for functional space 2.Use of sun pipes	Type: LED Light Improvement over Baseline : 45% Control: Motion sensor and lighting controls for daylighting optimization	Cooling System: VRF System : 0.68 kW/RT Air-side: Air Distribution Efficiency: -0.02 kW/RT	Nil	55	On-site RE Energy Replacement: 100% (ZE)
>30,000	29%	ETTV: 33 W/sqm	Workshops and Warehouses are majorly NV	Type: LED Light Improvement over Baseline : 58.3% Control: Motion sensor and lighting controls for daylighting optimization	Cooling System Plant Efficiency (Water Cooled System): 0.594 kW/RT Air-side: Air Distribution Efficiency: 0.195 kW/RT	1.Passive Displacement Cooling 2.Hybrid evaporative cooler with fan assisted cooling	200	On-site RE Energy Replacement: 26% (façade BaPV & Roof) (SLE)

*Other building type: Transit shelters, Gas stations, Camp facilities, etc

Area sqm	% of Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EUI Kwh/m2/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
10,000 to 20,000	6%	Nil	Largely Naturally ventilated	Type: T5 Improvement over Baseline: 22%	Cooling System: Split System: 0.813 kW/RT Air-side: Air Distribution Efficiency:0.087 kW/RT	Nil	24	On-site RE Energy Replacement: 100% (ZE)
>20,000	24%	Nil	Largely Naturally ventilated	Type: LED Improvement over Baseline: 55%	Cooling System: VRV: 0.735kW/RT Air-side: Air Distribution Efficiency:0.165 kW/RT	Nil	96	On-site RE Energy Replacement: 31% (SLE)

*Other building type: Transit shelters, Gas stations, Camp facilities, etc

Area sqm	% of Non Aircon area	Façade Performance	IPDF	Lighting	Air – Conditioning System		EEI Kwh/sqm/yr	Renewable Energy
					System Type & Efficiency	Innovative Technology		
10,000 to 20,000	>60% of living rooms & bedrooms are designed to be naturally ventilated.	RET_V :17.5 W/sqm Façade Properties: U Value: 4.1, SC value: 0.35	All above ground lobbies and corridors are naturally ventilated.	Type: LED Improvement over Baseline >60% Control: Motion Sensors	Cooling System: Split units - NEA 5 ticks	Use of ceiling fans in dwelling units for thermal comfort	44	On site PV Energy Replacement: 30% of the common facilities energy consumption (SLE)
>20,000	>60% of living rooms & bedrooms are designed to be naturally ventilated.	RET_V :19.09 W/sqm Façade Properties: U Value: 3.77, SC value: 0.49	All above ground lobbies and corridors are naturally ventilated. Void spaces in between levels for wind to penetrate.	Type: LED Improvement over Baseline >60% Control: Motion Sensors	Cooling System: Split units - NEA 5 ticks	Use of ceiling fans in dwelling units for thermal comfort	29.61	On site PV Energy Replacement: 30% of the common facilities energy consumption (SLE)
>100,000	>60% of living rooms & bedrooms are designed to be naturally ventilated.	RET_V :8.08 W/sqm	All above ground lobbies and corridors are naturally ventilated	Type: LED improvement over Baseline : 80% Control: Motion Sensors	Air conditioning not provided (HDB project)	Nil	5.12	NIL

GREEN MARK SUPER LOW ENERGY CASE STUDY*

**Case Studies mentioned in this document are not exhaustive, it's meant to illustrate the various available GBTs to achieve SLE*



1. Passive Strategies

Mass engineered Timber
Tropical Vernacular – shading, greenery, breezy non AC spaces



2. Active Strategies

New Cooling system that relies on convection currents of the cool air. Patented **Passive Displacement Cooling system**



3. Smart Energy Management

Full in house bespoke demand control system based on occupancy for lighting, AC and plug loads



4. Renewable Energy

Latest high efficiency photovoltaic (PV) panels

Project Team:

Client: SMU | Architect: MKPL | MEP: Meinhardt | ESD Consultant: Web Earth | Specialist: SMU (PDC system)



1. Passive Strategies

Massing to promote comfortable NV spaces. Large roof for shading and to aid with ventilation



2. Active Strategies

Hybrid cooling system using ceiling fans and air-conditioning set at a higher temperature (27°C)



3. Smart Energy Management

Extensive sensors for lighting and cooling systems



4. Renewable Energy

Latest high efficiency photovoltaic (PV) panels to offset 100% of its energy consumption

Project Team:

Client: NUS | Designer: Serie + Multiply Consultants | Architect/MEP/ESD: SJ | Specialist: Transsolar Energietechnik

Smart lighting with occupancy sensors in transient & functional spaces



Building attached PV panels on East, West & North Facade



Efficient chiller
Precision Secondary Pumping system for whole Admin block



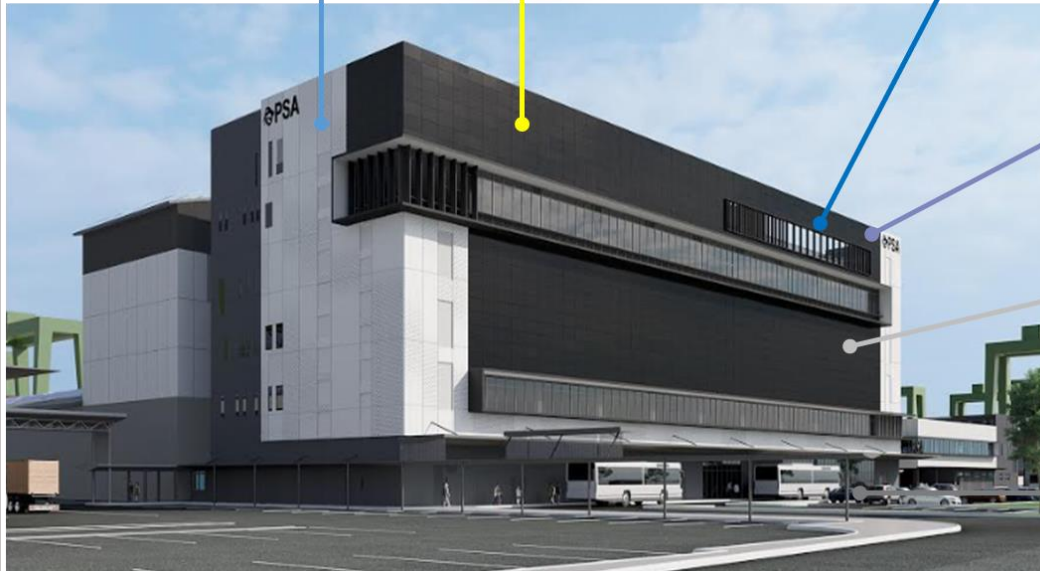
BMS controlled systems & monitoring
Model predictive Control for ACMV
Optimisation
IAQ sensing – Monitoring, trending



Passive Displacement Cooling for L2,L5,L6 of Admin Building
VAV thermal Diffusers for L1, L4 office areas



Hybrid evaporative cooler with fan assisted cooling for L1 Canteen



Passive Strategies

Adoption of good orientation and optimization of façade design to reduce heat gain



Active Strategies

Passive Displacement Cooling system and VAV thermal diffusers coupled with smart lighting.



Smart Energy Management

Model predictive control for ACMV and IAQ sensing for healthy indoor environment



Renewable Energy

Latest high efficiency photovoltaic (PV) panels for roof and façade.

Project Team:

Client: PSA | Architect: ID Architects | MEP: PDC Consulting Engineers | ESD Consultant: GreenA Consultants

**Project Team:**

Client: CDL | Architect: Nikken Sekkei & ADDP Architects | MEP: Squire Mech | ESD Consultant: BSD

**1. Passive Strategies**

Massing and unit layout to promote comfortable NV Dwelling units . Low RETV of 19.09 W/m² with good glass selection and shading devices to reduce overall building heat gain

**2. Active Strategies**

Installation of energy efficient air-conditioning systems with 5 ticks rating for all dwelling units
Use of 100% energy efficient LED lighting to achieve high energy savings compared to baseline

**3. Smart Energy Management**

Smart sensors and controls in common areas for lighting and ventilation

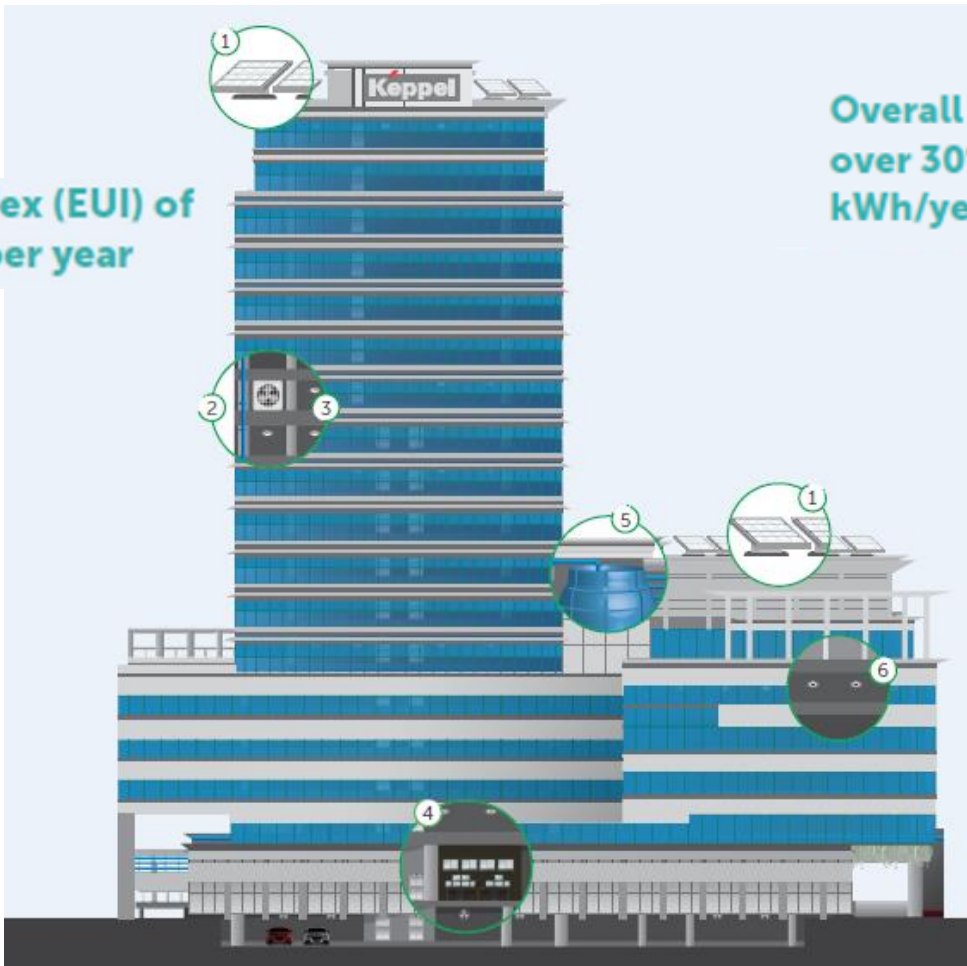
**4. Renewable Energy**

Roof top Solar photovoltaic (PV) panels to offset 30% of the common facilities energy consumption.

Keppel Bay Tower has implemented innovative solutions test-bedded under



Energy Use Index (EUI) of
<115 kWh/m² per year



Overall energy savings of
over 30% or 2.2 million
kWh/year



Reduction of over
2,400 tonnes of carbon
emissions per annum



Active Strategies

Energy Efficient Air Distribution System.

Demand Control Fresh Air Intake System to optimise energy use and improve indoor environment quality



Smart Energy Management

Use of Cooling Tower Management System, Smart Lighting System and Intelligent Building Control System to improve data analytics and control



Renewable Energy

Solar PV harvesting about 100,000 kWh per annum

Project Team:

Client: Keppel | FM: Johnson Controls | ESD Consultant: Johnson Controls

KEPPEL BAY TOWER - Keppel Land



LOGISTECH - CapitaLand



ONE RAFFLES LINK - Hong Kong Land



TUAS BIOMEDICAL PARK - JTC



Thank You

Useful Links for Reference

SLE Standard - <https://www1.bca.gov.sg/buildsg/sustainability/super-low-energy-programme>

SLE awarded project - <https://www.sleb.sg/Building/GreenMarkBuildingsDirectory>

SLEB Smart Hub - www.sleb.sg