Green Mark **2021**

EE

TECHNICAL GUIDE

Revision Log

Revision	Description	Effective Date
R1	1st Edition	01/11/2021
R1.1	Minor updates	01/11/2021
R1.2	Minor updates	01/11/2021
R1.3	Updates: • Permanent M&V (ii); • Electrical Sub-metering requirement • Airside pressure adjustment example • Table 2B – Mechanical Ventilation • Fixed Metrics Requirement Tables • Fixed Metrics for Residential to include landed housing	28/03/2023
R2	2nd Edition with minor updates	01/01/2024

Contents

Energy Efficiency Pathways

The Green Mark Energy Pathways are:

- Data driven and flexible – aligned to real project performance with validated data. Flexible routes for projects to demonstrate their performance.
- Outcome based – full recognition of passive design strategies and renewable energy systems' contribution to energy savings.
- Supportive of innovation – encourage the use of new technologies, approaches and solutions to energy performance.

TABLE 1A Energy Efficiency Pathways

Building Type	**PATHWAY 1**	**PATHWAY 2**	**PATHWAY 3**
Commercial			
Office Buildings	•	•	•
Hotels	•	•	•
Retail Buildings	•	•	•
Educational			
IHL (University, Polytechnics and ITE)	•	•	•
Private Schools and Colleges	•	•	•
Junior Colleges (MOE)	•	•	•
Secondary Schools (MOE)	•	•	•
Primary Schools (MOE)	•	•	•
Healthcare			
Hospitals (Private and General)	•	•	•
Community Hospitals	•	•	•
Polyclinics	•	•	•
Nursing Homes/ Youth Homes	•	•	•
Other Non-Residential			
Mixed Developments	*by GFA mix*		
Community Centres	•	•	•
Civic Buildings	•	•	•
Cultural Institution	•	•	•
Sports and Recreation Centres	•	•	•
Religious/ Places of Worship		•	•
Workers' Dormitories		•	•
Other Non-Residential Buildings		•	•
Industrial			
High Tech Industrial Buildings		•	•
Light Industrial Buildings	•	•	•
Warehouses, Workshops/Logistics and Others	•	•	•
Residential			
All Residential Buildings		•	
All Other Building Types		Bespoke	•

IHL – Institute of Higher Learning *ITE – Institute of Technical Education* *MOE – Ministry of Education*

For Buildings not listed – Pathway 2 or 3 would be the alternatives, however BCA may be able to work with the project team to develop a bespoke pathway requirement.

Energy Efficiency Assessment Approach

New Buildings under Design and Existing Buildings undergoing retrofit
All projects shall demonstrate the stipulated performance through the relevant pathways indicated in Table 1A. **Pathway 1** - Benchmark EUI (Table 1B and Table 1C), detailed measurement and calculation (Existing buildings) or energy model (new buildings) shall be used to calculate and justify the design EUI. **Pathway 2** – Fixed Metrics, the prescriptive performance values shall be met in all areas. Where there is a shortfall of performance, this shall be annualised and required to be offset through onsite renewables with the listed multiplication factor. Detailed calculations, drawings and specifications would be required to substantiate the declared performance. **Pathway 3** - Energy Savings, the energy modelling for evaluating the energy performance of a building shall be carried out in a prescribed manner to quantify the potential savings based on energy efficiency measures and improvements that reduce cooling load requirement over the Reference Model. Projects are to refer to the BCA Green Mark 2021 Energy Modelling Guide for details. **Note on Renewable Energy**: During design or pre-retrofit stage, the expected renewable energy generated percentage and the total annual electricity consumption of the development shall be calculated. Technical product information of the renewable energy system and detailed drawings showing the location of the system shall be provided.
New Building Verification Stage and Existing Buildings in Operation
When the building has completed construction or its retrofit, a verification audit shall be carried out. For new non-residential buildings, there are two stages of verification. For existing buildings with commitment, only stage 1 verification is applicable. For Buildings in operation, not undergoing retrofit, the assessment would be based upon its operational data. Stage 1 Verification (New Buildings and Existing Buildings with Commitment): The Green Mark verification shall demonstrate the implementation of the design stage strategies and note any deviations and their effect on the ability of the project to achieve the energy performance. Stage 2 Verification (New Non-Residential Buildings): The building shall demonstrate compliance to the committed performance stated in the pathway using 12-months of measured data with a requirement of minimum occupancy of 60% for the period of measurement. Deviation of less than 5% for the Energy Savings from energy modelling is allowed, otherwise a calibration would be required. Note on Renewable Energy The generated energy, using 12-month actual operation data, will be audited.

Pathway 1 – Energy Use Intensity (EUI)

For those buildings in the Table 1B and Table 1C, EUI pathway is applicable.

Assessment Criteria

For new buildings, the design EUI can be calculated based on energy modelling output, or from other simulation software.

For existing buildings, the EUI should be calculated based on the total energy consumption from the utility bills.

Total Building annual energy consumption over the Gross Floor Area (GFA) of the building (kWh/m^2/yr). Based on:

- Energy modelling (Design) for new buildings
- Energy Calculation and measured data (for existing buildings with major retrofit)
- Measurement – In operation

TABLE 1B Pathway 1 Energy Use Intensity (EUI) Quick look up table

Building Type	Gold^{PLUS} EE >50%	Platinum EE ≥55%	SLE EE ≥60%
Commercial			
Office Buildings (Large) (GFA ≥ 15,000sqm)	155	140	115
Office Buildings (Small) (GFA < 15,000sqm)	135	120	100
Hotels (Large) (GFA ≥ 15,000sqm)	230	220	190
Hotels (Small) (GFA < 15,000sqm)	180	160	140
Retail Malls	240	210	160
Educational			
IHL (University, Polytechnics and ITE)	130	120	90
Private Schools and Colleges	110	100	80
Junior Colleges (MOE)	60	50	40
Secondary Schools (MOE)	40	35	30
Primary Schools (MOE)	40	35	30
Healthcare			
Hospitals (Private and General)	375	340	300
Community Hospitals	230	210	185
Polyclinics	150	135	120
Nursing/Youth Homes	90	80	70
Other Non-Residential			
Mixed Developments	*by GFA mix*		
Community Centres	150	125	110
Civic Buildings	80	70	60
Cultural Institutions	180	140	120
Sports and Recreation Centres	110	80	50
Religious/ Places of Worship	N.A.		
Workers' Dormitories	N.A.		

Building Type	Gold^PLUS EE >50%	Platinum EE ≥55%	SLE EE ≥60%
Other Non-Residential Buildings	N.A.		
Industrial			
High Tech Industrial Buildings	N.A.		
Light Industrial Buildings	50	45	35
Warehouses, Workshops/Logistics and Others	50	45	35

Additional Notes	New	Existing
AC Total System Efficiency (kW/RT)	0.8	0.9
Occupancy rate for EUI	100% (design)	≥60%
Renewable Energy included	On-Site	

TABLE 1C Pathway 1 Energy Use Intensity (EUI) Quick look up table – DCS/DDC/CCS

Building Type	Gold^PLUS EE>50%	Platinum EE ≥55%	SLE EE ≥60%
Commercial			
Office Buildings (Large) (GFA ≥ 15,000sqm)	100	90	80
Office Buildings (Small) (GFA < 15,000sqm)	90	80	75
Hotels (Large) (GFA ≥ 15,000sqm)	150	135	120
Hotels (Small) (GFA < 15,000sqm)	120	110	95
Retail Malls	160	140	125
Healthcare			
Hospitals (Private and General)	245	230	210
Community Hospitals	150	140	130
Polyclinic	100	90	85
Nursing/Youth Homes	60	55	50
Other Non-Residential			
Mixed Developments	*by GFA mix*		
Community Centres	100	90	80
Civic Buildings	50	45	40
Cultural Institutions	115	100	85
Sports and Recreation Centres	70	65	35
Religious/ Places of Worship	N.A.		
Workers' Dormitories	N.A.		
Other Non-Residential Buildings	N.A.		
Industrial			

High Tech Industrial Buildings	N.A.
Light Industrial Buildings	N.A.
Warehouses, Workshops/Logistics and Others	N.A.

Additional Notes	New	Existing
Airside efficiency for buildings supplied by DCS/DDC/CCS (kW/RT)	0.2	0.25
Occupancy rate for EUI	100% (design)	≥60%
Renewable Energy included	On-Site	

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

Submission of the following if applicable:

- Detailed report from simulation software.
- For new buildings' EUI calculated based on simulation, if the building's operation hours are available, it shall be based on its actual operation hours; if the building's operation hours are unknown or uncertain, the fixed hours as indicated in Pathway 3 - Energy Savings should be used as reference.

At Verification stage (New Buildings & Existing Buildings):

- Scenario 1), based on utility bill, if the occupancy rate is low, e.g. 20% occupancy rate, the EUI needs to be adjusted to 80% occupancy for submission;
- Scenario 2), based on the utility bills, if the actual operation hours are the same as what were used during design stage, no adjustment is required for the operation hours; if the actual operation hours are different from what were used during design stage, adjustment needs to be done based on the actual operation hours.

Guidance Notes

Worked examples

Example 1:

A small office building	**Results** **1) based on EM proposed model for new buildings; or** **2) based on projected data for existing building undergoing retrofit**	
TBEC (Total Annual Building Energy Consumption):	**290,905**	**kWh/year**
GFA	**2,584**	**m2**
EUI	**112.60**	**kWh/m2/year**

Based on Table 1B (extracted below), it meets Platinum (>55%) EUI ≤120 requirement under pathway 1.

Example 2:

During verification stage, which is one year after TOP, if the occupancy rate is only 30%:

A small office building	<u>Results</u> 1) based on EM proposed model for new buildings; or 2) based on projected data for existing building undergoing retrofit	
Annual Total Building Energy Consumption: <u>At 30% occupancy</u>	115,489.3	kWh/year
GFA	2,584	m2
EUI	44.7	kWh/m2/year
TBEC Adjusted to 80% occupancy	=115,489.3 ÷ 0.3 × 0.8 = 307971.4	kWh/year
EUI after adjustment	119.2	kWh/m2/year

With adjusted EUI of 119.2, the project can pass the verification requirement for Platinum.

Example 3:

<table>
<tr><th>A mix development (retail and office)</th><th colspan="2"><u>Results</u>
1) based on EM proposed model for new buildings; or
2) based on projected data for existing building undergoing retrofit</th></tr>
<tr><td>GFA of retail component</td><td>18,552 (34% of total GFA)</td><td>m²</td></tr>
<tr><td>GFA of office component</td><td>35,992 (66% of total GFA)</td><td>m²</td></tr>
<tr><td>Required EUI for compliance</td><td colspan="2">Required EUI (kWh/m2/year) based information on table 1b and GFA breakdown:
Gold^{PLUS}: 240 x 34% + 155 x 66% = 183.9
Platinum: 210 x 34% + 140 x 66% = 163.8
SLE: 160 x 34% + 115 x 66% = 130.3
<table><tr><th>Gold^{PLUS}
EE >50%</th><th>Platinum
EE ≥55%</th><th>SLE
EE ≥60%</th></tr><tr><td>183.9</td><td>163.8</td><td>130.3</td></tr></table></td></tr>
<tr><td>Annual Total Building Energy Consumption:</td><td>8,217,552.3</td><td>kWh/year</td></tr>
<tr><td>GFA</td><td>54,544</td><td>m²</td></tr>
<tr><td>EUI</td><td>150.7</td><td>kWh/m2/year</td></tr>
</table>

With the calculation above, it meets Platinum (>55%) requirement under pathway 1.

Pathway 2 – Fixed Metrics

Pathway 2 is applicable to all buildings listed in the Fixed Metrics Requirement Tables.

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Assessment Criteria

- All aspects of key performance metrics that make an energy efficient project must be met individually.
- Any shortfall in performance can be made up with the use of onsite renewables, subject to the building typology multiplication factor.
- For projects using a District Cooling System (DCS), Distributed District Cooling (DDC) or Centralised Cooling System (CCS), the airside performance shall be complied in lieu of Total System Efficiency (TSE) and shall be as follows:

Gold^{PLUS} EE >50%	Platinum EE ≥55%	SLE EE ≥60%
0.2	0.18	0.16

Pathway 3 – Energy Savings

Assessment Criteria

Demonstrated energy savings following the Green Mark Energy Modelling guideline which looks at holistic energy performance against a reference model. This is the default pathway for projects not listed in Table 1A.

	Pathway 3 – Energy Savings		
	Gold^{PLUS} EE >50%	**Platinum EE ≥55%**	**SLE EE ≥60%**
Saving from BAU (2005 Code)	50	55	60
Saving from Current Reference (Annex C) **Including buildings supplied by DCS/DDC/CCS*	30	35	40

Additional Requirements	New	Existing
AC Total System Efficiency (kW/RT)	0.8	0.9
Airside efficiency for buildings supplied by DCS/DDC/CCS (kW/RT)	0.2	0.25
Savings from onsite Renewable Energy	no cap	
Savings from Passive Design	no cap	

**Based on Energy Modelling guidelines .*

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

Please refer to *Energy Modelling Guidelines* and requirements.

At Verification stage (New Buildings & Existing Buildings):

When the building starts to operate in a steady state, the developer/building owner shall, within 2 years after TOP, gather data for a 12-month period based on actual building's operation, to justify the claimed energy saving. Breakdown[1] of the energy consumption should be provided based on power meters' reading.

The project developer or building owner shall submit a Stage 2 Verification Audit Report of at least, but not be limited to, the following content:

a) Form for *Energy Modelling Form for Green Mark Scheme (Validation After Project Completion)*

b) Electricity bills: Building landlord/ tenants bills for 12 months if applicable.

c) Energy Audit Report

[1] Based on power meters' reading to provide the breakdown on the energy consumption from the utility's bills. *Sub-meters are required* to capture the annual consumption of data centre and car park lighting and mechanical ventilation. Separate meters shall be provided during design stage to record the annual energy consumption generated by renewable energy e.g., solar photovoltaic (PV) and energy savings claimed by energy-saving devices, e.g., escalators, lifts, CO sensors and occupancy sensors and photo sensors. Dedicated meters shall be installed to measure the operational energy consumption and intensities of receptacle load (W/m2) of office space to verify on the energy savings claimed in energy modelling. If required, a revised energy modelling must be conducted using data obtained from actual site operations.

Energy Efficiency Detailed Requirements

1. Permanent Instrumentation for Measurement and Verification

(i) Chilled Water Air Conditioning System

To monitor and verify the performance of a building's chilled water system with accurate permanent measuring instruments, detect operational anomalies and realise its optimisation potential through analysis of usage patterns.

Assessment Criteria

Applicable to all chilled-water air-conditioning systems.

Permanent measuring instruments for monitoring of chilled-water system (water cooled and air-cooled system) operating efficiency shall be provided. The installed instrumentation shall have the capability to calculate the resultant operating system efficiency (i.e. kW/RT) within 5% of its true value and in accordance with SS591:2013. Each measurement system shall include the sensor(s), any signal conditioning, the data acquisition system and wiring connecting these components. The permanent measuring instruments and devices are to be accessible[2] and must not be located directly above the chillers, to facilitate verification and maintenances as recommended by SS 591:2013. The permanent instrumentation shall comply with the following:

- Data logging with the capability to trend at 1-minute sampling time interval, recorded to the 3rd decimal digit.
- Building Management System (BMS), standalone Energy Monitoring System (EMS) or local sequential controller shall have the capability to compute and display key indicators such as water-side, air-side and total system efficiency and calculated heat balance of the chilled water system.
- Magnetic in-line flow meter, with 1% uncertainty, and capable of electronic in-situ verification to within ±2% of its original factory calibration. If installation of magnetic in-line meters is not possible, ultrasonic flow meters or other flow meters that can meet the indicated performance may be used.
- Temperature sensors are to be provided for chilled water and condenser water loop and shall have an end-to-end measurement uncertainty not exceeding ±0.05°C over the entire measurement range. Provisions shall be made for test-plugs or additional thermowells to be installed before and after each temperature sensor along the chilled water and condenser water lines for verification of measurement accuracy. All thermo-wells are recommended to be installed in a manner that ensures the sensors can be in direct contact with the fluid flow. There shall be valid justification if direct immersion of the temperature sensor(s) is/are not possible. Such projects will be assessed on a case-by-case basis.
- Dedicated power meters (of IEC Class 1 or better) and metering current transformers, where applicable, of Class 1 or better, are to be provided for each of the following groups of equipment: chillers, chilled water pumps, condenser water pumps, cooling towers, air distribution system (i.e. AHUs, PAHUs, FCUs)[3].
- A heat balance substantiating test for the water-cooled chilled-water system is to be computed in accordance with SS 591 for verification of the accuracy of the M&V instrumentation. The heat balance shall be computed over the entire normal operating hours with more than 80% of the computed heat balance within ± 5% over a 1-week period. Heat balance readings should be generated automatically from BMS/BAS.

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[2] The temperature sensors are best placed in an accessible location with mounting height of not more than 3m, where possible. Otherwise, there should be evidence of provision for access by way of mobile platform or other suitable forms.

[3] For existing buildings without major retrofit, where power meters for air distribution system are not available, VSD readings are acceptable for airside efficiency computation, provided the data are linked to the building's energy monitoring system. If FCU power consumption could not be metered due to valid constraints, their nameplate power may be used to derive the air distribution efficiency.

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

The following shall be submitted:

- Detailed schematic drawings of the instruments' locations and locations of test plugs.
- Technical specifications and/or sample data sheets/product information for instruments and meters
- Calculation of end-to-end measurement uncertainty.
- Detailed drawings and schematics of the power measurement strategies for the air conditioning system (inclusive of the air distribution equipment).
- Pressure drop due to flow meter, such as reduced bore flow meter, needs to compute in pump head calculation. For new installation, projects should be designed to use accurate flow meter with lesser pressure drop.
- Projects are encouraged to use metering current transformers of Class 1 or better to achieve better accuracy.
- Commitment to comply with the requirements.

At Verification stage (New Buildings & Existing Buildings):

The performance verification may include on-site testing by BCA. A heat balance-substantiating test for water cooled chilled-water plant computed in accordance with BCA Code on Periodic Energy Audit of Building Cooling System shall be submitted with the following information:

- Energy Audit report
- Extracts of the instrumentation specifications and brochures
- Instrumentation calibration certificates
- As-built schematic drawings showing the locations of each power meter, flow meter and temperature sensor.
- BMS screenshots showing the relevant calibration inputs have been entered for the temperature measurement.
- Site requirement: To determine the chilled-water plant efficiency, airside efficiency and total system efficiency using the following operation data/installations to demonstrate compliance with the design specifications:
  - From Building Management System
    - ➢ Chilled-water plant kW/RT
    - ➢ Air distribution system kW/RT
    - ➢ Total system kW/RT
    - ➢ Chilled-water supply & return temperatures of the header to be checked for consistency against the temperatures of individual chillers and/or individual branches
    - ➢ Condenser water supply & return temperatures of the header to be checked for consistency against the temperatures of individual chillers and/or individual branches
    - ➢ Chilled-water header flow rate to be checked for consistency against the flow rate(s) of individual branches
    - ➢ Condenser water header flow rate to be checked for consistency against the flow rate(s) of individual branches
    - ➢ The accuracy of the programmed formula for the computation of the kW/RT of the various parameters
  - From the operating chiller panel(s):
    - ➢ Chilled-water supply & return temperatures to be checked for consistency against the BMS data

- ➢ Condenser water supply & return temperatures to be checked for consistency against the BMS data
- ➢ Approach of chilled-water supply – refrigerant evaporating temperature
- ➢ Approach of condenser-water supply – refrigerant condensing temperature
- ➢ Location of the chilled-water flow meter(s) installed to comply with manufacturer's recommendations

Guidance Notes

<u>Determining Heat Balance</u>

- Verification of the OSE shall be conducted by computing the system heat balance of the water-cooled chilled water plant in accordance with SS 591 to the extent as prescribed.

  Note*: For air-cooled chilled water plant, heat balance requirements will not be applicable.*

- The heat balance shall be computed over the entire normal operating hours as defined in clause 6.1.14 with more than 80% of the computed heat balance within 5% over a one (1) week period

- For a perfectly balanced chiller system, the heat balance can be represented by,

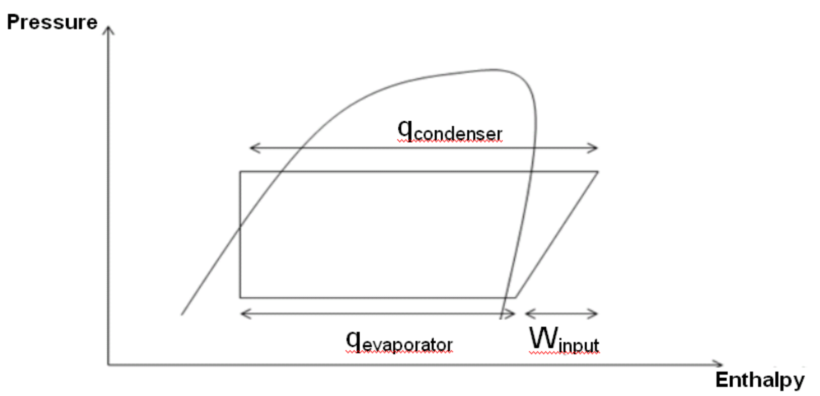
$$q_{condenser} = q_{evaporator} + W_{input.}$$

where $q_{condenser}$ = heat rejected by condenser, kW

$q_{evaporator}$ = heat gain in evaporator, kW

W_{input} = power input to compressor, kW

- The pressure enthalpy diagram below shows the concept of a heat balance equation in a vapour compression cycle.



Pressure Enthalpy Chart

- The system heat balance of the Chilled Water Plant shall be computed using the formula stated below over the normal operating hours,

$$\text{Percent Heat Balance} = \left| \frac{(q_{evaporator} + W_{input}) - q_{condenser}}{q_{condenser}} \right| \times 100\% \leq 5\%$$

The following example illustrates a successful heat balance where 80% of the computed heat balance falls within ± 5% as required.

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
	Chilled water supply temperature	Chilled water return temperature	Chilled water flow rate	Condenser water supply temperature	Condenser water return temperature	Condenser water flow rate	Chiller kWe	Heat Gain	Heat Rejected	Percent Heat Balance
dd/mm/yyyy hh:mm	**°C**	**°C**	**L/s**	**°C**	**°C**	**L/s**	**kW**	**RT**	**RT**	**%**
16/6/2012 15:00	6.70	12.60	84.10	29.4	35.5	97.65	308	591.14	709.65	-4.36
16/6/2012 15:01	6.71	12.50	84.20	29.5	35.4	97.60	309	580.81	686.03	-2.53
16/6/2012 15:02	6.72	12.30	84.30	29.6	35.3	97.55	310	560.41	662.44	-2.10
16/6/2012 15:03	6.73	12.10	84.20	29.7	35.2	97.50	311	538.68	638.86	-1.84
16/6/2012 15:04	6.74	12.20	84.10	29.8	35.1	97.55	312	547.05	615.95	3.22
16/6/2012 15:05	6.75	12.00	84.00	29.9	35	97.60	311	525.39	593.01	3.51
16/6/2012 15:06	6.74	12.30	84.10	29.8	35.1	97.65	310	557.07	616.58	4.64
16/6/2012 15:07	6.73	12.10	84.20	29.7	35.2	97.60	309	538.68	639.52	-2.03
16/6/2012 15:08	6.72	12.10	84.30	29.6	35.3	97.55	308	540.32	662.44	-5.21
16/6/2012 15:09	6.71	12.20	84.20	29.5	35.4	97.50	309	550.71	685.33	-6.82
16/6/2012 15:10	6.70	12.40	84.10	29.4	35.2	97.55	310	571.10	674.06	-2.20
16/6/2012 15:11	6.70	12.60	84.10	29.4	35.5	97.65	308	591.14	709.65	-4.36
16/6/2012 15:12	6.71	12.50	84.20	29.5	35.4	97.60	309	580.81	686.03	-2.53
16/6/2012 15:13	6.72	12.30	84.30	29.6	35.3	97.55	310	560.41	662.44	-2.10
16/6/2012 15:14	6.73	12.10	84.20	29.7	35.2	97.50	311	538.68	638.86	-1.84
16/6/2012 15:15	6.74	12.20	84.10	29.8	35.1	97.55	312	547.05	615.95	3.22
16/6/2012 15:16	6.75	12.00	84.00	29.9	35	97.60	311	525.39	593.01	3.51
16/6/2012 15:17	6.74	12.30	84.10	29.8	35.1	97.65	310	557.07	616.58	4.64
16/6/2012 15:18	6.73	12.10	84.20	29.7	35.2	97.60	309	538.68	639.52	-2.03
16/6/2012 15:19	6.72	12.10	84.30	29.6	35.3	97.55	308	540.32	662.44	-5.21
16/6/2012 15:20	6.71	12.20	84.20	29.5	35.4	97.50	309	550.71	685.33	-6.82
16/6/2012 15:21	6.70	12.40	84.10	29.4	35.2	97.55	310	571.10	674.06	-2.20
Total							**6814**	**12,202.71**	**14,367.72**	**32.36**
	Total data count									**22**
	Data Count > +5% error									**0**
	Data Count < -5% error									**4**
	Percentage of heat balance within ± 5%									**82%**

Heat Gain (h) = m x Cp x ΔT = (c) x 4.19kJ/kg ^{o}C x [(b) – (a)] / 3.517

Heat Rejected (i) = (f) x 4.19 kJ/kg ^{o}C x [(e) – (d)] / 3.517

Percent Heat Balance (j) = 100 x [(g) / 3.517 + (h) – (i)] / (i)

(ii) VRF system

For new Variable Refrigerant Flow (VRF) systems or replacements, as well as air distribution systems serving a combined conditioned floor area of 2000m2 or more belongs to a single tenant or landlord, it is necessary to provide permanent measuring instruments to monitor energy performance of the VRF condensing units and air distribution systems.

Assessment Criteria

The installed instrumentation must have the capability to calculate the resultant system efficiency within 10% uncertainty. Each measurement system shall include sensors, any signal conditioning, data acquisition system and the wiring connecting these components.

The measurement systems provided shall also comply with the following requirement:

- Data logging with the capability to trend at 5-minute sampling time interval, recorded to at least one decimal place.
- Building management system (BMS), standalone energy monitoring system (EMS) shall have the capability to compute and display the overall system energy efficiency to facilitate data extraction for verification purpose.
- Dedicated power meters (of IEC Class 1 or better) and metering current transformers (of Class 1 or better) where applicable, are to be provided for all condensing units of the VRF system and air-distribution sub-systems (e.g. AHUs, PAHUs, FCUs).
- VRF Suppliers' in-house monitoring system is acceptable if it's capable of monitoring the system efficiency within 10% uncertainty.

Documentation Requirements

- ➢ Detailed schematic drawings of the instruments and sensor locations
- ➢ Technical specifications and/or sample data sheets/product information for instruments and meters
- ➢ Detailed drawings and schematics of the measurement strategies for the VRF system
- ➢ Purchase orders and delivery orders of the instrumentation installed

(iii) Buildings with DCS/DDC/CCS[4] supply requirement

Dedicated power meters (of IEC Class 1 or better) and metering current transformers, where applicable, of Class 1 or better, are to be provided for air distribution sub-system (i.e. AHUs, PAHUs, FCUs).

2. Electrical Sub-metering requirement

Referring to Sub-metering requirement of SS 553: 2016, table 13.

Sub-System for Metering	
People moving	Sum of all feeders > 50 kVA
Lighting	Connected load > 50kVA
Process and plug loads	Connected loads >50 kVA
Process loads	Connected gas or district services load > 75 kW

Note: The provision of sub-metering for chiller plant systems and VRF system are stated under the respective sections.

[4] DCS (District Cooling System), Distributed District Cooling (DDC), Centralised Cooling System (CCS): The supply of chilled water for cooling purpose from a central source to multiple buildings through a network of pipes. Individual users purchase chilled water from the district cooling system operator and do not need to install their own chiller plant other than air distribution system. This is different from buildings' in-house air-conditioning system, in part or in full, being maintained and operated by a third party.

3. Envelope Thermal Transfer

Minimising thermal heat gain through the building envelope can enhance indoor thermal comfort and reduce the energy needed to condition the indoor environment.

Assessment Criteria

As per the *BCA Code on Envelope Thermal Performance for Buildings*.

Applicable to new non-residential building façades.

Projects using ***Pathway 1 and 3***, ETTV shall be less than or equal to the stipulated value under the Code for Environmental Sustainability.

Projects using ***Pathway 2*** shall be less than or equal to the following maximum values:

Building Type	**Maximum ETTV (EE Pathway 2)**		
	Gold^{PLUS} EE >50%	**Platinum EE ≥55%**	**SLE EE ≥60%**
Office Buildings	40 W/m^2	38 W/m^2	38 W/m^2
Retail Mall	40 W/m^2	38 W/m^2	35 W/m^2
Hotel	40 W/m^2	40 W/m^2	40 W/m^2
MOE Primary and Secondary Schools	40 W/m^2	40 W/m^2	40 W/m^2
MOE Junior College	40 W/m^2	40 W/m^2	40 W/m^2
Private Schools	40 W/m^2	38 W/m^2	35 W/m^2
Institute of Higher Learning	40 W/m^2	38 W/m^2	38 W/m^2
Hospitals	40 W/m^2	38 W/m^2	38 W/m^2
Polyclinic	40 W/m^2	40 W/m^2	40 W/m^2
Nursing/ Youth Home	40 W/m^2	40 W/m^2	40 W/m^2
High Tech/High Intensity	40 W/m^2	38 W/m^2	38 W/m^2
Light Industrial	40 W/m^2	40 W/m^2	40 W/m^2
Warehouses/ Workshops/ Logistics/ Others	40 W/m^2	40 W/m^2	40 W/m^2
Community Buildings	40 W/m^2	38 W/m^2	38 W/m^2
Civic Buildings	40 W/m^2	38 W/m^2	38 W/m^2
Cultural Buildings	40 W/m^2	38 W/m^2	38 W/m^2
Sports and Recreation Centres	40 W/m^2	40 W/m^2	40 W/m^2
Religious/ Places of Worship	40 W/m^2	38 W/m^2	38 W/m^2
Workers' Dormitories	40 W/m^2	38 W/m^2	38 W/m^2
Other Non-Residential Buildings	40 W/m^2	40 W/m^2	40 W/m^2

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

- ETTV:

- Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant to the computation of ETTV
- Architectural plan layouts and elevations showing all the air-conditioned areas
- Sectional or elevation drawings showing the relevant shading devices
- Extracts of the tender specifications or material schedules showing the salient data of the material properties that are to be used for the façade or external wall system
- ETTV calculation in excel format

At Verification stage (New Buildings & Existing Buildings):

- ETTV:
  - Purchase orders/delivery orders for the brands/models of the glazing and external wall system, stipulating the relevant thermal conductivity, U-value and SC specifications, to demonstrate compliance with the committed building façade thermal performance
  - As-built drawings/documents showing the material properties of the façade and external walls
  - Revised ETTV calculation in the event of any design or material changes

Guidance Notes

Worked Example1

ETTV - Multiple blocks within the same development:

A proposed building development comprises three building blocks. The individual ETTV of the each building computed are as follows:

$$\left.\begin{array}{ll} ETTV_{bldg1} = 35\ W/m^2 & A_{bldg} = 5000\ m^2 \\ ETTV_{bldg2} = 45\ W/m^2 & A_{bldg} = 6800\ m^2 \\ ETTV_{bldg3} = 39\ W/m^2 & A_{bldg} = 7500\ m^2 \end{array}\right\} \begin{array}{l} A_{devt} = 5000 + 6800 + 7500 \\ \quad\quad = 19300\ m^2 \end{array}$$

Therefore

ETTV Weighted average

$$= \frac{\sum(ETTV_{bldg} \times A_{bldg})}{A_{dvpt}}$$

$$= \frac{(ETTV_{bldg1} \times A_{bldg1}) + (ETTV_{bldg2} \times A_{bldg2}) + (ETTV_{bldg3} \times A_{bldg3})}{A_{dvpt}}$$

$$= \frac{(35 \times 5000) + (45 \times 6800) + (39 \times 7500)}{19300}$$

$$= 40\ \mathrm{W/m^2}$$

Thus, the overall ETTV meets Gold^{PLUS} certification requirements for Office buildings.

Worked Example2

How to calculate the amount of on-site RE required to make up the ETTV shortfall.

A building X with designed ETTV of 43W/m2, but targeting GM Platinum rating with ETTV requirement of 38W/m2, how much on-site RE required to make up the shortfall:

Building X	Designed ETTV (W/m2) (A)	Targeting GM Platinum ETTV requirement (W/m2) (B)	Shortfall of ETTV (W/m2) (C=B-A)	Façade area with AC based (m2) (D)	Operation hours (55hr/week, 52weeks/yr) (E)	Cooling energy required to make up (F=CXDXE)/1000/3.517 (RTh)	Cooling system efficiency (kW/RT) (G)	Annual Electrical energy required to make up the ETTV shortfall (kWh) (H=FXG)	On site RE required to make up the ETTV shortfall(kWh/yr) (I=Hx 1.1)
Calculation	43	38	5	5,000	2,860	20,330	0.7	14,231	15,654

4. Residential Envelope Thermal Transmittance Value

To reduce air conditioning energy consumption to cool the indoor environment of residential building due to thermal heat gain through the building façade.

Assessment Criteria

Applicable to all new residential buildings .

The residential envelope thermal transmittance value (RETV) of the building, as determined in accordance with the formula set out in the "Code on Envelope Thermal Performance for Buildings" issued by the Commissioner of Building Control, shall not exceed the following:

Maximum RETV

Level of Award	RETV
Gold^{PLUS}	22W/m^2 or lower
Platinum	20W/m^2 or lower
SLE	20W/m^2 or lower

Applicable for all Award levels:
The Average RETV of west, south-west and north-west facades of all buildings within development should not exceed maximum RETV of 25W/m2.

Documentation Requirements

At Design stage:

Submission of the following:

- RETV calculation
- Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant for the computation of RETV
- Architectural plan layouts and elevations showing all the air-conditioning areas
- Extracts of the tender specification or material schedules showing the material properties of the façade and external walls.

At Verification stage

Submission of the following:

- Purchase orders/delivery orders of the façade and external wall system
- As-built material schedules showing the material properties of the façade and external walls
- Revised RETV calculation in the event of any design changes that negatively affect the RETV

5. Ventilation Performance (Dwelling Units/Area)

Enhance building design to achieve good natural ventilation for better indoor comfort and health for the building occupants.

Assessment Criteria

Applicable to all new residential buildings and Workers' Dormitory.

The units must meet the minimum requirement as stated below for the living rooms and bedrooms/dwelling area to achieve good levels of natural ventilation. There are 2 methods for demonstrating performance:

Criteria (Meet either one)	**Gold^{PLUS} EE >50%**	**Platinum EE ≥55%**	**SLE EE ≥60%**
(i) Option 1: Plan Level (By Layout and Unit Design)	The dwelling unit design is considered to have cross ventilation when there is an unobstructed air flow path between the openings on opposite sides of the building, or within a room on adjacent walls.		
	40% of living rooms and bedrooms/dwelling area with unobstructed air flow between spaces and the outside.	50% of living rooms and bedrooms/dwelling area with unobstructed air flow between spaces and the outside.	60% of living rooms and bedrooms/dwelling area with unobstructed air flow between spaces and the outside.
(ii) Option 2: Simulation and Modelling	Use of Ventilation simulation modelling to identify the most effective design and layout to achieve good natural ventilation.		
	Micro level CFD to be conducted which demonstrate that 40% of the typical units/dwelling area achieve area weighted average wind velocity of 0.4m/s. OR Where the wind speed cannot be met alone, conduct thermal comfort modelling which can include the use of ceiling fans, where supplied by the developer, to achieve a PMV of +/- 1.	Micro level CFD to be conducted which demonstrate that 50% of the typical units/dwelling area achieve area weighted average wind velocity of 0.4m/s. OR Where the wind speed cannot be met alone, conduct thermal comfort modelling which can include the use of ceiling fans, where supplied by the developer, to achieve a PMV of +/- 0.8.	Micro level CFD to be conducted which demonstrate that 60% of the typical units/dwelling area achieve area weighted average wind velocity of 0.6m/s. OR Where the wind speed cannot be met alone, conduct thermal comfort modelling which can include the use of ceiling fans, where supplied by the developer, to achieve a PMV of +/- 0.6.

NOTE –

i. *The main entrance door (where the developer provides a lockable gate /grille*), all windows and internal doors are assumed to be open for both Option 1 & Option 2.*

* *The provision of grilles or gates for the main entrance is allowed provided:*

- *The gate swing does not obstruct public escape.*
- *Units situated along a common corridor must allow a minimum clearance of 1 m from the gate to the wall when gates are opened perpendicularly.*
- *Gates must not obstruct or hit neighbouring apartments windows or doors.*
- *The main door should be fire rated and complete with a self-closing device. This is true for HDB and private residential projects, as such, provided the unit design provides adequate space for the grilles/gates as above. The QP should consult SCDF as the fire code is a live document and subject to amendments.*

ii. *Dedicated power points provision should be provided to enable the installation of ceiling fans in the living room if using Option 1*
iii. *Ceiling fans,(as required by the Thermal Comfort modelling)should be provided by the developer for all the dwelling units within the development if using ceiling fans to comply with Option 2.Homeowners will have the choice to opt out of ceiling fans if they wish to do so.*
iv. *Simulations are to be conducted in accordance with the Green Mark 2021 Guideline for Computational Fluid Dynamics (CFD) Simulation. PMV recognises the use of assisted ventilation where this is provided once minimum wind speeds are met.*

Option 1: Plan Level (By Layout and Unit Design)

Enhance building design to achieve good natural ventilation for better indoor comfort through effective building layout and unit design.

Documentation Requirements

<u>At Design Stage:</u>

Submission of the following where applicable:

- Schedules showing the total number of living rooms and bedrooms/dwelling area in the development and those with true cross ventilation.
- Calculation showing the percentage of living rooms and bedrooms of dwelling units/area with true cross ventilation

<u>At Verification Stage:</u>

Submission of as built drawings of the approved floor plans.

Guidance Notes [example residential units]

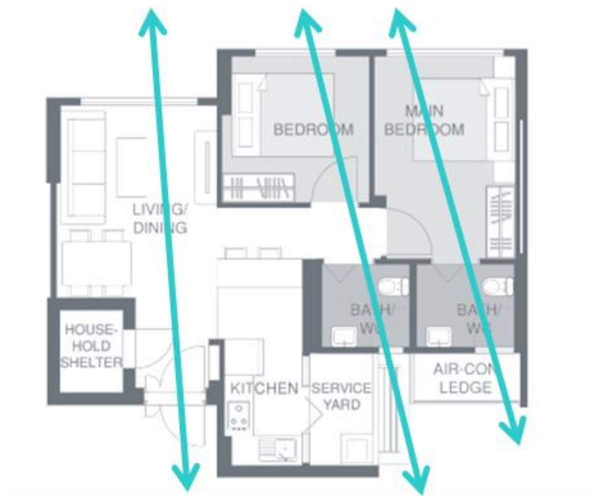
Dwelling unit design is considered to have true cross ventilation when there is a reasonably unobstructed air flow path between the windows or vents on opposite sides of the building. For this requirement, the main entrance door (where the developer provides a lockable gate /grille), all windows and internal doors are assumed to be open.

Illustrations on dwelling unit design that facilitates true cross ventilation

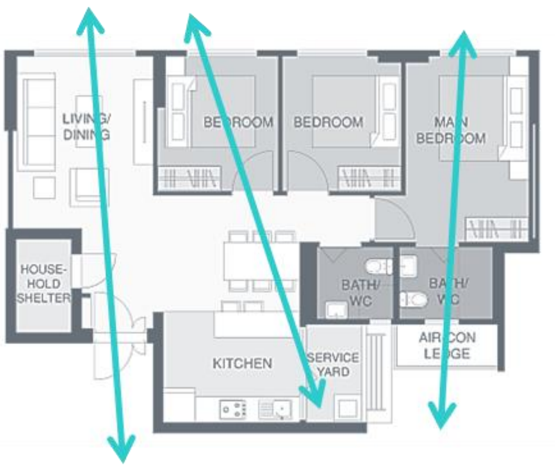
<u>Illustration –</u> Dwelling unit layout showing that both living room and bedrooms are considered to have true cross ventilation and meet the requirement (i) Option 1: Plan Level (By Layout and Unit Design)

Worked Example

Only living room is considered to have true cross ventilation. Bedroom do not meet the requirement.



Both the living room and all Bedrooms are considered to have true cross ventilation.



Both the living room and two of the Bedrooms are considered to have true cross ventilation. One of the bedrooms does not meet the requirement.

Only the living room and main bedroom is considered to have true cross ventilation. Common Bedrooms do not meet the requirement.

Dwelling Unit Design

Percentage of rooms with true cross ventilation

Unit Type	Total Number of Units (a)	Total number of living & bedroom per unit	Living room with true cross vent (b)	Bedroom with true cross vent (c)	Total living & bedroom with true cross vent (b+c)x(a)	Total number of living & bedrooms
2 Room	716	2	1	0	716	1432
3 Room	98	3	1	2	294	294
4 Room	501	4	1	2	1503	2004
5 Room	230	5	1	2	690	1150
Total	1545				3203	4880
Percentage of living rooms and bedrooms with true cross ventilation					65.64%	

Hence the dwelling unit meets the SLE requirement using (i) Option 1: Plan Level (By Layout and Unit Design).

Option 2: Simulation and Modelling

To encourage the design for effective natural ventilation for thermal comfort, indoor environmental quality for all dwelling units.

Documentation Requirements

At Design Stage:

Refer to the design stage Documentation Requirements as outlined in the Green Mark 2021 Guideline on Computational Fluid Dynamics (CFD) Simulation.

At Verification Stage:

Refer to the Verification stage Documentation Requirements as outlined in the Green Mark 2021 Guideline on Computational Fluid Dynamics (CFD) Simulation.

Guidance Notes

The simulation and modelling should be done in accordance with the requirements as provided in the Green Mark 2021 Guideline on Computational Fluid Dynamics (CFD) Simulation - Ventilation simulation for Residential projects.

Or

Thermal Comfort Modelling

The Thermal Comfort Modelling should be done in accordance with the requirements as provided in the Green Mark 2021 Guideline on Computational Fluid Dynamics (CFD) Simulation - Ventilation simulation for Residential projects (Thermal comfort modelling for units). The project team can further demonstrate meeting the thermal comfort criteria through mechanically assisted ventilation.

Worked Example

Example 1

A residential development with one block of 20-storey apartments comprises 200 units with 7 typical dwelling unit layouts or types.

The development conducted step 1 ventilation simulation modelling for the development. Based on step 1 ventilation simulation results, the development cannot meet the primary evaluation parameters. Step 2 ventilation simulation modelling for units was conducted and based on the ventilation simulation results, the total number of units for each typical dwelling unit type and its corresponding area-weighted average wind velocity are as tabulated below.

Dwelling unit layouts/ types		No. of units	Area weighted average wind velocity
1	Typical layout A	80	0.20
2	Typical layout B	30	0.30
3	Typical layout C	20	0.40
4	Typical layout D	20	0.20
5	Typical layout E	20	0.30
Total number of selected units:		170	
6	Typical layout F*	15	Not included
7	Typical layout G*	15	Not included

* Dwelling unit layout not selected for simulation

Percentage of units achieving good natural ventilation is given by

$$\frac{\sum \text{(No. of Selected Units for Each Layout x Area-Weighted Average Wind Velocity) x 100\%}}{\text{Total Number of Selected Units X 0.4m/s}}$$

$$= \frac{80 \times 0.20 + 30 \times 0.30 + 20 \times 0.40 + 20 \times 0.20 + 20 \times 0.30 \times 100\%}{170 \times 0.40}$$

$$= 63\%$$

63% of the dwelling units meets 0.4m/s, hence it meets the Platinum requirement using (ii) Option 2: Simulation and Modelling.

6. Ventilation Performance (Common Areas)

The internal spatial organisation of a building provides opportunities to improve the operational efficiency of the building over its entire life. Strategic decision-making including the location of transient spaces have lasting effects on the building's performance.

Assessment Criteria

Applicable to all new and existing residential (non-landed) buildings and workers' dormitory

Criteria	**Gold^{PLUS} EE >50%**	**Platinum EE ≥55%**	**SLE EE ≥60%**
Common spaces to be designed with Passive strategies	All above ground lobbies and corridors are to be naturally ventilated		

Documentation Requirements

At Design Stage:

Submission of the following where applicable:

- Plans and details of the common spaces including façade openings and ventilation modes

At Verification Stage:

- Submission of as built drawings of the approved spaces

7. Non-Air-conditioned Areas (Non-Residential Buildings)

Assessment Criteria

For Projects under ***Pathway 2***. the total non-air-conditioning areas shall at a minimum meet the following thresholds:

Building Type	**Minimum Non AC Areas**		
	Gold^{PLUS} EE >50%	**Platinum EE ≥55%**	**SLE EE ≥60%**
Office Buildings	-	10%	25%
Retail Mall	-	5%	15%
Hotel	-	10%	30%
MOE Primary and Secondary Schools	30%	50%	70%
MOE Junior College	20%	40%	60%
Private Schools	-	20%	40%
Institute of Higher Learning	-	20%	50%
Hospitals	-	-	15%
Polyclinic	10%	30%	50%
Nursing/ Youth Home	10%	40%	60%
High Tech/High Intensity	-	-	10%
Light Industrial	-	15%	30%
Warehouses/ Workshops/ Logistics/ Others	-	30%	40%
Community Buildings	10%	30%	40%
Civic Buildings	-	15%	30%
Cultural Buildings	-	10%	20%
Sports and Recreation Centres	-	15%	30%
Religious/ Places of Worship	-	15%	25%
Workers' Dormitories	70%	80%	90%
Other Non-Residential Buildings	-	30%	40%

Documentation Requirements

<u>At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):</u>

Submission of the following where applicable:

- Architectural plan layouts showing all the air-conditioned and non-air-conditioned areas.
- Calculation showing the percentage of non-air-conditioned areas.

<u>At Verification stage (New Buildings & Existing Buildings):</u>

Submission of as built drawings of the approved floor plans and percentage of non-air-conditioned areas.

Guidance Notes

The definition of non-air-conditioning area follows the URA's GFA guidelines. If a particular non-air-conditioning area is counted as GFA as per URA's GFA guidelines, it should be included in the non-air-conditioning area calculation. The percentage of non-air-conditioning area will be the non-air-conditioned area (by GFA definition) divided by the total GFA.

Worked Example 1

Office Building:

Description	Mode of ventilation	GFA (m2)
Open Office	AC	3000
Meeting Rooms	AC	100
Corridors	NV	500
Internal Stairs	MV	300
Lift Lobbies	AC	500
Toilets	MV	150
M&E Space	MV	Non-GFA
Car park	NV	Non-GFA
Total GFA		**4550**
% of Non-AC Areas		**21%**

Hence it meets the Platinum requirement for office buildings under ***Pathway 2.***

Worked Example 2

The same building as example 1, this building's average cooling load is 70W/m2, its cooling system efficiency is 0.68kW/RT, the operation hours is 8hrs/per day and 5day/week, it is targeting SLE (non-aircon area of 25%) using on-site RE to make up the shortfall of non-aircon area.

The calculation of on-site RE required:

This building's average cooling load/m2 x the shortage of non-aircon area (m2) X its cooling system efficiency X its operation hours X safety factor of 1.1

= (70W/m2/3.517/1000) x [4550 x (25%-21%)]m2 x 0.68kW/RT x 8hrs x 5days x 52 weeks x 1.1

= 5,635.9kWh

8. Air Conditioning Total System Efficiency (Non-Residential Buildings)

Applicable to all air-conditioning system serving the building's cooling needs.

Assessment Criteria

For Pathway 1 & 3 Total System Efficiency (TSE) shall not exceed the limits stated below:

	New Building	Existing Building
AC TSE	0.8	0.9

For Pathway 2 The Total System Efficiency (TSE) shall not exceed the limits stated below:

Building Type	Total System Efficiency (kW/RT)		
	Gold^{PLUS} EE >50%	Platinum EE ≥55%	SLE EE ≥60%
Office Buildings	0.8	0.74	0.68
Retail Mall	0.8	0.74	0.68
Hotel	0.8	0.74	0.68
MOE Primary and Secondary Schools	0.8	0.75	0.7
MOE Junior College	0.8	0.75	0.7
Private Schools	0.8	0.75	0.7
Institute of Higher Learning	0.8	0.74	0.68
Hospitals	0.8	0.75	0.7
Polyclinic	0.8	0.75	0.7
Nursing/ Youth Home	0.8	0.75	0.7
High Tech/High Intensity	0.8	0.78	0.75
Light Industrial	0.8	0.75	0.7
Warehouses/ Workshops/ Logistics/ Others	0.8	0.75	0.7
Community Buildings	0.8	0.75	0.7
Civic Buildings	0.8	0.75	0.7
Cultural Buildings	0.8	0.75	0.7
Sports and Recreation Centres	0.8	0.75	0.7
Religious/ Places of Worship	0.8	0.75	0.7
Workers' Dormitories	0.8	0.75	0.7
Other Non-Residential Buildings	0.8	0.75	0.7

For buildings with different types of air conditioning systems, the efficiency shall be weighted based on the collective efficiencies of the different air-conditioning systems used within the building. For new development, TSE is based on the expected part-load condition over the simulated average annual total cooling load profile for chilled-water systems, and total weighted system efficiency for unitary systems. For existing building, TSE should be based on the average annual total cooling load profile.

Operational design cooling load: The operational building cooling load profile shall be simulated for one whole year to generate the average cooling load over the building's operational hours for one day in RTh. The annual cooling system efficiency shall be computed based on the following operational hours:

Building Type	Operational Hours
Office Buildings	9 a.m. to 6 p.m. (Monday to Friday)
Retail Malls	10 a.m. to 10 p.m.
Hotels	24 hours
Other Building Types	To be determined based on operating hours

Note1: if the load beyond the standard operating hours exceeds 100RT, it must be included in the TSE efficiency calculation for compliance. For example, if the night load is greater than 100RT, it must be included in TSE calculation.

Note2: Airside pressure drop adjustment is allowed for: 1) MERV14-16 filters; 2) full return air duct; 3) HEPA filters with document proof. Please see Example 5 on air side pressure drop adjustment.

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

Submission of the following where applicable:

Drawings/layout showing:

- Proposed building cooling system (for new cooling systems) ➢ mode of ventilation of spaces ➢ location of the plant room and cooling towers
- Technical specifications and product information of the various components of the cooling system (for new cooling systems) and air distribution system designed and installed
- Part-load performance curves, pump head (for pumps of new cooling systems) and fan static pressure calculations
- Detailed calculations of fan input power for each PAU, AHU and FCU in the building based on operational design load
- Detailed calculations of the TSE that include the cooling load profile in the prescribed format as shown in the worked examples

At Verification stage (New Buildings & Existing Buildings):

Submission of the following where applicable:

- Area and operating hours of the spaces served by the air-conditioning system
- Compliance with verification requirements under P.14 Permanent Instrumentation for the Measurement and Verification of Water-Cooled Chilled Water Plant where applicable
- Chilled-water plants: Completed Energy Audit Report endorsed by PE(Mechanical) or Energy Auditor including the power for the air distribution system detailing the total operational performance measured over a 1-week period. (The Report template may be found at https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/annexb_energy_audit_report.doc)
- Unitary/split systems: energy consumption of the unitary systems

Guidance Notes

Unitary Air-Conditioning System

TSE = Unitary Cooling Equipment Efficiency + Air Distribution Efficiency

The unitary cooling efficiency component of the TSE (excluding the air distribution components) is computed based on the total weighted system efficiency. The formula used is 3.517/ IEER. For variable refrigerant flow (VRF) system, the efficiency should be based on normal design dry-bulb temperature of 24 ± 1°C and relative humidity RH ≤ 65%. The efficiency can be computed based on the full installed capacity of outdoor condensing units or part-load efficiency of the system. Where there are more than one most frequent occurring part-load conditions for the building operation hours specified, the efficiency shall be based on the worst-case scenario.

System Zone: Each system zone shall be simulated. A system zone is the internal area served by a singular unitary system which is determined by the condenser unit and the connected fan coil units/ air handling units.

Integrated Energy Efficiency Ratio **(IEER)** = (0.020 x A) + (0.617 x B) + (0.238 x C) + (0.125 x D)

where A = COP at full load cooling capacity, B = COP at 75% part-load cooling capacity,

C = COP at 50% part-load cooling capacity, D = COP at 25% part-load cooling capacity.

Weighted Operational Cooling Load: $RT_{weighted}$ refers to the weighted operational cooling load of the unitary system in RTh. It is calculated based on the operational schedule of the systems as follows:

$$RT_{weighted} = 0.02 \times RT100\% + 0.617 \times RT75\%\ RT100\% + 0.238 \times RT50\% + 0.125 \times RT25\%$$

Where RT100%, RT75%, RT50% and RT5% are the 100%, 75%, 50% and 25% of installed capacity of the zone (excluding standby units) respectively.

Water-Cooled/ Air-Cooled Chilled Water Plants

TSE = Chiller Plant Efficiency + Air Distribution Efficiency

TSE is computed based on the annual energy consumption (kWh) of the system over the annual cooling consumption in RTh. The unit is in kW/RT.

Worked Example

Example 1: Computation of the TSE for a theoretical office building which has a water-cooled chilled water system. The operating hours for office buildings as specified: Monday to Friday: 9 am. to 6 pm.

(a) Water Cooled Chilled Water System

- Average Cooling Load;
- Chiller Power input (P_{CH});
- Chilled Water Pump Power (P_{CHWP});
- Condenser Water Pump Power (P_{CWP});
- Cooling Tower Power (P_{CT})

Total Constant flow (CF) or Variable Flow (VF) Motor Input Power (total hourly motor input power is based on the aggregate of all constant or variable flow fans operating at this hour.

For Variable flow, Part-load pump and cooling tower fan power can be calculated by using the following formulae:

Pump power ratio = $0.0205x + 0.4101x^2 + 0.5753x^3$, where x is the part-load ratio

Cooling tower fan power ratio = $0.331629 - 0.885676x + 0.605565x^2 + 0.948482x^3$

Hrs	Water Cooled Chiller Plant							
	Daily Avg. Cooling Load (RT)	**P_{CH} (kW)**	**P_{CHWP} (kW)**	**P_{CWP} (kW)**	**P_{CT} (kW)**	**Chiller Plant Total Power (kW)**	**Chiller Plant (kW/RT)**	**Chiller configuration**
9AM	1,444	660	33	60	24	776	0.538	650 RT x 3 nos.
10AM	1,395	634	30	60	21	745	0.534	650 RT x 3 nos.
11AM	1,801	841	57	67	47	1,011	0.561	650 RT x 3 nos.
12PM	1,790	835	56	66	46	1,002	0.560	650 RT x 3 nos.
1PM	1,749	807	53	62	43	964	0.551	650 RT x 3 nos.
2PM	1,836	859	60	70	50	1,038	0.565	650 RT x 3 nos.
3PM	1,816	849	58	68	48	1,023	0.563	650 RT x 3 nos.
4PM	1,654	757	46	54	36	892	0.539	650 RT x 3 nos.
5PM	1,493	686	35	60	26	808	0.541	650 RT x 3 nos.
6PM	1,237	574	22	60	15	672	0.543	650 RT x 3 nos.
Total (9AM - 6PM)	ΣCL =16,215 RTh	7,502 kWh	450 kWh	627 kWh	356 kWh	8,931 kWh		
Efficiency (kW/RT)		0.463	0.028	0.039	0.022	kWh/RTh = 0.551 kW/RT		

Plant efficiency = Σ(chiller plant energy power consumption)/Σ(cooling load) = 8,931/16,215 = 0.551 kW/RT

Air distribution and total system efficiency

Fraction of full-load fan power = 0.0013 + 0.1470x + 0.9506x^2 - 0.0998x^3, where x is the part-load ratio (Ratio of current L/s against design L/s)

Hrs	Daily Avg. Cooling Load (RT)	Total air distribution power (kW)	Air distribution efficiency (kW/RT)	Air Distribution configuration (VAV/CAV)	Total system power (water+air) (kW)	TSE (kW/RT)
9AM	1,444	236	0.164	AHU-VAV	1,013	0.701
10AM	1,395	223	0.160	AHU-VAV	968	0.694
11AM	1,801	348	0.193	AHU-VAV	1,359	0.754
12PM	1,790	344	0.192	AHU-VAV	1,346	0.752
1PM	1,749	330	0.189	AHU-VAV	1,294	0.740
2PM	1,836	360	0.196	AHU-VAV	1,398	0.761
3PM	1,816	353	0.194	AHU-VAV	1,376	0.758
4PM	1,654	300	0.181	AHU-VAV	1,192	0.721
5PM	1,493	251	0.168	AHU-VAV	1,058	0.709
6PM	1,237	181	0.146	AHU-VAV	852	0.689
Total (9AM - 6PM)	16,215	2,924			11,856	

Air distribution system efficiency = Σ(Air distribution power consumption)/ Σ(cooling load)
= 2,924/16,215
= 0.18 kW/RT

TSE = 0.551 + 0.18 = 0.731 kW/RT
Thus, this office building meets TSE requirement for Pathway 1 & 3
For Pathway 2 would meet GM Platinum rating

Example 2: Computation of the TSE for a theoretical small office building which uses VRF system. The operating hours for office buildings as specified: Monday to Friday: 9 am. to 6 pm.

System no.	**Zone**	**Location served**	**Specification of VRF Outdoor Condensing Unit**						**IEER = (0.020 x A) + (0.617 x B) + (0.238 x C) + (0.125 x D)**
			Full Installed Capacity (kW)	**Weighted Cooling Capacity (kW)**	**100% EER (A)**	**75% EER (B)**	**50% EER (C)**	**25% EER (D)**	
VRF System 1	1	Lift lobby/ Corridor/ Reception	21.62	13.69	3.93	5.02	5.66	3.02	4.90
VRF System 2	2	Office 1	15.44	9.77	4.74	6.06	7.57	4.81	6.24
VRF System 3	3	Office 2	15.44	9.77	4.74	6.06	7.57	4.81	6.24
VRF System 4	4	Office 3	15.44	9.77	4.23	5.29	5.86	3.86	5.23
VRF System 5	5	Office 4	15.44	9.77	4.23	5.29	5.86	3.86	5.23
Total cooling capacity			83.38	52.8					

Weighted Design COP of condensing units = Σ(weighted capacity x IEER)/ Σ(weighted capacity)

= 291.12/52.8

= 5.52

Weighted Design system efficiency of condensing units = 3.517/ Weighted design COP

= 0.64 kW/RT

Air distribution system efficiency of VRF system

System no.	**Zone**	**Location served**	**Specification of Air-Distribution Units**				**Air-Distribution System efficiency based on weighted capacity (kW/RT)**
			Unit Type	**Installed Capacity (kW)**	**Weighted Capacity (kW)**	**Nameplate motor power (kW)**	
VRF System 1	1	Lift lobby/ Corridor/ Reception	Ceiling Cassette	7.1	4.49	0.08	0.063
				7.1	4.49	0.08	0.063
				7.1	4.49	0.08	0.063
VRF System 2	2	Office 1	Ceiling Cassette	7.6	4.81	0.12	0.088
				7.6	4.81	0.12	0.088
VRF System 3	3	Office 2	Ceiling Cassette	7.6	4.81	0.12	0.088
				7.6	4.81	0.12	0.088
VRF System 4	4	Office 3	Ceiling Cassette	7.6	4.81	0.12	0.088
				7.6	4.81	0.12	0.088
VRF System 5	5	Office 4	Ceiling Cassette	7.6	4.81	0.12	0.088
				7.6	4.81	0.12	0.088
Total cooling capacity				82.1	51.95 kW or 14.77 RT	1.2	

Air distribution system efficiency = Σ(Air distribution power consumption)/ Σ(cooling load in RT)

= 1.2/14.77

= 0.081 kW/RT

Total System Efficiency (TSE) of VRF systems = 0.64 + 0.081 kW/RT = 0.721 kW/RT

Thus, this office building meets TSE requirement for pathway 1&3
For Pathway 2 would meet GM Platinum rating

Example 3: Computation of the TSE for a theoretical office building which has both water-cooled chilled water system and VRF system. The operating hours for office buildings as specified: Monday to Friday: 9 am. to 6 pm.

Based on the same building air conditioning system in example 1 & 2

Assume that the VRF systems are operated throughout the standard operating hours, i.e. 9am to 6am

Total RTh of VRF systems = 14.77 RT x 10 hr = 147.7 RTh per day

System	**Design cooling load (RTh) (A)**	**TSE in kW/RT (B)**	**(A) X (B)**
Water cooled chilled water system	16,215	0.731	11,853.2
VRF systems	147.7	0.721	106.49
Total	16,362.7		11,959.69

Combined TSE of air conditioning systems = 11,959.69/16,362.7 = 0.73 kW/RT

Thus, this office building meets TSE requirement for pathway 1&3
For Pathway 2 would meet GM Platinum (0.74kW/RT) rating.

Example 4: Computation of the TSE for a theoretical office building which has a water-cooled chilled water system. The operating hours for office buildings as specified: Monday to Friday: 8 am. to 9 pm (there is cooling load beyond standard office building operating hour and it is higher than 100 RT)

Hrs	**Water Cooled Chiller Plant**							
	Daily Avg. Cooling Load (RT)	**P_{CH} (kW)**	**P_{CHWP} (kW)**	**P_{CWP} (kW)**	**P_{CT} (kW)**	**Chiller Plant Total Power (kW)**	**Chiller Plant (kW/RT)**	**Chiller configuration**
0 to 7 AM	0	0	0	0	0	0	0	0
8AM	175	130	6.25	7.39	4.76	148	0.848	250 RT x 2 nos.
9AM	317	155	7.14	8.44	7.66	178	0.562	250 RT x 2 nos.
10AM	362	165	9.86	11.66	11.03	198	0.546	250 RT x 2 nos.
11AM	375	165	10.76	12.71	12.24	201	0.535	250 RT x 2 nos.
12PM	378	165	10.97	12.96	12.54	201	0.533	250 RT x 2 nos.
1PM	370	165	10.41	12.30	11.77	199	0.539	250 RT x 2 nos.
2PM	380	165	11.11	13.13	12.74	202	0.532	250 RT x 2 nos.
3PM	382	165	11.26	13.31	12.94	203	0.530	250 RT x 2 nos.
4PM	375	165	10.76	12.71	12.24	201	0.535	250 RT x 2 nos.
5PM	372	165	10.55	12.46	11.96	200	0.538	250 RT x 2 nos.
6PM	360	165	9.73	11.50	10.86	197	0.547	250 RT x 2 nos.
7PM	232	110	9.15	10.82	4.76	135	0.581	250 RT x 1 nos.
8PM	194	90	5.85	6.91	4.76	108	0.554	250 RT x 1 nos.
9PM	142	75	6.25	7.39	2.97	92	0.645	250 RT x 1 nos.
10 to 11 PM	0	0	0	0	0	0	0	0
Total (8AM - 9PM)	ΣCL= 4,414 RTh	2,045 kWh	130 kWh	154 kWh	133 kWh	2,462 kWh		
Efficiency (kW/RT)		0.463	0.029	0.035	0.03	kWh/RTh = 0.557 kW/RT		

Plant efficiency = Σ(chiller plant energy power consumption)/Σ(cooling load)

= 2,462/4,414 = 0.557 kW/RT

Air distribution and total system efficiency

Fraction of full-load fan power = $0.0013 + 0.1470x + 0.9506x^2 - 0.0998x^3$, where x is the part-load ratio (Ratio of current L/s against design L/s)

Hrs	Daily Avg. Cooling Load (RT)	total air distribution power (kW)	Air distribution efficiency (kW/RT)	Air Distribution configuration (VAV/CAV)	Total system power (water+air) (kW)	TSE (kW/RT)
0 to 7 AM	0	0	0	0	0	0
8AM	175	31.50	0.180	AHU-VAV	179.9	1.028
9AM	317	47.37	0.149	AHU-VAV	225.6	0.712
10AM	362	59.65	0.165	AHU-VAV	257.2	0.711
11AM	375	63.44	0.169	AHU-VAV	264.1	0.704
12PM	378	64.32	0.170	AHU-VAV	265.8	0.703
1PM	370	61.97	0.167	AHU-VAV	261.4	0.707
2PM	380	64.92	0.171	AHU-VAV	266.9	0.702
3PM	382	65.52	0.172	AHU-VAV	268.0	0.702
4PM	375	63.44	0.169	AHU-VAV	264.1	0.704
5PM	372	62.55	0.168	AHU-VAV	262.5	0.706
6PM	360	59.08	0.164	AHU-VAV	256.2	0.712
7PM	232	31.50	0.136	AHU-VAV	166.2	0.717
8PM	194	31.50	0.162	AHU-VAV	139.0	0.717
9PM	142	31.50	0.222	AHU-VAV	123.1	0.867
10 to 11 PM	0	0	0	0	0	0
Total (8AM - 9PM)	ΣCL =4,414 RTh	738 kWh			3,200 kWh	

Air distribution system efficiency = Σ(Air distribution power consumption)/ Σ(cooling load)
= 738/4,414
= 0.167 kW/RT

TSE for chiller system = 0.557 + 0.167 = 0.724 kW/RT

Thus, this office building meets pathway 2 TSE requirement of 0.74 kW/RT for GM Platinum rating.

Example 5: Air side pressure drop adjustment

The baseline for pressure adjustment is the MERV13 filter pressure. If using MERV14-15 filters, a 100Pa adjustment can be used. For other situations, such as when using MERV16 filters or when dealing with a full return air duct, the adjustment method outlined in SS553 should be referred and evaluated on a case-by-case basis. It's important to note that pressure drop adjustments should only be applied to items that are installed beyond the standard air distribution design.

AHU	Description	CMH	Input kW	Proposed W/CMH	Baseline W/CMH [b]	Additional pressure drop over MERV 13	Adjusted W/CMH [b + A] where A = (Sum of PD)/2340	Baseline Power	Adjusted Power
AHU 1	Use of MERV 13 filter	20000	10.5	0.53	0.58	0	0.58	11.6	11.6
AHU 2	Use of MERV 13 filter	20000	10.5	0.53	0.58	0	0.58	11.6	11.6
AHU 3	Use of MERV 13 filter	20000	10.5	0.53	0.58	0	0.58	11.6	11.6
AHU 4	Use of MERV 14 filter	15000	9	0.60	0.58	100	0.623	8.7	9.3
AHU 5	Use of MERV 14 filter	15000	9	0.60	0.58	100	0.623	8.7	9.3
AHU 6	Use of MERV 14 filter	15000	9	0.60	0.58	100	0.623	8.7	9.3
AHU 7	Use of MERV 14 filter	15000	9	0.60	0.58	100	0.623	8.7	9.3
AHU 8	Use of MERV 16 filter and fully ducted return	30000	20	0.67	0.58	230*	0.678	17.4	20.3
AHU 9	Use of MERV 16 filter and fully ducted return	30000	20	0.67	0.58	230*	0.678	17.4	20.3
AHU 10	Use of MERV 16 filter and fully ducted return	30000	20	0.67	0.58	230*	0.678	17.4	20.3
	Total	210000	127.5					121.8	133.2
		kW/RT	0.255					0.244	0.266
		Delta kW/RT	0.023						

*example only

Revised baseline for new development	= baseline + delta kW/RT = 0.80kW/RT + 0.023kW/RT = 0.823kW/RT

Revised baseline for Existing building	= baseline + delta kW/RT = 0.90kW/RT + 0.023kW/RT = 0.923kW/RT

Example 6 Offset TSE by renewables*

Office building, with target rating of SLE, achieving TSE at 0.72kW/RT instead of required 0.68kW/RT. The shortfall is 0.04kW/RT. Assuming the annual RTh/yr is 2 x 10^6 RTh/yr.
Offset required
= Shortfall in kW/RT x annual RTh/yr x safety factor
= 0.04kW/RT x (2 x 10^6)RTh/yr x 1.1 (safety factor for office)
= 88,000kWh/yr

Assuming 3.5 peak sun hour per day
Solar panel required
= Offset required / [peak sun hour x 365 days/yr]
= (88,0000kWh/yr) / (3.5h x 365 days/yr)
= 69 kWp

*The above example for reference only. Designer to ensure sufficient buffer catered to cater for operational changes and weather conditions. Local Renewable Energy Certificates (REC) and offsite renewables are not allowed to offset first 60% energy saving (SLE) and beyond zero energy, such as positive energy building.

9. Air Conditioning System Efficiency (Residential Buildings)

The use of energy efficient, appropriately sized and designed air-conditioning system can reduce energy consumption.

Assessment Criteria

All air conditioned area.

Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
4 Ticks	5 Ticks	

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

- Architectural plan layouts showing all the air-conditioning areas and unit types
- Number of air-conditioning system and the respective energy label with reference to the dwelling units.

At Verification stage (New Buildings & Existing Buildings):

- Site photo of outdoor unit showing the respective energy label

Guidance Notes

Worked Example

A 20-storey residential development comprising of 280 units, club house, guard house and gym as the following ACMV schedule

Type of Rooms	Number of Dwelling Units	4 Ticks Air - Conditioners	5 Ticks Air -Conditioners
Type 1 – 1 room	10		10
Type 2 – 2 rooms	10		10
Type 3 – 3 rooms	10		10
Type 4 – 4 rooms	230		230
Type 4a – 4 rooms	20		20
Club & Guard		3	
Gym		2	

Number of air-conditioning system = 285 units

Number of air-condition system with 5 tick = 280 units

Only 98% of the dwelling units & common area are provided with 5 ticks air conditioning system. Hence the overall development only meets GM Gold^{PLUS} rating requirement.

10. Energy Efficient Dwelling Unit Equipment Selection (Residential Buildings)

Encourage the use of Energy Efficient Equipment in dwelling units that have a positive environmental impact in terms of energy savings.

Assessment Criteria

All new residential buildings with applicable electrical appliances* that are provided by the developer/MCST within all dwelling units and common areas.
For Existing Developments, this includes only Common Areas.
** Applicable electrical appliances include all appliances that are under the NEA's Energy Labelling scheme*

PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Energy Efficient Dwelling Unit Equipment Selection	3 Tick or the highest tick available		5 Tick or the highest tick available

Documentation Requirements

<u>At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):</u>

- Computation on the number of applicable electrical appliances and the respective energy label with reference to the dwelling units.

<u>At Verification stage (New Buildings & Existing Buildings):</u>

- Delivery orders of the applicable electrical appliances and the receptive energy label according to unit types.

11. Vertical Transportation System

To adopt energy efficient vertical transportation to reduce their energy consumption.

Assessment Criteria

Requirement for ***Pathway 2*** for all lifts and escalators in residential building developments. For existing residential building developments, this requirement is applicable upon replacement of lift and escalators.

Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
VVVF and Sleep Mode		VVVF & Sleep Mode Regenerative drive for 12 storeys or more

Documentary Requirements

<u>At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):</u>

- Submission of extracts of specification that indicate the types of lifts and related features used.

<u>At Verification stage (New Buildings & Existing Buildings):</u>

- Site photo of installed lifts and handover document product catalogue indicating the VVVF motor drive and sleep mode features.

12. Lighting Power Budget

Energy efficient lighting with adequate control strategies require less energy to illuminate a space.

Assessment

For Non-Residential Building Developments: Applicable to new and existing non-residential buildings interior lighting and landscape lighting, including tenant lighting provision and carpark lighting. Emergency lighting shall be excluded from the calculation.

For Residential building Developments: Applicable to new and existing residential buildings common areas and facilities such as staircase, corridors, lobbies, indoor carpark, landscape area, gym, function room etc and landscape lighting. Emergency lighting shall be excluded from the calculation.

For Pathway 1&3 The maximum Lighting power budget for artificial lighting shall be less than or equal to the maximum stated in SS 530 (column D).

For Pathway 2[5]- the maximum lighting power budget for artificial lighting shall comply with Table 2A.

TABLE 2A

Description	Pathway 2 - LPB Requirements (W/m2)			D SS 530 Reference Lighting Power Budget
	A Gold^{PLUS} EE >50%	B Platinum EE ≥55%	C SLE EE ≥60%	
	Office, Work and Study			
Offices	*6*	*5.5*	*5*	*12*
Meeting Room	*6*	*5.5*	*5*	*12*
Copy/Print Rooms	*6*	*5.5*	*5*	*12*
Classrooms	*6*	*5.5*	*5*	*12*
Lecture Theatre	*6*	*5.5*	*5*	*12*
Computer Rooms	*6*	*5.5*	*5*	*12*
Reading Areas	*6*	*5.5*	*5*	*12*
Laboratories	*8*	*7*	*6*	*16*
	Atria, Halls and Retail			
Entrance Hall	*6*	*5*	*4*	*10*
Atriums	*6*	*5*	*4*	*10*
Retail Atriums	*6*	*5*	*4*	*10*

[5] For new buildings under pathway 2, the tenanted space must comply with the lighting power budget (LPB) requirement as defined by the landlord in the Green Lease requirement.
For Existing building under pathway 2, the landlord may impose a Green Lease upon lease renewal or the next interior retrofit. In addition to the Green Lease, the LPB of the lighting in the existing tenants' areas must comply with GM: 2021 requirements, including the replacement of lighting at the time of the GM assessment. This can be achieved through commitments assessed under GM: 2021 full certification and must be verified before the expiry of the GM validity period

Description	Pathway 2 - LPB Requirements (W/m2)			D SS 530 Reference Lighting Power Budget
	A Gold^PLUS EE >50%	B Platinum EE ≥55%	C SLE EE ≥60%	
Retail Corridors (Interior)	4	3.5	3	7
Concourse	5	4.5	3.5	10
Lobby	5	4.5	3.5	10
Auditorium	5	4.5	3.5	10
Concert Hall	6	5	4	10
Multi Purpose Hall	8	7	6	16
Conference Hall	8	7	6	16
Retail (General Lighting)	10	7	6	15
Retail - Jewellery (Total)	23	19	14	35
Retail - Furniture, clothing & accessories, cosmetics, art (Total)	18	14	10	25
Retail - Supermarket, vehicle, sporting goods, stationary, hardware, others (Total)	15	11	8	20
	Food & Beverage Areas			
Food Courts & Hawker Centres	6	5	4	10
Canteens	6	5	4	10
Restaurants	7	6	5	12
Lounges	7	6	5	12
Bars	7	6	5	12
	Transport and Goods			
Corridors	4	3.5	3	7
Stairs, Escalators, Travellators	6	4.2	3.5	6
Lift Lobbies	4	3.5	3	7
Warehouses	6	5	4	7
Storage Areas	6	5	4	10
Carpark	2.5	2.25	2	3
	Rest, Clean, Exercise and Play			
Hotel Guest Rooms[6]	9	7	5	12

[6] In hotel buildings, a control device shall be installed in every guestroom to automatically switch off the lighting when unoccupied.

Description	Pathway 2 - LPB Requirements (W/m2)			D SS 530 Reference Lighting Power Budget
	A Gold[PLUS] EE >50%	B Platinum EE ≥55%	C SLE EE ≥60%	
Toilets	*6*	*5*	*4*	*10*
Changing Rooms	*6*	*5*	*4*	*10*
Laundries	*6*	*5*	*4*	*10*
Washing Areas	*6*	*5*	*4*	*10*
Gymnasium & Physical Exercise Areas	*7*	*6*	*4.5*	*11*
	Manufacturing & Maintenance			
Mechanical & Electrical Rooms	*6*	*5*	*4*	*10*
Manufacturing (general)	*8*	*6.5*	*5.5*	*13*
Manufacturing (electronic, fine detail or assembly)	*8*	*7*	*6*	*14*

The maximum lighting power budget for landscape lighting shall at minimum comply with SS 530:2014.

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

- Lighting layout plans and schedules showing the numbers, locations and types of lighting luminaries used.
- Technical product information of the luminaries used/data sheets
- Lighting control circuitry plans showing compliance to the stated requirements

At Verification stage (New Buildings & Existing Buildings):

- As-built lighting layout and lighting schedule.
- As-built lighting control circuitry plans

Guidance Notes

Worked Example

A 5-storey office development targeting Platinum using Pathway 2, has the following lighting schedule

Description	Areas (m^2)	Light Fitting Type	Power Consumption per fitting (W)	Driver Loss* (W)	No. of Fittings	Total power consumption based on fitting type (C+D) x (E)	Design Lighting Power Budget (W/m^2) (F/A)	LPB requirement For Platinum	Platinum total Power (A x H)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Office Type 1	1500	LED	12	0	450	5400	3.60	5.5	8250
Office Type 2	1250	LED	18	0	380	6840	5.47	5.5	6875
Meeting Room	75	LED	18	0	18	324	4.32	5.5	412.5
Corridors 1	150	LED	14	0	35	490	3.27	3.5	525
Corridors 2	205	LED	14	0	40	560	2.73	3.5	717.5
Atrium	850	LED	20	0	170	3400	4.00	5	4250
Carparks	7500	LED	28	2	850	25500	3.40	2.25	16875
Staircase	300	LED	28	2	40	1200	4.00	4.2	1260
Male toilets	45	LED	14	0	18	252	5.60	5	225
Female toilets	45	LED	14	0	18	252	5.60	5	225
					Total	***44,218***			***39,615***

* When the driver is integrated as part of an LED light fitting, the driver loss is 0. However, when the driver is not integrated, please add the driver's loss in the LPB calculation.

In this case, lighting performance doesn't meet the maximum lighting power budget as prescribed in table 2A for GM Platinum certification.
The shortfall is 44,218– 39,615 = 4,603W

This shortfall shall be annualised and used to calculate the additional energy required to be made up through on-site renewables.

Assume 55 hours a week:
4,603W x 55(hours) x 52 (weeks) = 13,164,580 Wh/yr (13.16 MWh/yr)

Pathway 2 Renewable safety factor for deficiencies for an office building is 1.1.
Onsite renewables needed = 13.16 x 1.1 = 14.49MWh/yr (14,481 kWh/yr)

13. Mechanical Ventilation

To improve the energy efficiency for buildings' mechanical ventilation system.

Assessment Criteria.

For Pathway 1& 3 to meet the minimum fan power as prescribed in SS 553 and the Code for Environmental Sustainability. Applicable to new developments and existing buildings with Mechanical Ventilation system.

For Pathway 2 - The fan power limitation must meet the prescribed MV efficiencies as stated in Table 2B. Applicable to both new developments and existing buildings.

TABLE 2B Mechanical Ventilation

Fan System	Efficiency (W/CMH)		
	Gold^{PLUS} EE >50%	Platinum EE ≥55%	SLE EE ≥60%
Fan nameplate power	0.32	0.28	0.25

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

- Design drawing showing the mechanical ventilation system
- Mechanical ventilation schematics, data sheets and calculations
- Mechanical ventilation control strategies

At Verification stage (New Buildings & Existing Buildings):

- As built drawings of the mechanical ventilation system.

Guidance Notes

Worked Example

A 4-storey industrial factory development comprising of 6 workshop spaces as the following MV fan schedule. Aiming for Gold^{PLUS}

MV fan schedule:

Area	Fan	Fan Type	Air Flow Rate (CMH)	Fan Nameplate Power (kW)
Workshop 1	FAF 1-1	Axial (CAV)	29000	9.28
Workshop 2	FAF 1-2		29000	9.28
Workshop 3	FAF 1-3		39000	8.28
Workshop 4	FAF 2-1		14000	4.92
Workshop 5	FAF 2-2		14000	4.92
Workshop 6	FAF 2-3		14000	4.92
Workshop 1	EAF 1-1		29000	9.28
Workshop 2	EAF 1-2		29000	9.28
Workshop 3	EAF 1-3		39000	8.28
Workshop 4	EAF 2-1		14000	4.92
Workshop 5	EAF 2-2		14000	4.92
Workshop 6	EAF 2-3		14000	4.92
		TOTAL	264000	78.28

Total fan input power = 78.28 kW

Total air flow rate = 264,000 CMH

Total Fan Efficiency = 0.30 < 0.32, hence the system design meets GM Gold^{PLUS} requirements.

References

Singapore Standard 553 (20016) 'Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings"; SPRING Singapore

14. Efficient Hot Water System

To encourage best practices in hot water system operation, and to drive industry forward in monitoring the hot water system performance.

Assessment Criteria

For buildings using central hot water system performance, such as hotels and hospitals.

Hot Water System Ratio (HWSR) better than baseline of 1.45;

Items	Description of criterion	Compliance
a)	Hot Water System Ratio (HWSR) baseline is 1.45	For Hotel and hospital with central hot water system, aiming for Platinum rating
b)	Provision of permanent measuring instruments for monitoring of Hot Water System Ratio	
c)	Measure Heat loss from Hot Water system, can be from third party energy audit or permanent M&V	

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

- Submission of design schematics and efficiency calculations
- Description of permanent measuring instruments for the monitoring of the hot water system

At Verification stage (New Buildings & Existing Buildings):

- As-built drawing showing the schematic and layout of the proposed building hot water system
- Delivery orders of the hot water plant equipment, including heat pumps, circulation pumps, M&V instruments (if applicable)
- Operation hours of the hot water system and spaces served by the hot water plant
- Compliance with verification requirements under Permanent Instrumentation for the Measurement and Verification of Hot Water Plant where applicable
- Submission of energy audit report endorsed by PE (Mechanical) or Energy Auditor detailing the hot water plant performance and heat loss measured over 1-week period (if applicable)

Guidance Notes

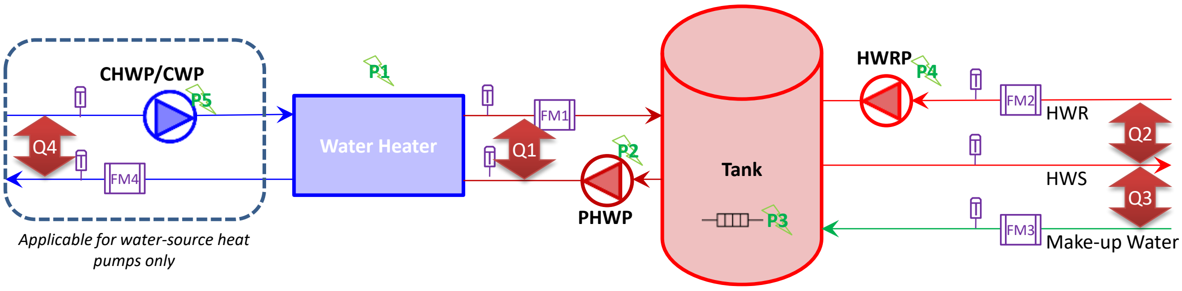
Only hot water systems with supply temperature up to 60°C are assessed. Systems which require higher temperature supply i.e. steam for lab and hot water for kitchen are excluded. If the make-up water to these higher temperature supplies are pre-heated to 60°C using heat pump system, the pre-heating heat pump system would be assessed.

For buildings with different heating systems, only the system with the larger aggregated capacity will be considered. For example, if a hotel has both electrical heaters and heat pump system with electrical heaters having a larger aggregated capacity than heat pump system, only the electrical heaters will be considered.

Definitions

Hot Water System: Refers to the hot water machine and ancillary equipment such as circulation pumps, booster pumps and water storage tanks supporting the operations of the hot water plant.

Make-up Water Pumps (MWP): Pumps to supply water to hot water system to make up water being used by the users; they are also used to pressurize the system depending on the system design.



Typical Hot Water System

Water Heater Output, Q1: Heat output from water heater(s)

$$Q1(kW_t) = FM1 \times Cp \times (T1_{out} - T1_{in})$$

in which,

FM1 : Primary hot water flow rate (L/s);

$T1_{out}$, $T1_{in}$: Temperature at water heater outlet and inlet respectively (°C).

Cp: Specific heat capacity of water (varies with water temperature and pressure). Cp is 4.18 J/(kg.K) within the temperature range of 45°C to 60°C.

Total Hot Water Plant Output, Q_{tot}: Total heat output by water heaters (boilers, heat pumps, solar hot water panels) and built-in electrical heaters inside calorifier tanks

$$Q_{tot}(kW_t) = Q1 + P3$$

P3: the electrical input to the electrical heaters in the calorifier tanks. It is assumed that all electrical input to the calorifiers is converted into heat, e.g 1kW electrical input = 1kW thermal output.

Hot Water Circulation Heat Loss, Q2 : The heat loss through hot water distribution piping network

$$Q2(kW_t) = FM2 \times Cp \times (T_S - T_R)$$

in which,

FM2 : Hot water return flow rate (L/s);

TS, TR : Hot water Temperature at point of leaving and returning to hot water storage tank respectively (°C)

Effective Hot Water Consumption, Q3

The heat required to heat up water from make-up water temperature to the hot water supply temperature from the hot water storage tank.

$$Q3(kW_t) = FM3 \times Cp \times (T_S - T_M)$$

in which,

FM3 : Make-up water flow rate (L/s);

T_M : Make-up water Temperature (°C).

Heat recovered from Heat Source, Q4: It could be the heat recovered from chilled/condenser water of water-source heat pump or ambient air from air-source heat pump. It is generally accepted that Cp is 4.18 J/(kg.K) for condenser side and 4.19 J/(kg.K) for chilled water side.

If it's from chilled water or condenser water,

$$Q4(kW_t) = FM4 \times Cp \times (T_{Cin} - T_{Cout})$$

in which,

FM4 : Chilled water or condenser water flow rate (L/s);

T_{Cin} : Chilled water (or condenser water) temperature returning to the heat source (°C)

T_{Cout} : Chilled water (or condenser water) temperature leaving the heat source (°C)

Electrical power recovered, E_R : The electricity consumed by the chiller plant or cooling tower plant to produce same amount of cooling as heat recovered from Heat Source (Q4).

$$E_R(kW_e) = Q4 \times \eta$$

in which,

h : Measured chiller plant or cooling tower efficiency;

a) Hot Water System Ratio (HWSR): A ratio of effective hot water consumption to the total power consumed by entire hot water system, after considering Electrical power recovered (E_R).

$$HWSR = \frac{Q3}{(P_{tot} - E_R)}$$

in which,

P_{tot}: Total Power Consumption of entire hot water system, excluding make-up water pumps, if any.

$$P_{tot}(kW_e) = P1 + P2 + P3 + P4 + P5$$

P1: Input power to Water Heater

P2: Input power to Primary Hot Water Circulation Pumps.

P3: Input power to built-in electrical heaters inside the calorifier tanks, if any.

P4: Input power to Hot Water Return Pumps.

P5: Input power to dedicated Chilled Water Pumps/Condenser Water Pumps for hot water system.

Plant Room Heat Loss (Q_{L1}): The heat loss through the surface of calorifier tanks and primary loop piping work.

$$Q_{L1}(kW_t) = Q_{tot} - (Q2 + Q3)$$

Total Heat Loss in Hot Water System (Q_{Ltot}): The sum of Plant Room Heat Loss and Circulation Heat Loss.

$$Q_{Ltot}(kW_t) = Q_{L1} + Q2$$

Total Heat Loss Ratio (TLR): The ratio of Total Heat Loss in Hot Water System to the Total Hot Water Plant Output, it's the sum of Plant Room Heat Loss Rate and Circulation Heat Loss Rate.

$$TLR = \frac{Q_{Ltot}}{Q_{tot}} = PRLR + CLR$$

b) M&V requirement

Instrumentation accuracy requirement for hot water system is similar with chilled water system. Close loop thermowells are acceptable for hot water system.

c) Heat loss of hot water system

The calculation can be done either using data from permanent M&V, or third-party instrumentation

Instrument	Accuracy	Location	Remarks
Flow Meters	1% + 1%	• HWSR: Make-up water pipe • Heat Loss computation: Chilled water / condenser water, primary hot water and return water pipes	With totalizer function for make-up water
Digital Temperature sensors c/w Thermowell	0.05 °C	• HWSR: Make-up water pipe • Heat Loss computation: Chilled water / condenser water, primary hot water and return water pipes	Immersion type with closed end thermowell
Logger / Energy Meter	-	Hot water plant room	• Display not less than 2 decimals • Per minute interval logging • Consistent with Chilled water plant trend logging
Digital Power meters	1%	At main incoming if possible, else at individual equipment	With totalizer function to log kWh
Overall Error	< 5%		

Worked example

The calculation can be done either using data from permanent M&V, or third-party instrumentation.

A hotel with 400 guestrooms is served by a hot water plant with 2 nos of water-to-water heat pumps and targeting Green Mark Platinum.

Step 1 - Determine the hot water usage profile

Consultant calculated the hot water consumption, estimated to be at the range of 20 to 160 kW with the average at 80 kW.

Step 2 - Propose hot water plant configuration and derive the respective power input of various components

The proposed hot water plant configuration for the building operating hours specified are as follows:

- **Heat Pumps**: 2 nos 180 kW with multiple compressors (1 duty and 1 standby). Hot water Inlet / Outlet temperature: 50/55°C, Chilled water Inlet / Outlet temperature: 12/7°C, rated COP 3.3.
- **Calorifier tanks**: 2 nos of 5.0 m^3, with 100kW built-in electrical heater
- **PHWP**: 2 nos, 8.4 L/s @ 15m, rated power 1.74 kW (1 duty and 1 standby).
- **CHWP:** 5.9 L/s @ 10m rated power 0.82 kW (1 duty and 1 standby).
- **HWRP:** 2 nos each at High Zone & Low Zone : 1 L/s@ 5m, rated power 0.11kW (1 duty and 1 standby).

- **MWP**: No dedicated Make-up Water Pump for hot water system.

The hot water plant is located at basement 1, just beside chiller plant.

A	Effective Hot Water Energy Consumption, Q3	80.0 kW	
B	Total Energy Loss Rate (TELR)	40%	(Assumed)
C	Heat Pump Output, Q1	133.3 kW	=A / (1-B)
D	Heat Pump COP	3.3	
E	Heat Pump average operating Power, P1	40.40 kW	=C / D
F	PHWP Operating Power, P2	1.74 kW	
G	CHWP Operating Power, P5	0.82 kW	
H	HWRP Operating Power (2nos), P4	0.22 kW	
I	**Total Power, Ptot**	**43.18 kW**	=E+F+G+H
J	Heat removed from Heat Source, Q4	92.9 kW	=(D-1)/D * C, or = C-E
K	Chiller Plant efficiency	0.65 kW/RT	
L	Electricity power recovered, E_R	17.2 kW	=J *(K /3.517)
M	**HWSR**	**3.1**	=A/(I-L)

The project achieves HWSP of 3.1 which is better than baseline of 1.45, and hence meet the requirement for GM Platinum.

15. Air side energy recovery for healthcare facilities

Promote airside energy recovery to all healthcare ventilation system through provision of energy recovery device with no-recirculation (i.e. 100% of the room air to be exhausted).

Assessment Criteria

For healthcare facilities such as hospitals.
The efficiency of energy recovery device, if applicable, shall meet the below prescribed requirement:

- Run Around coil – min 45% energy transfer efficiency
- Plate heat exchanger – min 50% energy transfer efficiency
- Thermal Wheel - 60% energy transfer efficiency
- Other types – min 50% energy transfer efficiency

Documentation Requirements

At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):

- Drawing showing the schematic and layout of the proposed energy-recovery device.
- Technical specifications and product information of the various components of the proposed energy recovery device

At Verification stage (New Buildings & Existing Buildings):

- Submission of purchase/ delivery orders of purchases with the technical product specifications of the energy-recovery device.

16. Integrated Energy Management & control Systems

For Pathway 2.

(i) Energy consumption monitoring and benchmarking system

Assessment Criteria

Tracking a building's energy use with the data presented in a relevant manner to engage its occupants can have an effect in helping to manage building energy consumption. Related to this ideal of sharing building data openly is the need to apply open standards to future-proof the building's management system and to facilitate data exchange between subsystems.

Documentation Requirements

<u>At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):</u>

- Specifications of the energy portal, dashboard or other equivalent forms and relevant parameters such as areas, occupancy areas or usage type that are to be included for monitoring and setting of energy consumption targets.
- The data acquisition system, typically a building or energy management system (BMS or EMS), must be able to store the measured data for at least 36 months, and to create reports showing hourly, daily, monthly, and annual energy consumption associated with each meter with the option to export data.
- Plans and schematics to illustrate:
  - Location and means of access of the portal
  - Electrical single line diagram of the sub-metering scheme and links to BMS or EMS

<u>At Verification stage (New Buildings & Existing Buildings):</u>

Photographic evidences of the installed energy portal or dashboard or equivalent form displaying metered energy data by area or use and other relevant parameters as well as trending and energy benchmark.

(ii) Lighting Demand Control

Assessment Criteria

Occupancy/vacancy sensing: Control automatically turns light off when motion is no longer detected and shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment. In hotel buildings, a control device shall be installed in every guestroom to automatically switch off the lighting when unoccupied.

Documentation Requirements

<u>At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):</u>

- Location plans of the relevant sensors that demonstrate that at least 80% of the applicable areas are covered
- Specifications of the sensors and a method statement of the lighting controls including the sensor regulation of lighting level (brightness)

<u>At Verification stage (New Buildings & Existing Buildings):</u>

- Specifications of the sensors installed and the associated controllers
- As-built building floor plan marked with the sensor deployment
- As-built control system screens showing the sensor inputs and the corresponding controller outputs

Guidance Notes

≥ 80% of transient areas (by area) use occupancy/vacancy sensing as a lighting control strategy.

≥ 80% of occupied areas use occupancy/vacancy sensing as a lighting control strategy.

(iii) ACMV Demand Control

Assessment Criteria

Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load using the following:

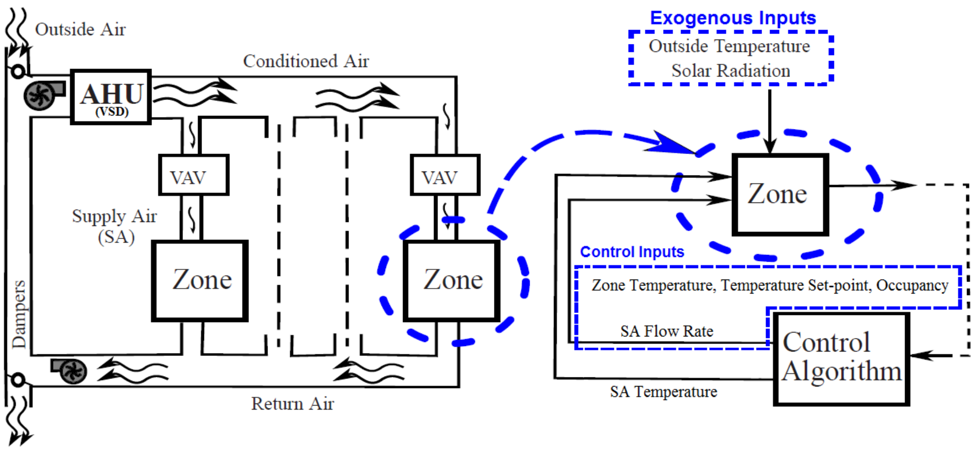
- Occupancy-based sensing: Control is exercised based on measured occupancy, e.g. number of occupants.
- In hotel buildings, a control device shall be installed in every guestroom to automatically reduce the air-conditioning loads when a guestroom is not occupied.
- Location plans of the relevant sensors demonstrating that at least 80% of the applicable areas are covered
- Specifications of the sensors and a method statement of the ACMV controls including the sensor regulation of temperature and fresh air supply

<u>At Verification stage (New Buildings & Existing Buildings):</u>

- Specifications of the sensors installed and the associated controllers
- As-built building floor plan marked with the sensor deployment
- As-built control system screens showing the sensor inputs and the corresponding controller outputs

Guidance Notes

- ≥ 80% of the applicable transient areas (by area) use occupancy-based sensing as a ACMV control strategy.
- ≥ 80% of the applicable occupied areas use occupancy-based sensing as a ACMV control strategy.
- The schematic of a typical multi-zone VAV-based HVAC system and a conceptual control algorithm that is implemented in an occupied zone is shown.
- Part of the air removed from the occupied zone (return air) is mixed with the outside air and conditioned at the AHU to the desired temperature and humidity ratio. The conditioned air, which is usually cold and dry, is distributed to the VAV boxes at the zones through the ductwork. This temperature set point is reset dynamically based on whether the zone is occupied or not. The control strategy is based on either occupancy-based sensing or binary sensing.



17. On-Site Renewables

Assessment Criteria

Where utilised For Non-Residential Building Developments: Applicable to new and existing buildings with on-site generation and consumption of renewable energy.

For Residential building Developments: Applicable to new and existing residential buildings targeting SLE with at least 30% replacement of club house, function room, swimming pool pumps, gym , MCST office and Guard house electricity consumption.

Documentation Requirements

<u>At Design stage (New Buildings) / Pre-retrofit stage (Existing Buildings):</u>

- Technical product information on the salient features of the renewable energy system and the expected renewable energy generated
- Detailed drawings showing the location and renewable energy provisions
- Calculation of the percentage replacement of electricity and the total annual electricity consumption of the development
- To provide power meter for PV generation monitoring.
- For Residential building Developments, provide separate power meter to monitor the energy consumption of club house, function room, swimming pool pumps, gym, MCST office and Guard house electricity consumption to substantiate the 30% replacement through renewables.

<u>At Verification stage (New Buildings & Existing Buildings):</u>

- As-built drawings and on site photographs of the renewable energy source(s)
- Technical specifications and integration reports of the installed system(s) including total capacity installed
- Testing and commissioning report
- Logging of the energy production and calculated energy replacement rate (please refer to work examples below)
- Updated details of the renewable energy systems installed as per table below:

Description on type of renewable energy system installed and location of installation	**Area of renewable energy system installed (m^2) (where applicable)**	**kWp installed (kWp)**	**Energy produced per year, i.e. annual yield (kWh), verified with actual energy production and consumption**	**Notes/ Remarks (if any)**
e.g. Monocrystalline solar panels at upper roof of Block A				
e.g. Thin film solar modules at roof of Block B				
Total				
Total energy produced per year (A)				
GFA of building (m^2) (B)				
Total building energy consumption (kWh/yr) (C)				
Annual energy replacement rate (%) (A/C)				
EUI ($kWh/m^2 \bullet yr$) (C/B)				

Guidance Notes

Worked Example

For Non-Residential Building Developments with on-site generation and consumption of renewable energy

Based on contractor/supplier's specifications and/or as-built details, fill up the details of the renewable energy systems installed in the table below:

Description on type of renewable energy system installed and location of installation	**Area of renewable energy system installed (m^2) (where applicable)**	**kWp installed (kWp)**	**Energy produced per year, i.e. annual yield (kWh), verified with actual energy production and consumption**	**Notes/ Remarks (if any)**
Monocrystalline solar panels at upper roof of Block A	1,000	100	120,000	
Thin film solar modules at roof of Block B	1,000	100	120,000	
Total		200	240,000	
Total energy produced per year (A)			240,000	
GFA of building (m^2) (B)			65,298	
Total building energy consumption (kWh/yr) (C)			7,868,852	
Annual energy replacement rate (%) (A/C)			3.05%	
EUI (kWh/m^2•yr) (C/B)			120.51	

For Private Residential Building Developments with on-site generation and consumption of renewable energy

Based on contractor/ supplier's specifications and/or as-built details, fill up details of the renewable energy systems installed in the table below:

Description on type of renewable energy system installed and location of installation	**Area of renewable energy system installed (m^2) (where applicable)**	**kWp installed (kWp)**	**Energy produced per year, i.e. annual yield (kWh), verified with actual energy production and consumption**	**Notes/ Remarks (if any)**
Monocrystalline solar panels at upper roof of Block A	1,000	100	120,000	

Thin film solar modules at roof of Block B	1,000	100	120,000	
Total		200	240,000	
Total energy produced per year (A)			240,000	
Total energy consumption for club house, function room, swimming pool pumps, gym and MCST office electricity consumption (kWh/yr) (B)			768,852	
Annual energy replacement rate (%) (A/B)			31.22% (met SLE requirements of 30%)	

<u>For Integrated Energy Management and control to use on-site Renewable Energy to make up the shortfall</u>

lighting demand control shortfall	On-site RE replacement required for 10% of the total interior lighting consumption of **the applicable areas**
ACMV demand control shortfall	On-site RE replacement required for 5% of the air-conditioning system consumption of **the applicable areas**

Fixed Metrics Requirement Tables

Office Buildings

OFFICE			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	-	10%	25%
ACMV TSE	0.8	0.74	0.68
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & Control Systems	-	Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.1		

Retail Mall

RETAIL			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	35
Non-AC Areas	-	5%	15%
ACMV TSE	0.8	0.74	0.68
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.1		

Hotel

HOTEL			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	-	10%	30%
ACMV TSE	0.8	0.74	0.68
Hot Water System Ratio (HWSR)	1.45		
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment. A control device shall be installed in every guestroom for the purpose of automatically switching off the lighting and reducing the air conditioning loads when a guestroom is not occupied.		Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.1		

MOE Primary and Secondary Schools

MOE PRIMARY AND SECONDARY SCHOOLS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	30%	50%	70%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.5		

MOE Junior Colleges

MOE JUNIOR COLLEGE			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	20%	40%	60%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.5		

Private Schools and Colleges

PRIVATE SCHOOLS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	35
Non-AC Areas	-	20%	40%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	Energy consumption monitoring and benchmarking system.	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Institute of Higher Learning

INSTITUTE OF HIGHER LEARNING			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	-	20%	50%
ACMV TSE	0.8	0.74	0.68
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	Energy consumption monitoring and benchmarking system.	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Hospitals

<table>
<tr><th colspan="4">HOSPITALS</th></tr>
<tr><th>PARAMETER</th><th>Gold PLUS EE >50%</th><th>Platinum EE ⩾55%</th><th>SLE EE ⩾60%</th></tr>
<tr><td>Reduced Heat Gain (ETTV)
[New Development only]</td><td>40</td><td>38</td><td>38</td></tr>
<tr><td>Non-AC Areas</td><td>-</td><td>-</td><td>15%</td></tr>
<tr><td>ACMV TSE</td><td>0.8</td><td>0.75</td><td>0.7</td></tr>
<tr><td>Hot Water System Ratio (HWSR)</td><td colspan="3">1.45</td></tr>
<tr><td>Heat Recovery</td><td colspan="3">Run-around coils / heat recovery from exhaust air or other system where reheat is needed for conditioned air</td></tr>
<tr><td>Lighting Power Budget</td><td colspan="3">Table 2A</td></tr>
<tr><td>Mechanical Ventilation</td><td colspan="3">Table 2B</td></tr>
<tr><td>Integrated Energy Management & control Systems</td><td>-</td><td>Energy consumption monitoring and benchmarking system.</td><td>Energy consumption monitoring and benchmarking system.

Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load.

Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.</td></tr>
<tr><td>On-Site Renewables - replacement to make up any deficiencies from the above list, with safety factor</td><td colspan="3">1.1</td></tr>
</table>

Polyclinics

POLYCLINIC			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	10%	30%	50%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	Energy consumption monitoring and benchmarking system.	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.3		

Nursing and Youth Homes

NURSING/ YOUTH HOME			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	10%	40%	60%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment. Youth Homes: A control device shall be installed in every bedroom for the purpose of automatically switching off the lighting and reducing the air-conditioning loads when a guestroom is not occupied. Nursing Homes: Motion sensors or equivalent sensors shall be deployed to common areas (e.g. lift lobbies and staircases), to dim lighting during period of no occupancy.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.5		

Industrial – High Technology

HIGH TECH/HIGH INTENSITY			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	-	-	10%
ACMV TSE	0.8	0.78	0.75
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.1		

Light Industrial

LIGHT INDUSTRIAL			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	-	15%	30%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Warehouses, Workshops/Logistics and Others

WAREHOUSES/ WORKSHOPS/ LOGISTICS/ OTHERS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	-	30%	40%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.4		

Community Buildings

COMMUNITY BUILDINGS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	10%	30%	40%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Note: *Community Buildings include Community Centres, Childcare Centres*

Civic Buildings

CIVIC BUILDINGS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ≥55%	SLE EE ≥60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	-	15%	30%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Note: *Civic Buildings include Courts, Police Stations, Fire Stations*

Cultural Institutions

CULTURAL BUILDINGS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC Areas	-	10%	20%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Note: *Cultural Buildings include Performing Arts, Library, Museum, Art Gallery*

Sports and Recreation Centres

SPORTS AND RECREATION CENTRES			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	-	15%	30%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system. Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Religious / Places of Worship

RELIGIOUS/ PLACES OF WORSHIP			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non AC Areas	-	15%	25%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Automatic controls for the air-conditioning system to respond to periods of non-use, or reduced heat load. Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.5		

Worker's Dormitories

WORKER'S DORMITORIES			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	38	38
Non-AC area	70%	80%	90%
Ventilation Performance of Dwelling area	**40%** of dwelling area shall be designed to have good natural ventilation OPTION 1: PLAN LEVEL unobstructed air flow between spaces and the outside OPTION 2: SIMULATION average wind velocity of 0.4m/s or provision of ceiling fans can be included	**50% of dwelling area** hall be designed to have good natural ventilation OPTION 1: PLAN LEVEL unobstructed air flow between spaces and the outside OPTION 2: SIMULATION average wind velocity of 0.4m/s or provision of ceiling fans can be included	**60%** of dwelling area shall be designed to have good levels of natural ventilation OPTION 1: PLAN LEVEL unobstructed air flow between spaces and the outside OPTION 2: SIMULATION average wind velocity of 0.6m/s or use of PMV where use of ceiling fans can be included
Ventilation Performance of Common Areas	All above ground lobbies and corridors are to be naturally ventilated		
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Energy Efficient Equipment Selection if any	3 Tick or the highest tick available		5 Tick or the highest tick available

Integrated Energy Management & control Systems	-	-	Lighting controls shall be provided in accordance with SS 530: 2014 Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.2		

Other Non-Residential Building Types

OTHERS			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (ETTV) [New Development only]	40	40	40
Non-AC Areas	-	30%	40%
ACMV TSE	0.8	0.75	0.7
Lighting Power Budget	Table 2A		
Mechanical Ventilation	Table 2B		
Integrated Energy Management & control Systems	-	-	Energy consumption monitoring and benchmarking system.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.4		

Residential

RESIDENTIAL			
PARAMETER	Gold^{PLUS} EE >50%	Platinum EE ⩾55%	SLE EE ⩾60%
Reduced Heat Gain (RETV) [Applicable to New Development only]	22	20	20
Ventilation Performance of Dwelling Units [Applicable to New Development only]	**40%** of Living rooms, bedrooms (including home office spaces) shall be designed to have good natural ventilation OPTION 1: PLAN LEVEL unobstructed air flow between spaces and the outside OPTION 2: SIMULATION average wind velocity of 0.4m/s or provision of ceiling fans can be included	**50%** of Living rooms, bedrooms (including home office spaces) shall be designed to have good natural ventilation OPTION 1: PLAN LEVEL unobstructed air flow between spaces and the outside OPTION 2: SIMULATION average wind velocity of 0.4m/s or provision of ceiling fans can be included	**60%** of Living rooms, bedrooms (including home office spaces) shall be designed to have good levels of natural ventilation OPTION 1: PLAN LEVEL unobstructed air flow between spaces and the outside OPTION 2: SIMULATION average wind velocity of 0.6m/s or use of PMV where use of ceiling fans can be included
ACMV	4 Ticks	5 Ticks	
Energy Efficient Dwelling Unit Equipment Selection	3 Tick - or the highest tick available	5 Tick - or the highest tick available	
Ventilation Performance – Common Areas	All above ground lobbies and corridors are to be naturally ventilated		
Vertical Transportation System [Applicable to New Developments and Existing Development upon replacement of lift and escalators]	VVVF & Sleep Mode	VVVF & Sleep Mode Regenerative Drive for 12 Storeys or more	
Lighting Power Budget			

[All areas excluding dwelling units]	Table 2A		
Mechanical Ventilation	Table 2B		
Demand Control Systems	Lighting and Ventilation controls (Timer, sensor, dimming, switches) for all common areas.		
Adoption of Renewables to offset energy consumption	-	-	[For non-landed and cluster housing Development] 30% replacement of club house, function room, swimming pool pumps, gym, MCST office and Guard house electricity consumption [For landed house] 30% replacement of total building's energy consumption by onsite renewables
On-Site Renewables - *replacement to make up any deficiencies from the above, excluding RETV and Dwelling Unit Ventilation Performance, with safety factor*	1.2		

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