BSR

Green Mark International

TECHNICAL GUIDE

EE

BSR

Energy Efficiency

Base Sustainability Requirements

(New Developments and Existing Buildings)

Revision Log

Revision	Description	Effective Date
R0	1st Version	1 September 2022

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Energy Efficiency Pathways

There are three (3) Energy Efficiency Pathways for projects to demonstrate their energy performance as shown in Table 1A. For building types not covered, Pathway 3 i.e. Energy Savings would be the default compliance route.

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 (International)

Building Types	**PATHWAY 1** EUI	**PATHWAY 2** Fixed Metrics	**PATHWAY 3** Energy Savings
Commercial			
Office Buildings	•	•	•
Hotels	•	•	•
Retail Buildings	•	•	•
Educational			
Tertiary Institutions (University, and Polytechnics)	•	•	•
Schools and Colleges	•	•	•
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 Institutions	•	•	•
Sports and Recreation Centres	•	•	•
Religious/ Places of Worship		•	•
Industrial			
High Tech Industrial Buildings		•	•
Light Industrial Buildings		•	•
Warehouses, Workshops and Others		•	•
Residential			
Non-Landed Residential (condominiums, private apartments)		•	
Cluster Housing		•	
Landed Housing		•	
ALL OTHER BUILDING TYPES		Bespoke	•

Energy Efficiency Assessment Approach

New Buildings under Design and Existing Buildings
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. Benchmark EUI is not appliable to non-tropical climate requiring space heating, examples are China and etc. **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 off set through onsite renewables with the listed multiplication factor. Detailed calculations, drawings and specifications would be required to substantiate the declared performance. Fixed Metrics can be applied to non-tropical climate, Total System Efficiency (TSE) and Air Fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019. The Thermal Performance of the Building Envelope and Façade of non-residential buildings shall refer to China national standard (GB 50189-2015) and requirements by the local/region authorities for residential developments. **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. Pathway 3 is applicable to projects in non-tropical climate. Baseline of the heating system shall refer to the prevailing code in the country or district of the project. Baseline of other systems including air-conditioning system shall refer to GM 2021 Energy modelling Guidelines, including the requirements in AC TSE and Airside efficiency (for buildings supplied by DCS). Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China and/or local. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019. The Thermal Performance of the Building Envelope and Façade of non-residential buildings shall refer to China national standard (GB 50189-2015). **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. Onsite renewable sources refer to renewable energy generated within the project boundary under the scope of Green Mark Assessment. 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
When the building has completed construction or its retrofit, a verification audit shall be carried out. For Existing Buildings in operation which has not been retrofitted, the assessment shall be based upon its operational data. Stage 1 Verification (New Buildings): The Green Mark verification shall demonstrate the implementation of the design stage strategies and note any deviance from these and their effect on the ability of the project to achieve the energy performance. Stage 2 Verification (New Buildings) and Existing Buildings in operation: The building shall demonstrate compliance to the committed performance stated in the pathway through 12-months measured data with a requirement of minimum occupancy of 60% for the period of measurement. The Energy Savings from energy modelling would require deviance less than 5% else a calibration would be required. Note on Renewable Energy The generated energy, using 12-month actual operation data will be audited. Note for Zero Energy Buildings The building shall demonstrate compliance to the committed 100% net replacement through onsite and/or off-site renewable sources. Note for Positive Energy Buildings The building shall demonstrate compliance to the committed 115% net replacement through onsite renewable sources.

Pathway 1 – Energy Use Intensity (EUI) (International)

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
- Calculation and measured data
- Building's annual electricity consumption based on actual utility bills (for existing buildings in operation)

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

Building Type	**New and Existing Buildings**			
	Certified, Gold	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Commercial				
Office Buildings (Large) (GFA ≥ 15,000sqm)	155	155	140	115
Office Buildings (Small) (GFA < 15,000sqm)	135	135	120	100
Hotels (Large) (GFA ≥ 15,000sqm)	230	230	220	190
Hotels (Small) (GFA < 15,000sqm)	180	180	160	140
Retail Malls	240	240	210	160
Educational				
Tertiary Institutions (University and Polytechnics)	130	130	120	90
Schools and Colleges	110	110	100	80
Healthcare				
Hospitals (Private and General)	375	375	340	300
Community Hospitals	230	230	210	185
Polyclinics	150	150	135	120
Nursing/Youth Homes	90	90	80	70
Other Non-Residential				
Mixed Developments	by GFA mix			
Community Centres	150	150	125	*110*
Civic Buildings	80	80	70	*60*
Cultural Institutions	180	180	140	120
Sports and Recreation Centres	110	110	80	50
Religious/ Places of Worship	NA			
Industrial				
High Tech Industrial Buildings	NA			
Light Industrial Buildings				
Warehouses, Workshops and Others				

Additional Notes	**New Buildings (Certified & Gold)**	**New Buildings (Gold^{PLUS} & Platinum)**	**Existing Buildings**
AC Total System Efficiency	0.85 kW/RT	0.8 kW/RT	0.9 kW/RT
EUI occupancy rate	100% (design)		≥ 60%
Renewable Energy included	On-Site		

Note: Pathway 1 - EUI is not appliable to non-tropical climate requiring space heating such as China and etc…

TABLE 1C Pathway 1 Energy Use Intensity (EUI) Quick look up table – DCS[*](International)

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

Additional Notes	**New Buildings (Certified & Gold)**	**New Buildings (Gold^{PLUS} & Platinum)**	**Existing Buildings**
Airside efficiency for buildings supplied by DCS	0.25 kW/RT	0.2 kW/RT	0.25 kW/RT
EUI occupancy rate	100% (design)		≥ 60%
Renewable Energy included	On-Site		

[#]District Cooling System (DCS) is 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. Operating conditions and business model of DCS is different from buildings' in-house air-conditioning system, in part or in full, being maintained and operated by a third party.

Note: Pathway 1 - EUI is not appliable to non-tropical climate requiring space heating such as China and etc…

Documentation Requirements

At Design stage (New 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 the 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 In operation):

- Scenario 1: Based on utility bill, if the occupancy rate is low, e.g. only 20% occupancy rate, it needs to be projected to 80% to get the EUI which reflects the actual operation situation;
- Scenario 2: Based on the utility bills, if the actual operation hours are the same as what were used during the design stage, no adjustment required for operational hours; If fixed operational hours were used during design and they are different from actual operation hours, adjustment needs to be done based on actual operational 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 measured data or actual utility bills for existing buildings	
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 since 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	Results 1) based on EM proposed model for new buildings; or 2) based on measured data or actual utility bills for existing buildings	
Annual Total Building Energy Consumption: At 30% occupancy	115,489.3	kWh/year
GFA	2,584	m2
EUI	44.7	kWh/m2/year
TBEC Adjusted to 80% occupancy	$=115{,}489.3 \div 0.3 \times 0.8$ $= 307971.4$	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:

A mix development (retail and office)	<u>Results</u> 1) based on EM proposed model for new buildings; or 2) based on measured data or utility bills for existing buildings	
GFA of retail component	18,552 (34% of total GFA)	m^2
GFA of office component	35,992 (66% of total GFA)	m^2
Required EUI for compliance	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 Gold^{PLUS} / Platinum / SLE 183.9 / 163.8 / 130.3	
Annual Total Building Energy Consumption:	8,217,552.3	kWh/year
GFA	54,544	m^2
EUI	150.7	kWh/m2/year

With the calculation above, it meets Platinum requirement under Pathway 1.

Pathway 2 – Fixed Metrics (International)

Pathway 2 is applicable to all buildings listed in the Fixed Metrics Requirement Tables. Fixed Metrics can be applied to non-tropical climate, Total System Efficiency (TSE) and Air fan System are not applicable to projects without air-conditioning.

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, the airside performance shall be complied in lieu of TSE and shall be as follows:

Additional Notes	**New & Existing Buildings**			
	Certified & Gold	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Airside efficiency for buildings supplied by DCS (kW//RT)	0.25	0.2	0.18	0.16

Note: Onsite renewables refers to renewable energy generated within the project boundary under the scope *of Green Mark Assessment.*

Pathway 3 – Energy Savings (International)

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.

Energy Savings can be applied to non-tropical climate. Baseline of the heating system shall refer to the prevailing code of the country. Baseline of other systems including air-conditioning system shall refer to GM 2021 Energy modelling Guidelines, including the requirements in AC TSE and Airside efficiency (for buildings supplied by DCS).

Pathway 3 is applicable to projects in non-tropical climate. Baseline of the heating system shall refer to the prevailing code in the country or district of the project. Baseline of other systems including air-conditioning system shall refer to GM 2021 Energy modelling Guidelines, including the requirements in AC TSE and Airside efficiency (for buildings supplied by DCS). Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China and/or local. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019. The Thermal Performance of the Building Envelope and Façade of non-residential buildings shall refer to China national standard (GB 50189-2015).

	Pathway 3 – Energy Savings			
	Certified EE and Gold EE	**Gold^{PLUS} EE**	**Platinum EE**	**SLE EE**
Saving from BAU (2005 Code)	50% (New Buildings) 40% (Existing Buildings)	50%	55%	60%
Saving from Current Reference (Annex C) **Including buildings supplied by DCS*	30% (New Buildings) 20% (Existing Buildings)	30%	35%	40%

Additional Requirements	**New Buildings**		**Existing Buildings**
	Certified and Gold	**Gold^{PLUS} and Platinum**	
AC TSE	0.85	0.8	0.9
Airside efficiency (for buildings supplied by DCS)	0.25	0.2	0.25
Savings from Renewable Energy	no cap		
Savings from Passive Design	no cap		

**Based on Energy Modelling guidelines or saving generated from SLEB Smart Hub.*

Documentation Requirements

At Design stage (New 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. Using the data on actual site operation, a revised energy modelling should be performed if necessary.

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) :

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 officers. 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 (OSE)
- 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 and the display of the key indicators including total system energy efficiency and its component (water-side and air-side efficiency) as well as the calculated heat balance of the chilled water system.
- Temperature measurement verification report with evidence that the temperature sensors installed for chilled water and condenser water loop have a measurement uncertainly within ±0.05°C.
- 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

Determining Instrumentation Measurement Uncertainties

As instrumentation measurement uncertainties stated in calibration certificates and technical specifications are based on controlled conditions in a laboratory, it is necessary to allow for on-site deviations and measurements. The overall measurement system comprising the temperature, flow and power measurement shall be capable of calculating resultant chiller-water plant efficiency with the uncertainty within ±5% for on-site measurement. Each measurement shall include the sensor, any signal conditioning (if available), the data acquisition system and the wiring connecting them.

The methodology for determining the total uncertainty of measurement shall be computed using the root-sum square formula as follows:

$$\text{Error}_{rms} = \sqrt{\sum (U_N)^2}$$

where

U_N = Individual uncertainty of variable N (%)

N = Mass flow rate, electrical power input or delta T

In deriving the measurement uncertainty contributed by flow meters, an additional 1% is to be included in the computation.

Work Example

Computation of uncertainty of the overall measurement system

Item	Measurement System	Measurement Uncertainty (% of reading)
1	Temperature see Note(1)	$\dfrac{\sqrt{0.05^2 + 0.05^2}}{5.5} = 1.3$
2	Flow see Note(2)	1% + 1% (i.e. 2%)
3	Power see Note(3)	$\sqrt{1^2+1^2} = 1.4\%$

Note(1): The temperature measurement system shall have a measurement uncertainty not exceeding ± 0.05°C over the entire measurement range. The combined uncertainty for ΔT is computed based on the root-sum square formula with ΔT assumed to be 5.5 °C as illustrated above.

Note(2): An additional 1% to be included in the computation of measurement uncertainty for flow meter.

Note (3): Uncertainty of power measurement system shall include that of the current transformer where applicable. It is recommended that 3rd party verified power meter be specified to ensure accuracy.

The overall uncertainty of the measurement system shall be the combination of the individual uncertainty of each measurement system. Based on the above information, the overall uncertainty of measurement is as shown in the following:

$$\text{Error}_{rms} = \sqrt{\sum (U_N)^2}$$

$$= \sqrt{(1.3^2 + 2^2 + 1.4^2)}$$

$$= 2.8\ \%$$

where U_N = individual uncertainty of variable N (%)

N = mass flow rate, electrical power input or delta T

Therefore, the total uncertainty for the calculated chilled-water plant efficiency (kW/RT) is 2.8 %, which falls within 5% of the true value.

Determining Heat Balance

It is important to ensure correct placement of the temperature sensors for proper measurement. A heat balance-substantiating test can be carried out to ascertain the overall accuracy of the measurement result of the permanent instrumentation provided for the central chilled water system.

To meet the accuracy requirement, more than 80% of the heat balance (%) derived over the entire normal operating hours is to be within ± 5% for a period of one (1) week.

Detailed guidelines on the placement of temperature sensors and heat balance-substantiating test can be found in SS 591 – Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency as well as the Code on Periodic Energy Audit of Building Cooling System.

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

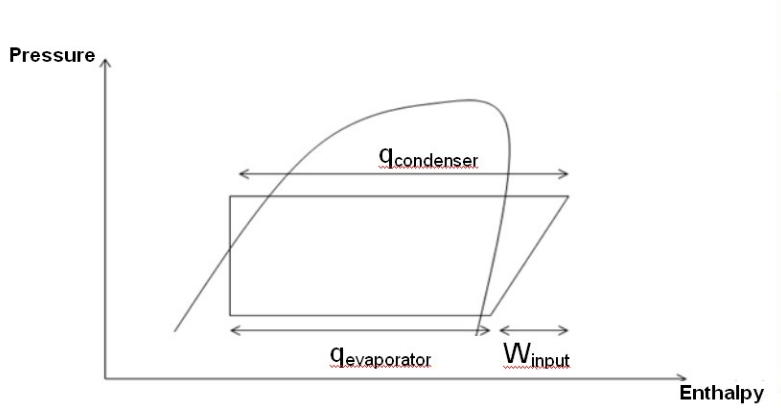
$$q_{condenser} = q_{evaporator} + W_{input.}$$

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,

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

Work Example

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

	(a) Chilled water supply temperature	(b) Chilled water return temperature	(c) Chilled water flow rate	(d) Condenser water supply temperature	(e) Condenser water return temperature	(f) Condenser water flow rate	(g) Chiller kWe	(h) Heat Gain	(i) Heat Rejected	(j) 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 °C x [(b) – (a)] / 3.517

Heat Rejected (i) = (f) x 4.19 kJ/kg °C x [(e) – (d)] / 3.517

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

(ii) Variable Refrigerant Flow (VRF) System

There shall be provision of permanent measuring instruments for monitoring of the energy performance of the Variable Refrigerant Flow (VRF) condensing units and air distribution systems, applicable to all sizes of air-conditioned areas.

- Gold^{PLUS} and Platinum Rating shall provide Instrumentation for all VRF systems and air distribution systems.
- Certified and Gold Rating: Instrumentation for VRF systems and air distribution systems that serve an aggregate conditioned floor area of 2000 m^2 or more.

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 (i.e. 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[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).

[4] DCS (District Cooling System) 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.

2. Electrical Sub-metering requirement

Sub-System for Metering	
Lifts and escalators	More than 5 numbers or sets or with sum of all feeders > 50 kVA
Mechanical Ventilation Systems	Total subsystem's load > 15 kW Sub-metering applicable to individual fan system motors that are more than 1.5 kW in the following areas • Normally Occupied Spaces • M & E Plant Rooms • Carparks
Centralised hot water	> 50 kW thermal heating capacity supply system
General power supply and lighting systems for tenancy areas and owners' premises	Sub-metering for tenancy areas and owners' premises are to be separated. The sub-circuits serving these areas can be provided based on sub-system basis and /or per floor level. If there is a need to cater to high plug loads or process loads exceeding 50 kVA in areas such as manufacturing, carpark, data centre, EV charging stations, please provide separate submetering for these specific areas to better manage the energy consumption, where relevant.

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

If there is a need to cater to high plug loads or process loads exceeding 50 kVA, please provide separate sub-metering for these specific loads or areas to better manage and audit the building energy consumption.

3. Envelope Thermal Transfer (International)

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 45 W/m^2.

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

Building Type	**Maximum ETTV (EE Pathway 2)**			
	Certified & Gold	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Office Buildings	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Retail Mall	45 W/m^2	40 W/m^2	38 W/m^2	35 W/m^2
Hotel	45 W/m^2	40 W/m^2	40 W/m^2	40 W/m^2
Schools and Colleges	45 W/m^2	40 W/m^2	38 W/m^2	35 W/m^2
Tertiary Institutions (University, and Polytechnics)	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Hospitals	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Polyclinic	45 W/m^2	40 W/m^2	40 W/m^2	40 W/m^2
Nursing/ Youth Home	45 W/m^2	40 W/m^2	40 W/m^2	40 W/m^2
High Tech/High Intensity	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Light Industrial	45 W/m^2	40 W/m^2	40 W/m^2	40 W/m^2
Warehouses/ Workshops/Others	45 W/m^2	40 W/m^2	40 W/m^2	40 W/m^2
Community Buildings	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Civic Buildings	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Cultural Buildings	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2
Sports and Recreation	45 W/m^2	40 W/m^2	40 W/m^2	40 W/m^2
Religious/ Places of Worship	45 W/m^2	40 W/m^2	38 W/m^2	38 W/m^2

Projects in China shall achieve the percentage of improvements on Thermal Performance of the Building Envelope and Façade from the China national standard (GB 50189-2015) for non-residential buildings. Refer to the table below.

ETTV	**45 W/m^2**	**40 W/m^2**	**38 W/m^2**	**35 W/m^2**
Percentage of Improvements from China National Standard (GB 50189-2015)	Required to meet China National Standard	10%	15%	20%

Documentation Requirements

At Design stage (New 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

Detailed guidelines on the methodology and formula to derive the ETTV can be found in the Code on Envelope Thermal Performance for Buildings. For developments consisting of more than one building, the weighted average of the ETTVs based on the facade areas of these buildings shall not exceed 45 W/m^2. There must also be due design consideration for the ETTV of each block to be of reasonable range (i.e. less than 45 W/m^2) to ensure good thermal comfort.

That is

$$ETTV_{\substack{\text{Weighted}\\\text{average}}} = \sum (ETTV_{bldg} \times A_{bldg}) / A_{devt}$$

where

$ETTV_{bldg}$ = ETTV for a building (W/m^2)

A_{bldg} = Summation of all facade areas that enclose all the air-conditioning areas (m^2) in a building

A_{devt} = Summation of total applicable facade areas of all buildings within the development (m^2) (i.e. $\sum A_{bldg}$)

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 Example 1

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:

$ETTV_{bldg1} = 35\ W/m^2$ $A_{bldg} = 5000\ m^2$

$ETTV_{bldg2} = 45\ W/m^2$ $A_{bldg} = 6800\ m^2$

$A_{devt} = 5000 + 6800 + 7500$

$= 19300\ m^2$

$ETTV_{bldg3} = 39\ W/m^2$ $A_{bldg} = 7500\ m^2$

Therefore

ETTV Weighted average

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

$$= \frac{(ETTV_{bld} \quad \times A_{bldg}\ ) + (ETTV_{bldg2} \times A_{bldg}\ ) + (ETTV_{bldg3} \times A_{bldg3})}{A_{dvpt}}$$

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

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

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

Worked Example 2

The base requirement shall deem to be satisfied if the building envelope design and glazing specifications meets. the 45 W/m^2. This method is not applicable to ETTV < 45 W/m^2.

Table C1 – Design Parameters for Building Envelope – Non-Residential Building	
Window to Wall Ratio (WWR)	**Shading Coefficients of Glass (SC_{glass})**
<0.20	≤0.51
0.20 to <0.25	≤0.41
0.25 to <0.30	≤0.35
0.30 to <0.35	≤0.30
0.35 to ≤0.40	≤0.27
0.40 to ≤0.50	≤0.22
Note: Window to Wall Ratio (WWR) refers to fenestration areas/gross area of the exterior wall.	

Proposed erection of an industrial warehouse building and office block with the following design parameters.

Façade Facing	Fenestration Areas	Gross Areas of Exterior Wall/Facade	Window to Wall Ratio WWR	Prescribed SC_{glass}	Proposed SC_{glass}	Remarks
Office block						
NE	410	970	0.42	0.22	0.22	ok
NW	480	1000	0.48	0.22	0.22	ok
SE	370	1010	0.37	0.30	0.27	ok
SW	160	500	0.32	0.27	0.27	Ok
Warehouse						
N	440	1000	0.44	0.22	0.22	Ok
S	330	1000	0.33	0.30	0.30	Ok
E	450	1010	0.37	0.22	0.22	Ok
W	240	1000	0.24	0.41	0.40	Ok

In this case, the selection of the proposed Shading Coefficients of Glass (SC_{glass}) is better than the prescribed value stated in Table C1 and therefore, it is deemed to have met the ETTV of 45 W/m^2.

4. Residential Envelope Thermal Transmittance Value (International)

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
Certified	22 W/m^2 or lower
Gold	22 W/m^2 or lower
Gold^{PLUS}	22 W/m^2 or lower
Platinum	20 W/m^2 or lower
SLE	20 W/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.

For projects in China, Certified, Gold and Gold^{PLUS} shall meet the Thermal Performance of the Façade requirements by the local/region authorities. Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.

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 (International for Dwelling Units)

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.

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

Criteria (Meet either one)	Certified and Gold	Gold[PLUS]	Platinum	SLE EE
(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.			
	30% of applicable spaces with unobstructed air flow between spaces and the outside	40% of living rooms and bedrooms with unobstructed air flow between spaces and the outside.	50% of living rooms and bedrooms with unobstructed air flow between spaces and the outside.	60% of living rooms and bedrooms 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 30% of the typical units 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 +/- 1.2	Micro level CFD to be conducted which demonstrate that 40% of the typical units 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 60% of the typical units 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 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 – For both options:

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

ii. *Dedicated power points provision should be provided to enable the installation of ceiling fans in the living room.*

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

<u>At Verification Stage:</u>

Submission of as built drawings of the approved floor plans.

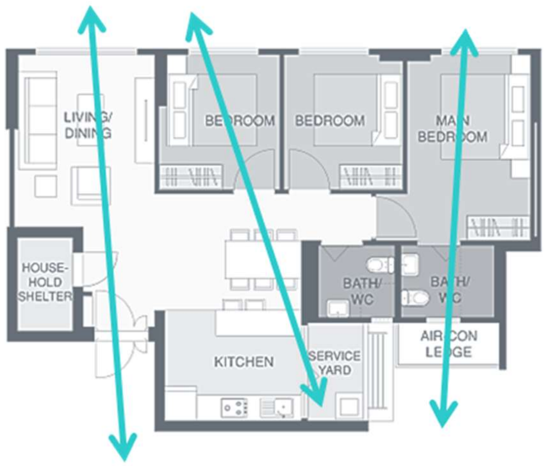
Guidance Notes

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 1

<table>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>Only living room is considered to have true cross ventilation. Bedroom do not meet the requirement.</td>
<td>Both the living room and all Bedrooms are considered to have true cross ventilation.</td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>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.</td>
<td>Only the living room and main bedroom is considered to have true cross ventilation. Common Bedrooms do not meet the requirement.</td>
</tr>
</table>

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 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

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

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

= 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 (International for 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 buildings.

Criteria	Certified and Gold	Gold^{PLUS}	Platinum	SLE EE
Common spaces to be designed with Passive strategies	All-natural ventilation with minimum coverage of 80%	All above ground lobbies and corridors are to be naturally ventilated		

Documentation Requirements

<u>At Design Stage:</u>

Submission of the following where applicable:

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

<u>At Verification Stage:</u>

- Submission of as built drawings of the approved spaces

7. Non-Air-conditioned Areas (International for 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			
	Certified & Gold	Gold^{PLUS}	Platinum	SLE EE
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/Others	-	-	30%	40%
Community Buildings	-	10%	30%	40%
Civic Buildings	-	-	15%	30%
Cultural Buildings	-	-	10%	20%
Sports and Recreation	-	-	15%	30%
Religious/ Places of Worship	-	-	15%	25%

Documentation Requirements

<u>At Design stage (New 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 GFA guidelines. If a particular non-air-conditioning area is counted as GFA, 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.

<u>Worked Example 1</u>

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.***

<u>Worked Example 2</u>

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

= 5,635.9 kWh

8. Air Conditioning Total System Efficiency (International for 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

Additional Requirements	New Buildings		Existing Buildings
	Certified and Gold	Gold^{PLUS} and Platinum	
AC TSE	0.85	0.8	0.9
Airside efficiency (for buildings supplied by DCS)	0.25	0.2	0.25

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

Additional Notes	New & Existing Buildings			
	Certified & Gold	GoldPLUS	Platinum	SLE EE
Airside efficiency for buildings supplied by DCS (kW//RT)	0.25	0.2	0.18	0.16

Building Type	Total System Efficiency (kW/RT)				
	Existing Buildings	New Buildings	New & Existing Buildings		
	Certified and Gold	Certified and Gold	Gold^{PLUS}	Platinum	SLE EE
Office Buildings	0.9	0.85	0.8	0.74	0.68
Retail Mall	0.9	0.85	0.8	0.74	0.68
Hotel	0.9	0.85	0.8	0.74	0.68
Schools and Colleges	0.9	0.85	0.8	0.75	0.7
Tertiary Institutions - University and Polytechnics	0.9	0.85	0.8	0.74	0.68
Hospitals	0.9	0.85	0.8	0.75	0.7
Polyclinic	0.9	0.85	0.8	0.75	0.7
Nursing/ Youth Home	0.9	0.85	0.8	0.75	0.7
High Tech/High Intensity	0.9	0.85	0.8	0.78	0.75
Light Industrial	0.9	0.85	0.8	0.75	0.7
Warehouses/ Workshops/Others	0.9	0.85	0.8	0.75	0.7
Community Buildings	0.9	0.85	0.8	0.75	0.7
Civic Buildings	0.9	0.85	0.8	0.75	0.7
Cultural Buildings	0.9	0.85	0.8	0.75	0.7
Sports and Recreation	0.9	0.85	0.8	0.75	0.7
Religious/ Places of Worship	0.9	0.85	0.8	0.75	0.7

Where there is a combination of water-cooled and air-cooled building cooling systems adopted, the respective TSEs shall be complied with, except for the building cooling system that serves an aggregate air-conditioned floor area of not more than 500 m^2.

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 buildings that tap on the existing chilled water plant for cooling provision, the compliance will be based on the TSE which is the combined system efficiency of the existing plant and air distribution systems. 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.

In any hotel building, a control device shall be installed in every guestroom for the purpose of automatically reducing the air-conditioning when a guestroom is not occupied.

Air-conditioning system shall be equipped with manual switches, timers or automatic controllers for shutting off part of the air-conditioning system during periods of non-use or reduced heat load.

The air-conditioning systems designed should be rightly sized with good configuration to cater to a wider range of operating cooling load conditions so that the systems could operate at optimal energy efficiency level and comfort most of the time. There should also be considerations to cater for night load conditions for better building energy effectiveness and performance.

The air-side component efficiency of the fan systems can be adjusted to allow for pressure drop adjustments where there is a need for more allowance due to functionality and activities as recommended in SS 553: Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.

Derive the Total System Efficiency (TSE) of the proposed building cooling system (in kW/RT) based on total power input of the air-conditioning plant (kWh) and air distribution system required over the total average cooling load requirement in RTh during building operating hours.

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

Note: 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.

Documentation Requirements

At Design stage (New 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.

The Energy Efficiency Ratio (EER) describes the system's level of efficiency and can be defined as the ratio of cooling capacity to effective electrical power input required to provide the cooling. The higher EER, the more energy efficient is the equipment/system.

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:

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

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

In the case of single and multiple split unitary conditioners, the efficiency can be computed based on the weighted Coefficient of Performance (COP) measured and registered in accordance with the applicable test standards under the Mandatory Energy Labelling Scheme (MELS) under the Energy Conservation Act.

$$COP_{weighted} = 0.4 \times COP_{100\%} + 0.6 \times COP_{50\%}$$

$COP_{100\%}$ is defined as the ratio of the cooling capacity to effective power input at full load cooling capacity

$COP_{50\%}$ is defined as the ratio of the cooling capacity to effective power input at 50% cooling capacity

The methodology in determining the TSE is as follows:

- Determine the cooling capacity requirement by conducting heat load calculations, cooling load profile and system sizing analysis for the various zones.
- Propose the required system configuration in terms of the number of indoor units and the outdoor condensing unit capacity by considering the total capacity and operational requirements.
- Where there is a combination of unitary air-conditioning systems serving different zones, the weighted system efficiency will be determined by pro-ration according to the respective cooling capacity served and expressed as follows:

$$TSE_{\text{Weighted average}} \text{ (in kW/RT)} = \frac{3.517 / \sum (\text{Cooling capacity x IEER})}{\text{Total cooling capacity}_{\text{Overall}}}$$

- As there could be a need to account for possible efficiency losses due to site inherent constraints and considerations, the site derating factor should be included to account for the system efficiency of the condenser units to better reflect its expected operating performance when measured.

<u>Water-Cooled/ Air-Cooled Chilled Water Plants</u>

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 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 = $0.331629 - 0.885676\,x + 0.605565\,x^2 + 0.948482\,x^3$

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	449 kWh	626 kWh	354 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

(b) 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

Worked 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						
			Full Installed Capacity (kW)	Weighted Cooling Capacity (kW)	100% EER (A)	75% EER (B)	50% EER (C)	25% EER (D)	IEER = (0.020 x A) + (0.617 x B) + (0.238 x C) + (0.125 x 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.

Worked 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.

Worked 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.

Worked Example 5 (for New Buildings)

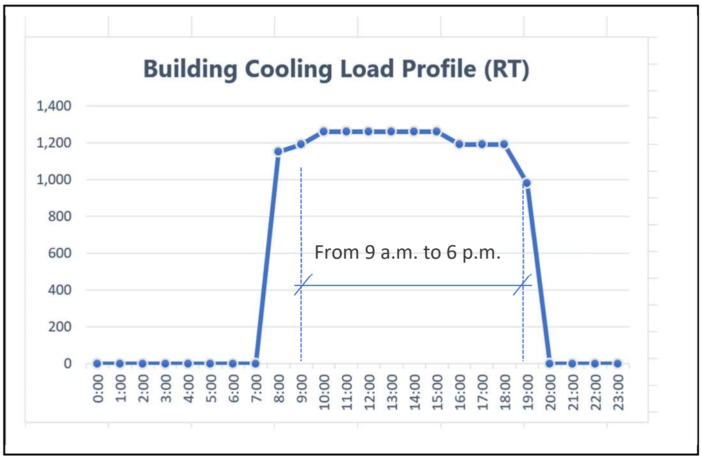
Computation of the Total System Efficiency (TSE) of a Water-Cooled Chilled-Water Plant with Primary Chilled-Water System

An office building has an air-conditioned floor area of 67,500 m^2 with cooling provision served by a chilled water plant. Variable speed drive (VSD) systems will be used in connection with the pump and fan applications to vary the speed of chilled-water pumps, condenser water pumps and cooling tower fans according to demand. The building operating hours specified for the office building is Monday to Friday from 9 a.m. to 6 p.m.

Step 1 – Determine the building cooling load profile

Simulation of annual building cooling load profile shall be carried out to determine the daily average cooling load profile and as follows :

Time	Average Cooling Load (RT)
8:00	**1,150**
9:00	**1,190**
10:00	**1,260**
11:00	**1,260**
12:00	**1,260**
13:00	**1,260**
14:00	**1,260**
15:00	**1,260**
16:00	**1,190**
17:00	**1,190**
18:00	**1,190**
19.00	**980**



Important note: It is essential to design and consider for other load conditions that are not within the building operating hours specified so as to minimise overall energy usage for cooling, although this is not required for TSE calculation purposes

Step 2 – Propose air-conditioning plant configuration and derive the respective power input of various system components

The proposed water-cooled chilled water plant configuration for the building operating hours specified are as follows:

- Chillers: 3 nos. x 700 RT (2 duty and 1 stand by)
- Chilled Water Pumps (CHWP): 3 nos. x 45 kW (2 duty and 1 stand by)
- Condenser Water Pumps (CWP): 3 nos. x 37 kW (2 duty and 1 stand by)
- Cooling Towers (CT): 3 nos. x 900 RT (2 duty and 1 stand by)
- Each cooling tower has 3 no. of 7.5 kW fans

Step 2(a) Centrifugal water-cooled chiller (700 RT)

Based on the performance data of the selected chillers from the manufacturer:

% Load	Capacity (RT)	Chiller Input Power (kW)	Chiller Efficiency kW/RT	Evaporator		Condenser	
				CHWST (°C)	CHWRT (°C)	CWST (°C)	CWRT (°C)
100	700	363	0.519	6.67	12.31	29.68	34.80
90	630	329	0.522	6.67	12.31	29.68	34.29
80	560	291	0.520	6.67	12.31	29.68	33.78
70	490	260	0.533	6.67	12.31	29.68	33.28

Installed capacity of the chillers (excluding standby) = 1,400 RT

Chillers configuration: 2 x 700 RT centrifugal chillers (operating)
1 x 700 RT centrifugal chiller (standby)

Based on the simulated total building load profile, the proposed chiller plant configuration is as follows:

Time	Cooling Load (RT)	No. of Chillers in Operation	Chiller Efficiency	Chiller Input Power (kW)
From 900 to 1000 and 1500 to 1800	1,190 RT	2 x 700RT @ 85%	0.521	620
From 1000 to 1500	1,260 RT	2 x 700RT @ 90%	0.522	658

Step 2(b) Chilled-water pumps (primary only):

- 2 nos. x 45 kW primary chilled-water pump to be installed with Variable Speed Drives (VSDs)
- Water flow rate per pump at full load (Q) = 106 L/s
- Operating static head (h)= 28 m
- Pump efficiency (η_p) = 86.8 %
- Motor efficiency (η_m) = 94.2 %

Power requirement of chilled-water pump at full load (kW) = $\frac{(Q)(\rho)(g)(h)}{(10^6)(\eta_p)(\eta_m)}$

where

Q: Water flow rate in L/s
ρ: Density of water in kg/m^3
g: Gravitational acceleration in m/s^2
h: Static pressure head m
η_p: Pump efficiency
η_m: Motor efficiency

Power requirement of chilled-water pump (kW) = $\frac{(106)(1000)(9.81)(28)}{(10^6)(0.868)(0.942)}$ = 35.61 kW

Power of 2 pumps @ full load = 35.61 kW x 2 = 71.22 kW

The following equation for pump part load power curve, referenced from Appendix 5.7 of the *Non-Residential Alternative Calculation Method Reference Manual 2013* by the California Energy Commission (CEC) takes into account for the losses during actual operating conditions and is to be used to estimate the pump power at the part load conditions.

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

Total Pump Power @ 85% part-load (kW) $\Big\}$ Total Pump power @ full load x Pump power ratio
= 71.22 x 0.66703 = 47.50 kW *(when x = 0.85, the corresponding power ratio is 0.66703)*

Total Pump Power @ 90% part-load (kW) $\Big\}$ Total Pump power @ full load x Pump power ratio when x = 0.90
= 71.22 x 0.77002 = 54.84 kW *(when x = 0.90, the corresponding power ratio is 0.77002)*

Cooling Load (RT)	No. of Chilled-Water Pumps in Operation	Total Operating Pump Power (kW)
1,190 RT	2 x 45 kW @ 85%	47.50
1,260 RT	2 x 45 kW @ 90%	54.84

Step 2(c) Condenser water pumps:

- 2 nos. x 55 kW condenser water pumps to be installed with VSDs
- Water flow rate for the condenser water pump (Q) = 132.5 L/s
- Operating static head (h) = 20 m
- Pump efficiency (η_p)= 88.5%
- Motor efficiency (η_m) = 94.7%

Power requirement of condenser water pump at full load (kW) = $\dfrac{(132.5)(1000)(9.81)(20)}{(10^6)(0.885)(0.947)}$ = 31.02 kW

Power of 2 pumps @ full load = 31.02 kW x 2
= 62.04 kW

Although VSDs are installed, the flow is fixed at 45Hz (90%). Hence, power consumption should be based on 90% part load condition.

Using the pump part load power curve equation,

Total Pump Power @90% part-load (kW) } Total Pump power @ full load x Pump power ratio
= 62.04 x 0.77002 = 47.77 kW *(when x = 0.90, the corresponding power ratio is 0.77002)*

Cooling Load (RT)	No. of Condenser Water Pumps in Operation	Total Operating Pump Power (kW)
1,190 RT	2 x 37 kW @ 90%	47.77
1,260 RT	2 x 37 kW @ 90%	47.77

Step 2(d) Cooling towers:

- 2 nos. of cooling towers to be installed with VSDs
- Heat rejection capacity per cooling tower = 900 RT
- Total heat rejection for 2 x cooling towers = 1,800 RT
- Each cooling tower with 3 fan cells with fan motor = 7.5 kW
- Fan motor efficiency = 92%

Input power per cooling tower = (7.5 kW x 3 fans) / 92% = 24.46 kW

Total input power for 2 nos. of cooling towers = 24.46 kW x 2 = 48.92 kW

In general, total heat rejection of chiller plant (kW) = Total Cooling load (kW) + Total electrical power input of chiller compressor (kW)

The following equation for cooling tower power adjustment curve, referenced from Appendix 5.7 of the Non-Residential Alternative Calculation Method Reference Manual 2013 by the California Energy Commission (CEC) is to be used to estimate the power input requirement at the part-load conditions to take into account losses during actual operating conditions:

Cooling tower fan power ratio = $0.331629 - 0.885676x + 0.605565x^2 + 0.948482x^3$
where x is the part-load ratio.

Fan power @76% part-load (kW) } Fan power @ full load x Cooling tower fan power ratio
= 48.92 x 0.42465
= 20.77 kW *(when x = 0.76, the corresponding power ratio is 0.42465)*

Fan power (kW) } Fan power @ full load x Cooling tower fan power ratio when x =0.80 @80% part-load
= 48.92 x 0.4963
= 24.28 kW *(when x = 0.80, the corresponding power ratio is 0.4963)*

Cooling Load	Chiller Input Power	Required Heat Rejection	Total Heat Rejection capacity for 2 no. of Cooling Towers	Percentage Loading for Required and Available Heat Rejection	Total Fan Motor Power at Required Part Load Condition
A	B	C = A + (B/3.517)	D	C / D x 100%	
1,190 RT	620	1,366.28	1,800	76%	20.78 kW
1,260 RT	658	1,447.08	1,800	80%	24.28 kW

Step 3 – Derive the Chilled Water Plant Efficiency during defined building operating hours.

Hours	Daily Average Cooling Load (RT)	Chillers Power Input (kW)	CHWP Power (kW)	CWP Power (kW)	CT Power (kW)	Total Power Input (kW)
9:00:00 AM	1,190	620	47.50	47.77	20.78	736.05
10:00:00 AM	1,260	658	54.84	47.77	24.28	784.89
11:00:00 AM	1,260	658	54.84	47.77	24.28	784.89
12:00:00 PM	1,260	658	54.84	47.77	24.28	784.89
1:00:00 PM	1,260	658	54.84	47.77	24.28	784.89
2:00:00 PM	1,260	658	54.84	47.77	24.28	784.89
3:00:00 PM	1,260	658	54.84	47.77	24.28	784.89
4:00:00 PM	1,190	620	47.50	47.77	20.78	736.05
5:00:00 PM	1,190	620	47.50	47.77	20.78	736.05
6:00:00 PM	1,190	620	47.50	47.77	20.78	736.05
Daily Consumption (9:00AM to 6:00 PM)	12,320 RTh	6,428 kWh	519.04 kWh	477.70 kWh	226.80 kWh	7,653.54 kWh
Chilled Water Plant Efficiency kW/RT		0.522	0.042	0.038	0.019	0.62

Proposed chiller water plant efficiency = Total Power Input /Total Cooling Load
= 7,665.44/12,320
= 0.62 kW/RT better than the minimum threshold of 0.63 kW/RT ok

Step 4 –Derive the Air Distribution System Efficiency and Total System Efficiency (TSE) during defined building operating hours

Hours	Daily Average Cooling Load (RT)	Total Power Input from Chilled Water Plant (kW)	Air Distribution System		Total System	
			Type	Air-Side (CF/VF) (kW)	Total Water + Air	
					kW	KW/RT
9:00:00 AM	1,190	736.05	AHU-VAV	262.84	998.89	0.839
10:00:00 AM	1,260	784.89	AHU-VAV	253.91	1038.80	0.824
11:00:00 AM	1,260	784.89	AHU-VAV	298.58	1083.47	0.860
12:00:00 PM	1,260	784.89	AHU-VAV	302.31	1087.20	0.863

Cont'd

Hours	**Daily Average Cooling Load (RT)**	**Total Power Input from Chilled Water Plant (kW)**	**Air Distribution System**		**Total System**	
			Type	Air-Side (CF/VF) (kW)	Total Water + Air	
					kW	KW/RT
1:00:00 PM	1,260	784.89	AHU-VAV	295.60	1080.49	0.858
2:00:00 PM	1,260	784.89	AHU-VAV	297.84	1082.73	0.859
3:00:00 PM	1,260	784.89	AHU-VAV	294.86	1079.75	0.857
4:00:00 PM	1,190	736.05	AHU-VAV	289.65	1025.70	0.862
5:00:00 PM	1,190	736.05	AHU-VAV	271.78	1007.83	0.847
6:00:00 PM	1,190	736.05	AHU-VAV	224.87	960.92	0.807
Daily Consumption (9:00AM to 6:00 PM)	12,320 RTh	7,653.54 kWh	-	2792.23 kWh	10445.77 kWh	0.848
Water-Side Component System Efficiency, kW/RT				0.62		
Air-Side Component System Efficiency, kW/RT				0.23		
Total System Efficiency (TSE), kW/RT				0.85 0.85 kW/RT		

The above methodology will also apply to air-cooled chilled water plant systems.

Consideration for Part Load Performance of VAV AHUs

In the case of Variable Air Volume (VAV) AHUs with VSDs, the part load fan power calculator from ASHRAE 90.1, Table G3.1.3.15, Part Load Performance for VAV Fan Systems, Method 2 – Part-Load Fan Power Equation can be used to account for the part load performance.

> 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)

In this instance, the power input can be derived based on the part-load fan ratio at 100%, 75%, 50% and 25%.

The fan ratios computed based on the equation are as follows:

x	1 (100%)	0.75 (75%)	0.50 (50%)	0.25 (25%)
Fan ratio	0.9991	0.60415938	0.299975	0.299975

To derive the air distribution system efficiency of the VAV-AHUs based on the same concept of IEER

IEER = (0.020 x A) + (0.617 x B) + (0.238 x C) + (0.125 x D)

where

A = EER or COP at full load

B = EER or COP at 75% load

C = EER or COP at 50% load

D = EER or COP at 25% load

In this instance,

$EER_{100\%}$ = Installed capacity at 100%/Fan part-load power ratio x power input

= 44.8*1.0 / (0.9991 x 5.2) = 8.623

$EER_{75\%}$ = Installed capacity at 75%/Fan part-load power ratio x power input

= 44.8*0.75 / (0.60415938 x5.2) = 10.695

$EER_{50\%}$ = Installed capacity at 50%/Fan part-load power ratio x power input

= 44.8*0.50 / (0.299975 x 5.2) = 14.360

$EER_{25\%}$ = Installed capacity at 25%/Fan part-load power ratio x power input

= 44.8*0.25 / (0.299975 x 5.2) = 7.180

Note that the minimum volume setpoint shall be 50% of the maximum design airflow rate. In this instance, the Fan part-load power ratio at 25% is to be the same as that at 50%.

System efficiency of VAV-AHU (in kW/RT) is as follows:

= 3.517/ (0.020 x 8.623) + (0.617 x 10.695) + (0.238 x 14.360) + (0.125 x 7.180)

= 0.317 kW/RT

Determine the overall weighted system efficiency of air distribution system by proration

$$\text{Weighted System Efficiency of air distribution system } \eta_{a\,(overall)} \text{ (in kW/RT)} = \left[\frac{\sum (\text{Cooling capacity} \times \eta_a)_i}{\text{Total Cooling Capacity}_{Overall}} \right]$$

$$\text{That is } \left[\frac{(2.67 \times 0.0569) + 2 \times (5.70 \times 0.0568) + 2 \times (27.85 \times 0.227) + (28.36 \times 0.317)}{98.13} \right]$$

= 0.229 kW/RT instead of 0.324 kW/RT

9. Air Conditioning System Efficiency (International for Residential Buildings)

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

Assessment Criteria

All new (dwelling units and common areas) and existing (common areas) residential building developments.

Certified and Gold	Gold^{PLUS}	Platinum	SLE EE
Single phase – 3 Ticks Grade 3[1]	Single phase - 4 Ticks Grade 2[1]	Single phase - 5 Ticks Grade 1[1]	

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. All other projects except China shall refer to Mandatory Energy Labelling Scheme (MELS) by National Environment Agency, Singapore.[1] Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

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 1

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 (International for 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	Certified and Gold	Gold^{PLUS}	Platinum EE	SLE
Energy Efficient Dwelling Unit Equipment Selection	3 Tick or Grade 3[1] where provided			5 Tick or Grade 1[1] where provided

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 such as lifts and escalators and to reduce their energy consumption by adopting energy-efficient technologies and controls. The lift and escalator systems provided for the buildings are required to be equipped with Variable Voltage Variable Frequency (VVVF) and sleep mode features. In the case of escalators, the provision of occupancy sensors, standby speed and/or standby stop features will be required, where relevant.

Guidance Notes

Other than the provision of vertical transportation systems that come with VVVF and sleep mode features, there are other energy-efficient technologies such as regenerative drive or deployment of advanced dispatching software that could reduce occupant wait time while reducing energy use by up to 50% compared to traditional systems.

Assessment Criteria

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

Certified and Gold	Gold^{PLUS} EE	Platinum EE	SLE
VVVF and Sleep Mode			VVVF & Sleep Mode Regenerative drive for 12 storeys or more

Documentary Requirements

At Design stage (New Buildings) :

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

At Verification stage (New Buildings) & Existing Buildings:

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

12. Lighting Power Budget (International)

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

Guidance Notes

Other than the provision of energy-efficient lighting, it is important to ensure that proper lighting level is considered. For guidance on the illuminances recommended for different applications or spaces given, reference is to be made to Singapore Standard SS 531 – Code of practice for lighting of workplaces.

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 and Pathway 3 The maximum Lighting power budget for artificial lighting shall be less than or equal to the maximum stated in SS 530 (in the last column in Table 2A).

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

TABLE 2A (International)

Description	Pathway 2 - LPB Targets (W/m2)				SS 530
	Certified and Gold	Gold^{PLUS}	Platinum	SLE EE	Reference Lighting Power Budget (W/m^2)
Office, Work and Study					
Offices	7.2	6	5.5	5	12
Meeting Room	7.2	6	5.5	5	12
Copy/Print Rooms	7.2	6	5.5	5	12
Classrooms	7.2	6	5.5	5	12
Lecture Theatre	7.2	6	5.5	5	12
Computer Rooms	7.2	6	5.5	5	12
Reading Areas	7.2	6	5.5	5	12
Laboratories	9.6	8	7	6	16
Atria, Halls and Retail					
Entrance Hall	6.0	6	5	4	10
Atriums	6.0	6	5	4	10
Retail Atriums	6.0	6	5	4	10
Retail Corridors (Interior)	4.2	4	3.5	3	7
Concourse	6.0	5	4.5	3.5	10
Lobby	6.0	5	4.5	3.5	10
Auditorium	6.0	5	4.5	3.5	10
Concert Hall	6.0	6	5	4	10
Multi Purpose Hall	9.6	8	7	6	16
Conference Hall	9.6	8	7	6	16
Retail (General Lighting)	9.0	10	7	6	15

Description	Pathway 2 - LPB Targets (W/m2)				SS 530
	Certified and Gold	Gold[PLUS]	Platinum	SLE EE	Reference Lighting Power Budget (W/m^2)
Atria, Halls and Retail					
Retail - Jewellery (Total)	21.0	23	19	14	35
Retail - Furniture, clothing & accessories, cosmetics, art (Total)	15.0	18	14	10	25
Retail - Supermarket, vehicle, sporting goods, stationary, hardware, others (Total)	12.0	15	11	8	20
Food & Bevarge Areas					
Food Courts & Hawker Centres	6.0	6	5	4	10
Canteens	6.0	6	5	4	10
Restaurants	7.2	7	6	5	12
Lounges	7.2	7	6	5	12
Bars	7.2	7	6	5	12
Transport and Goods					
Corridors	4.2	4	3.5	3	7
Stairs, Escalators, Travelators	3.6	6	4.2	3.5	6
Lift Lobbies	4.2	4	3.5	3	7
Warehouses	4.2	6	5	4	7
Storage Areas	6.0	6	5	4	10
Carpark	3.0	2.5	2.25	2	5
Rest, Clean, Exercise and Play					
Hotel Guest Rooms[6]	7.2	9	7	5	12
Toilets	6.0	6	5	4	10
Changing Rooms	6.0	6	5	4	10
Laundries	6.0	6	5	4	10
Washing Areas	6.0	6	5	4	10
Gymnasium & Physical Exercise Areas	6.6	7	6	4.5	11
Manufacturing & Maintenance					
Mechanical & Electrical Rooms	6.0	6	5	4	10
Manufacturing (general)	7.8	8	6.5	5.5	13
Manufacturing (electronic, fine detail or assembly)	8.4	8	7	6	14

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

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

Documentation Requirements

At Design stage (New 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
- Calculation of Lighting Power Budget (in Excel) based on actual installation and percentage improvement over the prescribed lighting power budget.

Worked Example 1

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)	Ballast 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, Table 2A)	Platinum total Power (A x H)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Office Type 1	1500	LED	18	1	450	8100	5.40	5.5	8250
Office Type 2	1250	LED	18	1	380	6840	5.47	5.5	6875
Meeting Room	75	LED	18	1	18	324	4.32	5.5	412.5
Corridors 1	150	LED	14	1	35	490	3.27	3.5	525
Corridors 2	205	LED	14	1	40	560	2.73	3.5	717.5
Atrium	850	LED	20	1	170	3400	4.00	5	4250
Carparks	7500	LED	28	1	850	23800	3.17	2.25	16875
Staircase	300	LED	28	1	40	1120	3.73	4.2	1260
Male toilets	45	LED	14	1	18	252	5.60	5	225
Female toilets	45	LED	14	1	18	252	5.60	5	225
					Total	***45138***	***3.79***	***3.32***	***39615***

In this case, lighting performance does not meet the maximum lighting power budget as prescribed in table 2A for GM Platinum certification.
The shortfall is 45,138 – 39,615 = 5,523W

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:
5,523W x 55(hours) x 52 (weeks) = 15,795,780Wh/yr (15.8 MWh/yr)

Pathway 2 Renewable safety factor for deficiencies for an office building is 1.1.

Onsite renewables needed = 15.8 x 1.1 = 17.38MWh/yr (17,380 kWh/yr)

13. Mechanical Ventilation (International)

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 Base Sustainability Requirements. 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.

For Pathway 1, 2 & 3 Mechanical ventilation systems for normally occupied spaces shall be designed to be at least **10% more energy efficient** than the prescribed standard stated in SS 553; and meet the efficiency requirements in the table below:

TABLE 2B Mechanical Ventilation

Fan System	Efficiency (W/CMH)			
	Certified and Gold	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Nameplate motor power ≥ 4kW	0.32	0.32	0.28	0.25
Nameplate motor power < 4kW	0.17			

Documentation Requirements

At Design stage (New 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

To reduce energy required to supply and distribute fresh air within the space through the use of energy-efficient mechanical ventilation systems and controls.

(i) Mechanical ventilation systems for normally occupied spaces shall be designed to be at least **10% more energy efficient** than the prescribed standard stated in SS 553; and

(ii) Provision of Carbon Monoxide (CO) detection sensor controls with Variable Speed Drives (VSDs) to regulate demand for mechanical ventilation in car parks.

The energy efficiency improvement can be considered based on Option (1) Fan System Motor Nameplate Power or Option (2) Fan System Input in accordance with SS 553 and as stated in Table below.

Table C7 – Baseline Standard for Mechanical Ventilation System for Normally Occupied Spaces
Fan Power Limitation for Constant Volume and Variable Volume
Option 1: Fan system motor nameplate ⟶ Allowable nameplate motor: 0.35 W/CMH
Option 2: Fan System Input ⟶ Allowable Fan System Input Power: ≤ 0.3 + A* W/CMH
***A is the sum of the pressure drop adjustments (in Pa) that can be considered according to the recommendation provided in Table 2b of SS 553 and are subject to BCA's evaluation.**

Worked Example 1 - For Pathway 1, 2 & 3

The small industrial factory development comprises a 4-storey block with 6 workshop spaces that are mechanically ventilated with the following schedule and information.

Option 1 – Fan Motor Nameplate Power

MV Fan Schedule									
Work shop	Fan Ref	Fan Type	Floor Areas (m^2)	Space Height (m)	Air Change per Hour (ACH)	Air Flow Rate (CMH)	External static (Pa)	Motor Nameplate Power (kW)	Fan Efficiency (W/CMH)
1	FAF 1-1	Axial	650	10	6	39000	650	11	0.28
2	FAF 1-2	Axial	650	10	6	39000	650	11	0.28
3	FAF 1-3	Axial	650	10	6	39000	650	11	0.28
4	FAF 1-4	Axial	500	8	6	24000	500	5.5	0.23
5	FAF 1-5	Axial	500	8	6	24000	500	5.5	0.23
6	FAF 1-6	Axial	500	8	6	24000	500	5.5	0.23
1	EAF 1-1	Axial	650	10	6	39000	650	11	0.28
2	EAF 1-2	Axial	650	10	6	39000	650	11	0.28
3	EAF 1-3	Axial	650	10	6	39000	650	11	0.28
4	EAF 1-4	Axial	500	8	6	24000	500	5.5	0.23
5	EAF 1-5	Axial	500	8	6	24000	500	5.5	0.23
6	EAF 1-6	Axial	500	8	6	24000	500	5.5	0.23

Total Air-Flow Rate	378000 CMH
Total Fan Power (Design)	99 kW
Total Fan Power (Baseline)	378000 CMH x 0.35 W/CMH = 132.3 kW
% Improvement over Baseline	25 % over baseline > 10% ok

Option 2 – Fan Motor Input Power

MV Fan Schedule									
Work shop	Fan Ref	Fan Type	Floor Areas (m^2)	Space Height (m)	Air Change per Hour (ACH)	Air Flow Rate (CMH)	External static (Pa)	Fan System Input Power (kW)	Fan Efficiency (W/CMH)
1	FAF 1-1	Axial	650	10	6	39000	650	8.28	0.21
2	FAF 1-2	Axial	650	10	6	39000	650	8.28	0.21
3	FAF 1-3	Axial	650	10	6	39000	650	8.28	0.21
4	FAF 1-4	Axial	500	8	6	24000	500	3.92	0.16
5	FAF 1-5	Axial	500	8	6	24000	500	3.92	0.16
6	FAF 1-6	Axial	500	8	6	24000	500	3.92	0.16
1	EAF 1-1	Axial	650	10	6	39000	650	8.28	0.21
2	EAF 1-2	Axial	650	10	6	39000	650	8.28	0.21
3	EAF 1-3	Axial	650	10	6	39000	650	8.28	0.21
4	EAF 1-4	Axial	500	8	6	24000	500	3.92	0.16
5	EAF 1-5	Axial	500	8	6	24000	500	3.92	0.16
6	EAF 1-6	Axial	500	8	6	24000	500	3.92	0.16

Total Air-Flow Rate	378000 CMH
Total Fan Power (Design)	73.20 kW
Total Fan Power (Baseline)	378000 CMH x 0.30 W/CMH = 113.4 kW
% Improvement over Baseline	35% over baseline > 10% ok

Worked Example 2

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) :

- 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

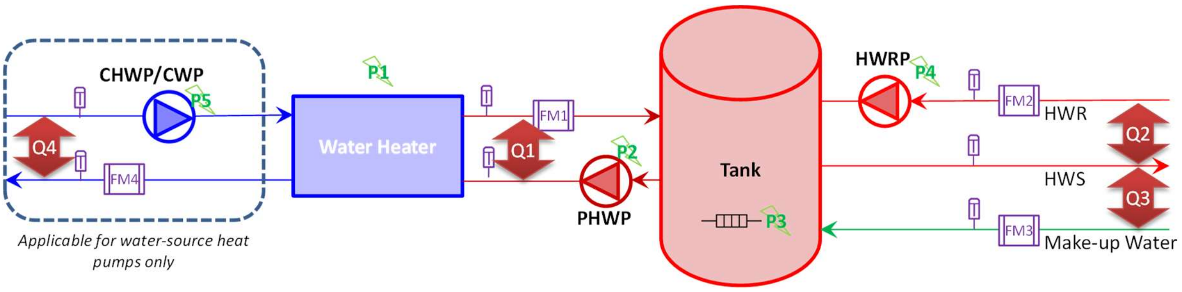
Only hot water systems with supply temperature up to 60°C are assessed. Systems which require higher temperature supply i.e. steam for lab and hot water for kitchen are excluded. If the make-up water to these higher temperature supplies are pre-heated to 60°C using heat pump system, the pre-heating heat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

η : 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 1

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

<u>At Design stage (New Buildings)</u>

- 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

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

- 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

At Design stage (New Buildings):

- 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

At Verification stage (New Buildings) & Existing Buildings:

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

At Design stage (New Buildings) :

- 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)

At Verification stage (New Buildings) & Existing Buildings:

- 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:

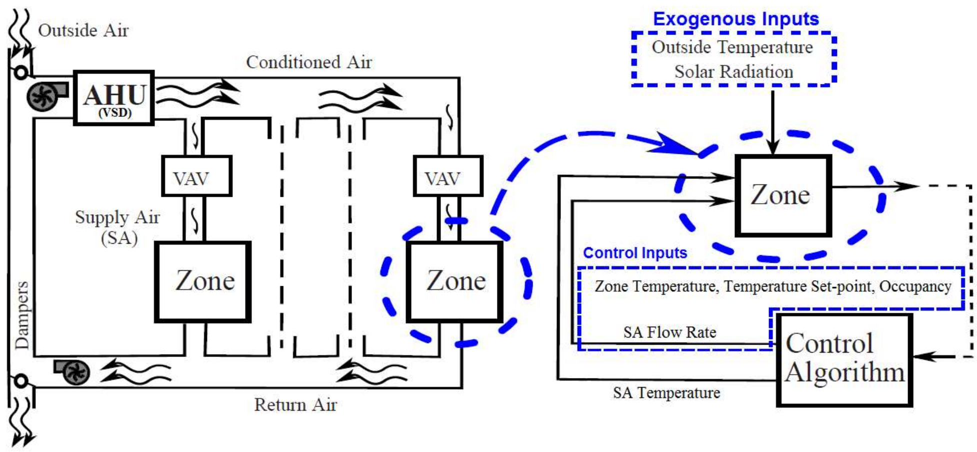
- Occupancy-based sensing: Control is exercised based on measured occupancy, e.g. number of occupants.
- In hotel buildings, a control device shall be installed in every guestroom to automatically reduce the air-conditioning loads when a guestroom is not occupied.
- Location plans of the relevant sensors 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

At Design stage (New Buildings):

- 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.
- Onsite renewable sources refer to renewable energy generated within the project boundary under the scope of Green Mark Assessment.
- Where the project is using Renewable Energy Certificate (REC), the length of time of REC commitment is minimally three years with commitment of re-certification.

At Verification stage (New Buildings) & Existing Buildings:

- 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•yr) (C/B)				

Guidance Notes

Worked Example 1

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%)	

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

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 (International)

OFFICE				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	38	38
Non-AC Areas	-	-	10%	25%
ACMV TSE	0.85 (New Buildings) 0.9 (Existing Buildings)	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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS} shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.

Retail Mall (International)

RETAIL				
PARAMETER	**Certified & Gold**	**Gold PLUS**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	38	35
Non-AC Areas	-	-	5%	15%
ACMV TSE	0.85 (New Buildings) 0.9 (Existing Buildings)	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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold PLUS shall achieve at least 10% improvements, Platinum shall achieve at least 15% improvements, and SLE Platinum shall achieve at least 20% improvements on the Thermal Performance of the Façade from national local/region authorities.

Hotel (International)

HOTEL				
PARAMETER	**Certified and Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	40	40
Non-AC Areas	-	-	10%	30%
ACMV TSE	0.85 (New Buildings) 0.9 (Existing Buildings	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. 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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS}, Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.

Schools and Colleges (International)

PRIVATE SCHOOLS				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	38	35
Non-AC Areas	-	-	20%	40%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS} shall achieve at least 10% improvements, Platinum shall achieve at least 15% improvements, and SLE Platinum shall achieve at least 20% improvements on the Thermal Performance of the Façade from national local/region authorities.

Tertiary Institutions - University and Polytechnics (International)

INSTITUTE OF HIGHER LEARNING				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	38	38
Non-AC Areas	-	-	20%	50%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings)	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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] *For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS} shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.*

Hospitals (International)

<table>
<tr><th colspan="5">HOSPITALS</th></tr>
<tr><th>PARAMETER</th><th>Certified & Gold</th><th>GoldPLUS</th><th>Platinum</th><th>SLE EE</th></tr>
<tr><td>Reduced Heat Gain (ETTV) [1]
[New Development only]</td><td>45</td><td>40</td><td>38</td><td>38</td></tr>
<tr><td>Non-AC Areas</td><td>-</td><td>-</td><td>-</td><td>15%</td></tr>
<tr><td>ACMV TSE</td><td>0.85 (New Buildings)
0.9 (Existing Buildings</td><td>0.8</td><td>0.75</td><td>0.7</td></tr>
<tr><td>Heat Recovery</td><td>-</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="4">Table 2A</td></tr>
<tr><td>Mechanical Ventilation</td><td colspan="4">Table 2B</td></tr>
<tr><td>Integrated Energy Management & control Systems</td><td>-</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="4">1.1</td></tr>
</table>

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). GoldPLUS shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.

Polyclinics (International)

POLYCLINIC				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	40	40
Non-AC Areas	-	10%	30%	50%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV Unitary	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

[1] *For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS}, Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.*

[2] *Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.*

Nursing and Youth Homes (International)

NURSING/ YOUTH HOME				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	40	40
Non-AC Areas	-	10%	40%	60%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV Unitary	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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 bedroom for the purpose of automatically switching off the lighting and reducing the air-conditioning loads when a guestroom is not occupied.
On-Site Renewables - *replacement to make up any deficiencies from the above list, with safety factor*	1.5			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS}, Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.

[2] Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

Industrial – High Technology (International)

HIGH TECH/HIGH INTENSITY				
PARAMETER	**Certified & Gold**	**Gold[PLUS]**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	38	38
Non-AC Areas	-	-	-	10%
ACMV TSE	0.85 (New Buildings) 0.9 (Existing Buildings	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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold[PLUS] shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.

Light Industrial (International)

LIGHT INDUSTRIAL				
PARAMETER	**Certified & Gold**	**Gold[PLUS]**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	40	40
Non-AC Areas	-	-	15%	30%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV (Unitary)	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

[1] *For projects in China,* Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold[PLUS], Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.

[2] Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

Warehouses, Workshops and Other Industrial (International)

WAREHOUSES/ WORKSHOPS/OTHERS				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	40	40
Non-AC Areas	-	-	15%	30%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV (Unitary)	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase – 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

[1] *For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS}, Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.*

[2] *Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.*

Community Buildings (International)

COMMUNITY BUILDINGS				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	38	38
Non-AC Areas	-	10%	30%	40%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV (Unitary)	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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 1: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

Note 2: Community Buildings include Community Centres, and Childcare Centres

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS} shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.

[2] Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

Civic Buildings (International)

CIVIC BUILDINGS				
PARAMETER	**Certified & Gold**	**Gold^PLUS**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	38	38
Non-AC Areas	-	-	15%	30%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV (Unitary)	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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 1: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

Note 2: Civic Buildings include Courts, Police Stations, and Fire Stations

[1] *For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^PLUS shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.*

[2] *Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.*

Cultural Institutions (International)

CULTURAL BUILDINGS				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV) [1] [New Development only]	45	40	38	38
Non-AC Areas	-	-	10%	20%
ACMV TSE	0.85 (New Buildings) 0.9 (Existing Buildings	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 1: Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

Note 2: Cultural Buildings include Performing Arts, Library, Museum and Art Gallery

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS} shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.

Sports and Recreation (International)

SPORTS AND RECREATION				
PARAMETER	**Certified & Gold**	**Gold^{PLUS}**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	40	40
Non-AC Areas	-	-	15%	30%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV (Unitary)	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

[1] For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold^{PLUS}, Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.

[2] Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

Religious / Places of Worship (International)

RELIGIOUS/ PLACES OF WORSHIP				
PARAMETER	**Certified & Gold**	**Gold PLUS**	**Platinum**	**SLE EE**
Reduced Heat Gain (ETTV)[1] [New Development only]	45	40	38	38
Non-AC Areas	-	-	15%	25%
ACMV TSE; **OR**	0.85 (New Buildings) 0.9 (Existing Buildings	0.8	0.75	0.7
ACMV (Unitary)	Three phase - 3 Ticks Single phase - 3 Ticks Grade 3[2]	Three phase - 3 Ticks Single phase - 4 Ticks Grade 2[2]	Three phase - 4 Ticks Single phase - 5 Ticks Grade 1[2]	
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			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning.

[1] *For projects in China, Certified and Gold shall meet the Thermal Performance of the Façade requirements by China national standard (GB 50189-2015). Gold PLUS shall achieve at least 10% improvements, Platinum and SLE shall achieve at least 15% improvements on the Thermal Performance of the Façade from national local/region authorities.*

[2] *Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.*

Residential (International)

RESIDENTIAL				
PATHWAY 2 - FIXED METRICS				
PARAMETER	**Certified and Gold**	**GoldPLUS**	**Platinum**	**SLE EE**
Reduced Heat Gain (RETV) [1] [New Development only]	22	22	20	20
Ventilation Performance of Dwelling Units [New Development only]	<u>OPTION 1: PLAN LEVEL</u> **30%** of applicable spaces with unobstructed air flow between spaces and the outside <u>OPTION 2: SIMULATION</u> - Area weighted average wind speed 0.4m/s for 30% of applicable areas. OR - PMV of +/- 1.2	<u>OPTION 1: PLAN LEVEL</u> **40%** of applicable spaces with unobstructed air flow between spaces and the outside <u>OPTION 2: SIMULATION</u> - Area weighted average wind speed 0.4m/s for 40% of applicable areas. OR PMV of +/- 1	<u>OPTION 1: PLAN LEVEL</u> **50%** of applicable spaces with unobstructed air flow between spaces and the outside <u>OPTION 2: SIMULATION</u> Area weighted average wind speed 0.4m/s for 60% of applicable areas. OR - PMV of +/- 0.8	<u>OPTION 1: PLAN LEVEL</u> **60%** of applicable spaces with unobstructed air flow between spaces and the outside <u>OPTION 2: SIMULATION</u> Area weighted average wind speed 0.6m/s for 60% of applicable areas. OR - PMV of +/- 0.6
	NOTE – For both options, the main entrance door (where the developer provides a lockable gate / grille), all windows and internal doors are assumed to be open. *Simulations are to be conducted in accordance with the Green Mark 2021 Guideline for Computational Fluid Dynamics Simulation. PMV recognises the use of assisted ventilation where this is provided once minimum wind speeds are met.*			
ACMV [New Development includes Dwelling Units and common facilities]	Single phase – 5 Ticks Grade 1[2] **80%** of applicable spaces	Single phase - 4 Ticks Grade 2[2] **100%** of applicable spaces	Single phase - 5 Ticks Grade 1[2] **100%** of applicable spaces	
Energy Efficient Dwelling Unit Equipment Selection [New Development only]	3 Ticks or Grade 3[1] where provided			5 Ticks or Grade 1[1] where provided
Ventilation Performance – Common Areas	All above ground lobbies and corridors to be naturally ventilated			
Vertical Transportation System	VVVF and Sleep Mode			VVVF & Sleep Mode Regenerative Drive for 12 Storeys or more.
Lighting Power Budget	TABLE 2A			
Mechanical Ventilation	TABLE 2B			
Demand Control Systems	Lighting and ventilation controls (timer, sensor, dimming, switches) for common areas such as corridors, function rooms, gyms, pavilions etc			
On-Site Renewables to offset common area consumption	-			30% replacement of club house, function room, swimming pool pumps, gym and MCST office electricity consumption
On-Site Renewables - *replacement to make up any deficiencies from the above, excluding RETV and Dwelling Unit Ventilation Performance, with safety factor*	1.2			

Note: Pathway 2 - Fixed Metrics can be applied to non-tropical climate, TSE and Air fan System are not applicable to projects without air-conditioning. All other projects except China shall refer to Mandatory Energy Labelling Scheme (MELS) by National Environment Agency, Singapore.

[1] For projects in China, Certified, Gold and GoldPLUS shall meet the Thermal Performance of the Façade requirements by the local/region authorities. Platinum and SLE shall achieve at least 10% improvements on the Thermal Performance of the Façade from national local/region authorities.[2] Projects in China shall refer to the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency Labels required by Energy Efficiency Label Management Law in China. The minimum allowable values of the energy efficiency and energy grades for room air conditioners shall refer to the standards for GB 21455-2019.

Other Base Sustainability Requirements for New Developments

NRB06 Maintenance of Building Cooling System Performance

Intent

Ensure adequate access space provision for building cooling system maintenance and upgrade so as to upkeep the system energy performance during operation.

Applicability & Scope

Applicable to new building developments with centralised chilled water plant system and air distribution systems. In the case of existing buildings with major additions and alterations /retrofits, the compliance with any of the requirements under NRB06-1 to NRB06-4 can be considered as alternative solutions under the Carbon Reduction Measures – Section 2 Sustainable Design Strategies.

Requirements

A building shall be designed and constructed with access space provisions to facilitate maintenance of building cooling system performance. The access space provisions for the following equipment shall comply with either the service clearances as per manufacturers' specification or the specifications set out in NRB06-1 to NRB06-4, whichever governs.

NRB06-1. Chillers

Access space provisions shall be as follows:

(a) Clearance of 2.0 m or more at the front of chiller unit piping section for tube maintenance and cleaning, repair and replacement of bigger components;

(b) Clearance of 1.2 m or more between the chillers measured from plinth to plinth for regular maintenance; and

(c) Clearance of 1.5 m or more above the chiller for maintenance, overhaul or replacement.

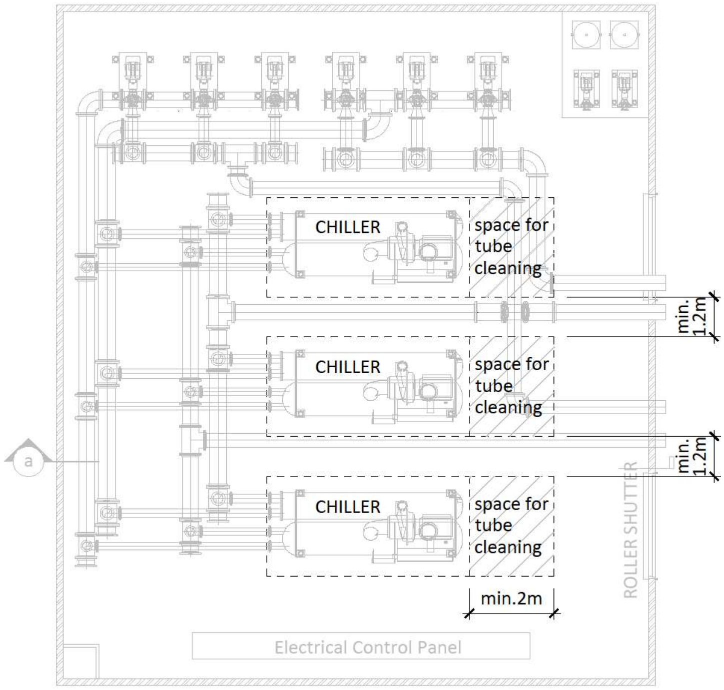


Figure 06-1 – Access space for the chillers

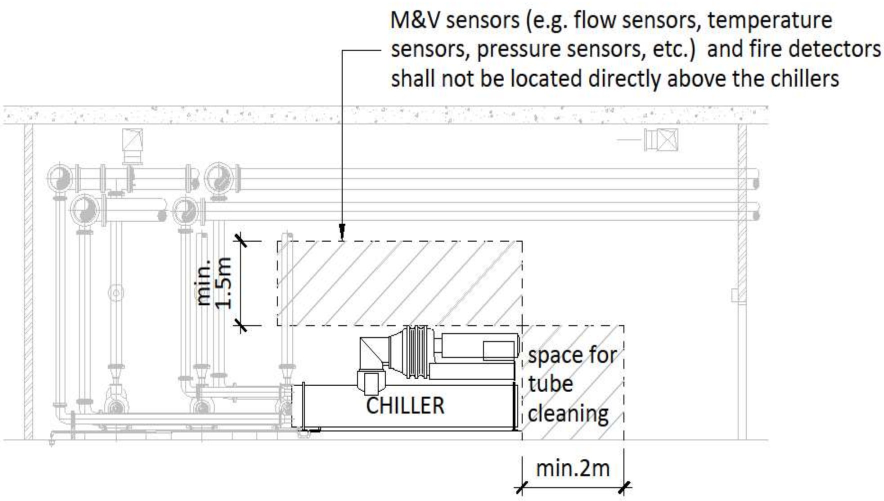


Figure 06-2 – Head room requirements for the chillers

Documentation Requirements

<u>At Design stage:</u>

- Architectural/mechanical plan drawings indicating the chiller plant location; and

- ACMV chiller plant layout drawing showing the access space provisions or tender specifications indicating the access space provisions.

.

<u>At Verification stage:</u>

The following documents are to be made available on-site or upon request.

- Shop drawing/as-built chiller plant layout and sectional drawing indicating the access space provisions based on actual equipment selection; and
- Photographs showing the clear access space provisions for chiller plant equipment including M&V sensors.

NRB06-2. Pump Systems

Access space provisions shall be as follows:

a) Except for the areas where the pipes are connected, clearance of 0.6 m or more is to be provided around the pump for regular maintenance; and

b) Clear headroom of 1.0 m or more above the pump and motor to facilitate maintenance, overhaul or replacement.

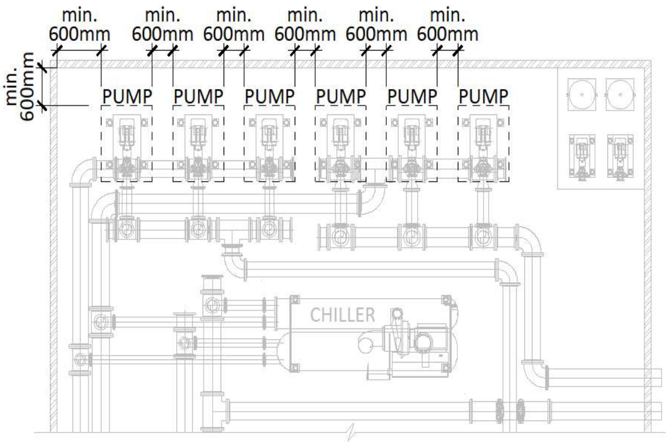


Figure 06-3 – Access space for the pump systems

Documentation Requirements

At Design stage (New Buildings)

- Chiller plant layout drawing showing the access space provisions and headroom requirement; and
- Tender specification indicating the access/space provisions for chilled water pumps and condenser water pumps.

At Verification stage:

The following documents are to be made available on-site or upon request.

- Shop drawings/as-built drawings highlighting the space and headroom provision for pumps with dimensions as per the actual equipment selection; and
- Photographs showing the provision of access space and headroom.

NRB06-3. Cooling Towers

Maintenance provisions shall be as follows:

- Provision of maintenance platform, stairs and catwalks of 600 mm width or more with handrails around the cooling towers and access to the level for periodic maintenance and the inspection of water basin and fill media; and
- Clear distance of 2.0 m or more from the top of cooling towers to the location of the trellis, where applicable.

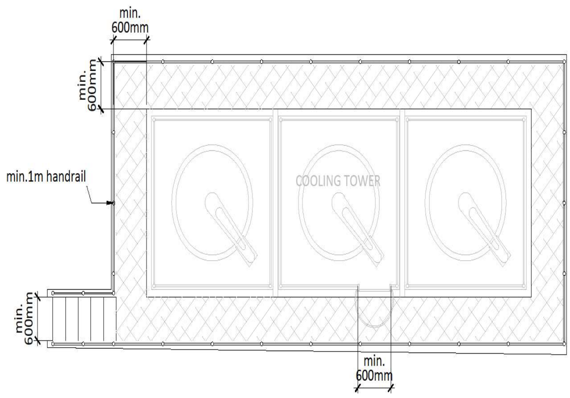


Figure 06-4 – Maintenance provisions for the cooling towers

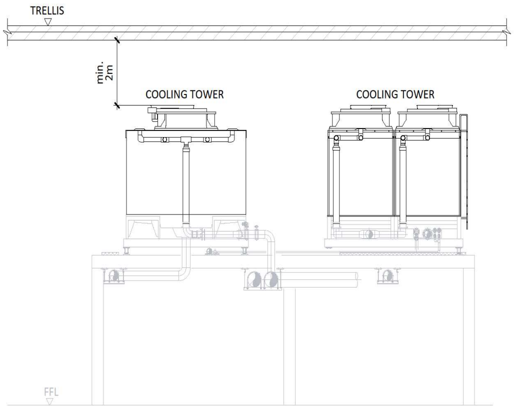


Figure 06-5 – Clearance from top of cooling towers to the location of the trellis

Note(1): In the event that the clearance from the top of cooling towers to the location of trellis could not be met due to height restrictions, the trellis must be designed to be easily removable for access and maintenance.

Note(2): Proper clearances on all sides of the cooling tower should be provided in accordance with the manufacturer's technical recommendation to ensure the heat rejection performance of cooling towers is not affected or should not be less than the lateral width of the cooling tower, whichever governs.

Documentation Requirements

At Design stage (New Buildings)

- ACMV plan drawing showing the requirement on the maintenance platform; and
- Tender specifications indicating the maintenance platform requirements.

At Verification stage:

- The following documents are to be made available on-site or upon request.
- ACMV shop drawing/as-built drawings indicating the permanent stairs and catwalk around the cooling tower; and
- Photographs showing the catwalk and maintenance platform installed.

NRB06-4. Air Distribution Systems

Maintenance provisions shall be as follows:

(a) Air handling units (AHUs) of *cooling capacity greater than 35 kW shall be floor mounted* as stipulated in SS 553; and

(b) For AHUs that are floor mounted, the access space provisions are as follows:

(i) AHU access – Provide minimum 1.0 m clearance from the AHU room door entrance to the AHU for general maintenance;

(ii) Cooling coil pipe and filter access – Provide minimum 800 mm clearance after pipe connection to facilitate cooling coil cleaning and filter access;

(iii) Fan access – Provide minimum 800 mm clearance for fan/motor access and maintenance (if the access is not from the cooling coil connection side); and

(iv) AHU side and back clearance – Provide minimum 600 mm clear width for general access and maintenance.

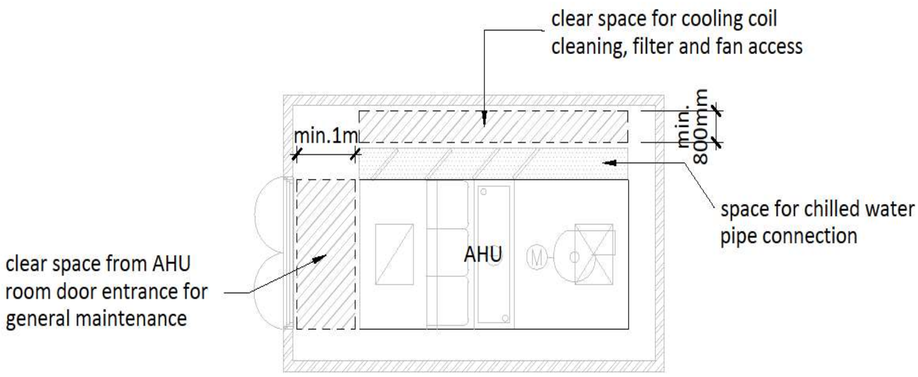


Figure 06-6 – Space provisions for Air Handling Units

Note: All AHUs of cooling capacity greater than 35 kW shall be floor mounted

Documentation Requirements

At Design stage (New Buildings)

- Tender specifications indicating the access/space provisions for air handling units (AHUs).

At Verification stage :

- The following documents are to be made available on-site or upon request.
- As-built drawings/shop drawings (including plan drawing/section) highlighting the AHU room access space provision; and;
- Photographs showing the access space provisions.

References

- Design for Maintainability Guide on Non-Residential Buildings published by the Building and Construction Authority (BCA)
- Maintainability Section under the Green Mark 2021 Framework

Carbon Reduction Measures for New Developments

Section 1 – Sustainable Design Strategies

Optimise the use of passive design strategies in response to local climate and site conditions to improve on indoor environmental quality thus reducing energy use.

- NRBE01-1 Enhanced Building Envelope Performance
- NRBE01-2 Naturally Ventilated Building Design
- NRBE01-3 Effective Daylighting

NRBE01-1 Enhanced Building Envelope Performance

Enhance building envelope performance to minimise heat gain to internal spaces for better indoor thermal comfort with any of the following provisions:

(a) Façade design with Envelope Thermal Transmittance Value (ETTV) of not more than 40 W/m^2 or enhanced with the provision of good thermal break/insulating profile framing.

(b) Application of cool materials that are certified by an approved local product certification body for 80% of all external walls of the building development or applicable roof areas.

(c) Provision of innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, parametric façade for at least 20% of the fenestration areas.

Guidance Notes

NRBE01-1(a): The Envelope Thermal Transfer Value (ETTV) is to be determined using the methodology set out in the Code on Envelope Thermal Performance for Buildings and shall not exceed 40 W/m^2. Alternatively, it can be considered acceptable if the building envelope design is enhanced with the provision of a thermally broken framing system. The thermal transmittance value of the frame design U_{fr} should be less than 2.5 W/m^{2}K for each frame for ⩾ 80% of the applicable facades.

In view of the complex construction of fenestration frames, it is recommended to use simulation tools to derive the thermal properties of fenestration U_{fr} for the different profile sections used in the project. The calculation procedures should exclude the thermal transmittance of the glazing and comply with ANSI/NRFC standard or ISO 10077 using the environmental conditions of Singapore context and as specified in the following Table C8.

Table C8 – Environmental Conditions of Singapore Context	
Temperature Inside, T_i	25 ^{o}C
Temperature Outside, T_o	35 ^{o}C
Solar Radiation	400 W/m^2
Surface Heat Transfer Coefficient (inside), h_i	8 W/m^{2}K
Surface Heat Transfer Coefficient (outside), h_o	19 W/m^{2}K

NRBE01-1(b): Cool materials in this context refer to surface coating, paints, tiles that come with high solar reflectance and infrared emissivity properties and are certified by an approved local product certification body. The extent of the application shall cover at least 80% of all external wall areas of building blocks or all applicable roof areas.
Example of a proposed building development with application of cool paints on external wall areas

Block Description	Total Applicable External Wall Areas (m^2)	Areas with cool materials (m^2)	Extent of coverage = 16500/22500 *100 = 80.5% ok Note: The green wall areas can be excluded in the computation.
Blk 1	4500	3500	
Blk 2	6000	5000	
Blk 3	10000	8000	
Total:	20500	16500	

Example of a proposed building development with application of cool paints on roof areas

Block Description	Total roof areas (m^2)	Non-Applicable Areas (m^2)	Total Applicable Roof Areas (m^2)	Roof Areas with Cool Materials (m^2)
Blk 1	5000	400	4600	3100
Blk 2	4000	400	3600	3500
Blk 3	5000	500	4500	4000
	14000	1300	12,700	10600
Extent of coverage = 10600/12700*100 = 83.5% ok				
Note(1): Non-applicable areas can include green roofs and areas beneath large equipment such as cooling towers, water tanks or photovoltaic (PV) panels where the application of cool materials may not be relevant. Note(2): The selected cool materials or paint system must meet the allowable limits set for daylight reflectance as required under the Approved Document.				

NRBE01-1(c): Innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, parametric façade for at least 20% of the fenestration areas.

Example of a proposed single building with a combination of electrochromic glass and Building Integrated Photovoltaic (BIPV) system incorporated as part of its envelope design.

Innovative Solutions	Areas of Application (m^2)	
Electrochromic glass	2000	Total Fenestration Areas = 20500 Extent of coverage = 5000/20500 = 24% ok
BIPV system	3000	
Total areas of application	5000	

Documentation Requirements

<u>At Design stage (New Buildings):</u>

<u>NRBE01-1(a)</u>

- ETTV computation in the prescribed forms and formats;
- Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant for the computation of the ETTV;
- Architectural plan layouts and elevations showing the mode of ventilation and location for various spaces including air-conditioning areas; and
- Where relevant, extracts from tender specifications showing the requirement to have a thermally broken framing system incorporating thermal break/insulating profile and the requirement of U_{fr} value < 2.5 W/m^2K for each frame for ⩾ 80% of the applicable facades.

<u>NRBE01-1(b)</u>

- Extracts from tender specifications showing the requirement to incorporate cool materials for the specific wall or roof areas; and
- Relevant certificate from an approved local product certification body.

<u>NRBE01-1(c)</u>

- Extract from tender specifications showing the requirements on the specific façade technology or solutions.

At Verification stage :

The following documents are to be made available on-site or upon request.

NRBE01-1(a)

- Material schedules showing salient data of material properties used for the façade and external wall systems; and
- As-built ETTV computation if there are material changes that will affect the design and ETTV.
- Frame with thermal break/ insulating profile clearly labelled in the as-built drawings; and
- Thermal simulation report from fenestration supplier or facade consultant showing that Ufr of the relevant facades used in the project meets the requirements

NRBE01-1(b)

- Certification details of the cool materials used, technical product information, delivery orders, confirmation on the extent of the application and coverage.

NRBE01-1(c)

- Elevation drawings and details showing the areas where the façade technology or solutions are used and confirmation on the extent of application and coverage.

References

- ISO 15099 : 2003 - Thermal Performance of Windows, Doors and Shading Devices
- BS EN ISO 10077-1 : 2017 -Thermal Performance of Windows, Doors and Shutters : Calculation of Thermal Transmittance – Part 1 - General.
- ANSI/NFRC 100-2020 Procedure for determining fenestration product U-factors
- ANSI/NFRC 200-2020 Procedure for determining fenestration product solar heat gain coefficient and visible transmittance at normal incidence
- NFRC simulation manual (July 2017)

Related Information

Daylight Reflectance: Under Section P Daylight Reflectance, the external surface (including a roof) of a building must be designed and constructed in a manner such that any reflection of sunlight off the external surface of the building does not result in loss of amenity to occupants of other buildings in the vicinity of that building. Hence, there is a need to ensure that the selected cool materials meet the allowable daylight reflectance in Document issued by the Building and Construction Authority (BCA).

NRBE01-2 Naturally Ventilated Building Design

Enhance building and space layout design to facilitate good natural ventilation and better thermal comfort with any of the following provisions.
Building layout design with openings that are oriented to take advantage of the prevailing wind conditions for minimum coverage of 20% of all normally occupied spaces of the building development.

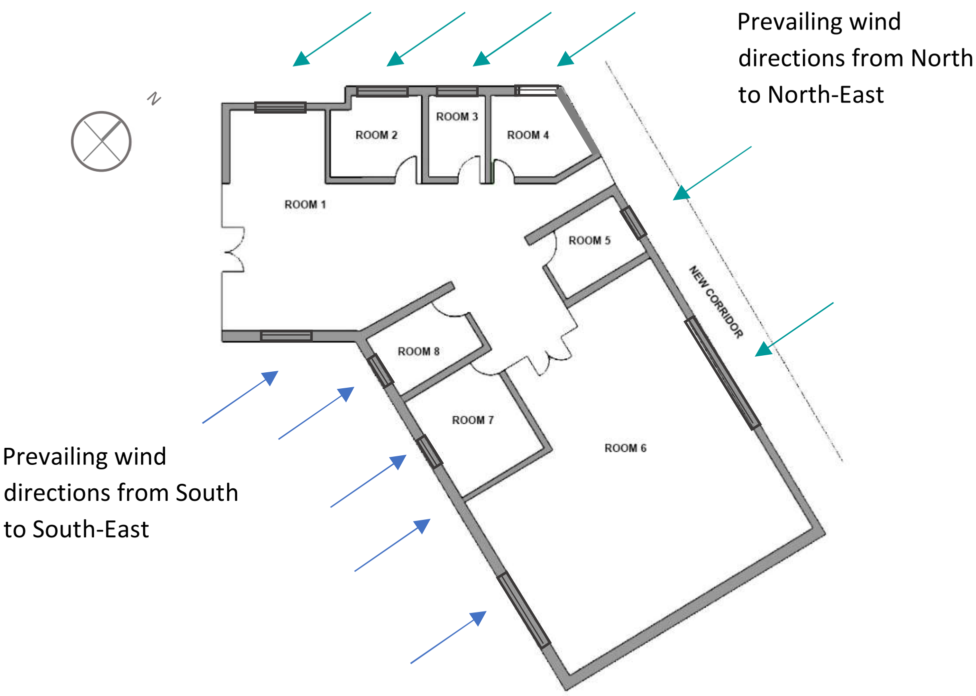
Design for natural ventilation with minimum coverage of 80% in at least two (2) of the following areas:

- Lift lobbies
- Corridors
- Staircases
- Car parks
- Atriums
- Toilets

Guidance Notes

NRBE01-2(a): Naturally ventilated buildings with window openings facing prevailing wind conditions would enhance indoor thermal comfort thus reducing the need for air-conditioning. Locally, the two predominant wind directions are North to North-East during Northeast monsoon seasons and South to South-East during the South-West monsoon seasons. Meteorological data on the precise wind directions and velocity at site location should be used as the basis for design to optimise ventilation and thermal comfort, where available.

In considering the building layout design and coverage, it is not necessary for window openings to be located perpendicularly to the prevailing wind directions. However, there must be openings facing the prevailing wind directions as shown in the following illustrations.



Note: Building layout shows that not all rooms with window openings facing the North and South directions. Room 2 to 5 and Room 7 & 8 would only have prevailing wind directions in one direction. Only Room 1 and 6 can be considered. In this case, there are two (2) out of eight (8) rooms which is 25% which is greater than the minimum requirement of 20%.

NRBE01-2(b): As these spaces are generally typical in terms of areas, the extent of coverage can be determined based on the number or areas of the applicable spaces that are naturally ventilated.

For example, a proposed development with 6 levels of car parks and only one level is mechanically ventilated, the extent of coverage will be 83%. In addition, it comprises an atrium that is naturally ventilated. In this case, it meets the requirement of having two areas that are naturally ventilated with minimum coverage of 80%.

Documentation Requirements

At Design stage :
NRBE01-2(a) Building Design Layout

- Architectural plan layouts showing the units/rooms of all blocks with highlights of those with window openings facing the prevailing wind directions; and
- Tabulation showing the total number/applicable areas and percentage of units or rooms with window openings facing the prevailing wind directions.

NRBE01-2(b) Common Areas

- Architectural plan layouts showing the applicable common areas with highlights of those that are designed to be naturally ventilated; and
- Tabulation showing the total number/areas and percentage of applicable common areas that are naturally ventilated.

At Verification stage):

- As-built submission of the above if there are changes.

Related Information

Natural Ventilation: Under Section G – Ventilation regulated under the Building Control Regulations, there are specific requirements in relation to natural ventilation, to protect people from loss of amenity due to lack of fresh air. There are requirements on the minimum size of openable windows or other openings as well as their location to ensure adequate ventilation is provided in a building.

NRBE01-3 Effective Daylighting

Encourage design that optimises the use of natural lighting to improve visual comfort and reduce energy use associated with artificial lighting.

Normally occupied spaces – Daylighting provision with the integration of daylighting controls or other suitable means for minimum coverage of 15% of the total normally occupied spaces. The extent of daylight provision shall be determined based on the Daylight Availability Tables and Methodology provided in Appendix E of this Code and shall meet the desired lighting level and specific Daylight Autonomy (DA) requirements as listed below:

S/N	Minimum Lighting Level Based on Space Occupancy Type	Daylight Autonomy requirement per unit area of space
1	Office, Institutional spaces where lux requirement is 500 lux	$DA_{500lx,50\%}$
2	Industrial, sports facilities, retail areas where lux requirement is 300 lux	$DA_{300lx,50\%}$
3	Hotel, resort-like and service apartment where lux requirement is 200 lux	$DA_{200lx,50\%}$

Common areas – Daylighting provision with the integration of daylighting controls for minimum coverage of 80% in at least two (2) of the following areas.

- Lift lobbies
- Corridors
- Staircases
- Car parks
- Atriums
- Toilets

Provision of daylight redirecting technologies such as light shelves or tubular daylight/sun pipes to enhance lighting level.

Guidance Notes

NRBE01-3(a): The effective daylighting of normally occupied spaces can be quantified using the Daylight Availability Tables provided in Appendix E if the building design layouts are relatively standardised and have the following characteristics and urban parameters stated below.

Building Characteristics and Urban Parameters suitable for use of Daylight Availability Tables
Spaces that are side lit and located adjacent to the vertical fenestration.
Spaces with typical room floor-to-ceiling heights within the range of 2.5 m to 3.1 m
Simple horizontal overhang/shading devices or no shading devices adopted for the vertical fenestration
Relatively unobstructed by surrounding buildings and with average urban obstruction angles (AUOA) $\leqslant$ 57.25°
Note: Average Urban Obstruction Angle describes the portion of the sky blocked by surrounding obstructions such as neighbouring buildings. Refer to Appendix E for more details.

The simplified methodology in determining the availability of daylighting is as follows:
Determine the quality of daylight provision, daylit and overlit areas of normally occupied spaces through the use of Daylight Availability Tables based on the following design parameters :

Orientation and Obstruction and Lux requirement for the space
Space design (applicable areas), Façade (WWR) and Glazing type (visible light transmittance)
Determine the percentage of normally occupied spaces that have effective daylighting. There must be provision and integration with a light sensor lighting control system that can turn the lights up to provide proper lighting levels when required.

NRBE01-3(b): In general, the provision of windows and openings is not the only determining factor that would translate to the actual daylighting provision. There will be a need to consider other factors such as the building overhangs, opening configurations and placement among other things.

For simplicity, if daylight can be infiltrated over spaces such as common corridors with a depth of about two (2) times the height of the openings it is deemed to have been designed with daylighting. These spaces must be well-lit without the need for artificial lighting provision during the daytime to meet the requirement.

Depending on the locality and design of the common areas, there may be a need to integrate with daylight sensor lighting control system to turn the lights up to provide proper lighting level, when required.

NRBE01-3(c): Daylight redirecting technologies would help reduce the need for artificial lighting by bringing natural light to the interior space. These technologies can come in the form of light shelves, tubular daylight/sun pipes, light redirecting blinds, daylight redirecting films etc.

Documentation Requirements

At Design stage
NRBE01-3(a) Normally Occupied Areas

- Extract of drawings showing the spaces with effective daylight provision;
- Tabulation showing the total number of spaces with effective daylight provision and the percentage of daylit areas over total areas. Refer to the worked example for non-residential buildings on the detailed computation in Appendix E; and
- Details of the daylighting control system or other proposed means.

NRBE01-3(b) Common Areas

- Extracts of drawings showing the use of daylighting and opening provision for staircase areas, corridors & lift lobbies and car parks, where applicable;
- Tabulation showing the total number of applicable common areas with effective daylight provision and the percentage of daylit areas (in number) over the total number of applicable areas; and
- Details of the daylighting control system or other proposed means.

NRBE01-3(c) Daylight redirecting technologies

- Extract of drawings showing the spaces with the application of daylight redirecting technologies; and
- Technical information of the technologies used.

At Verification stage (New Buildings & Existing Buildings):

- The following documents are to be made available on-site or upon request.
- Spot measurements of the effective daylighting through lux measurements and photographs of the applicable functional/normally occupied spaces; and
- Photographs of the daylight redirecting technologies implemented.

References

- Daylight Availability Tables developed under the BCA-SUTD Joint Research Collaboration: Daylighting in Singapore - Establishing Lighting Preferences, Design Guidelines and Predictive Method.

Carbon Reduction Measures for New Developments

Section 2 – Sustainable Construction

Promote the adoption of sustainable practices, materials procurement and design which inculcate responsible use and conservation of resources during construction and building operation.

- NRBE02-1. Resource Efficiency Measures
- NRBE02-2. Sustainable Construction
- NRBE02-3. Sustainable Products

NRBE02-1 Resource Efficiency Measures

Encourage design that optimises resource efficiency and minimises waste generation in building construction.

Existing building structures with more than 50% of the floor and/or wall areas are conserved for adaptive reuse.

Design with Concrete Usage Index (CUI) of not more than 0.50.

Embodied carbon reporting to account for the upfront carbon emissions of three (3) key construction materials namely, concrete, steel, and glass used in building developments.

Guidance Notes

NRBE02-1(a): Existing buildings, whether they are of historic significance or not, can be conserved for adaptive reuse. This can form an important part of sustainability strategies to reduce the overall resource use and building waste. To meet this requirement, there must be more than 50% of the existing building floor and/or wall areas conserved for reuse.

NRBE02-1(b): It is critical and more effective to optimise concrete usage at the early design stage where a range of design solutions that could improve concrete efficiency for e.g. post-tensioned concrete or void formers can be considered. In this requirement, the benchmark set is based on the Concrete Usage Index (CUI) which is an indicator of the amount of concrete used to construct the superstructure that includes both the structural and non-structural elements. It is defined as the volume of concrete in cubic meters needed to cast a square metre of constructed floor area and expressed as follows :

$$\textit{Concrete Usage Index (CUI)} = \frac{\textit{Concrete Volume in } m^3}{\textit{Constructed Floor Area in } m^2}$$

The benchmark set for this requirement is CUI of 0.50.

Worked Example NRBE02-1(b)

Proposed development comprises a 30-storey block with a basement car park. The quantity of concrete used for different structural systems is tabulated below:

Concrete usage for the superstructure	Constructed floor areas
1st storey = 1,035.5 m^3 **From 2nd to 30th storey = 27,360 m^3** **(including roof level)**	1st storey = 2,200 m^2 From 2nd to 30th storey = 57,798 m^2 (including roof level)
Total concrete usage = 28,395.5 m^3	Total constructed floor areas = 59,998m^2

$$\textit{Concrete Usage Index (CUI)} = \frac{\textit{Concrete Volume in } m^3}{\textit{Constructed Floor Area in } m^2}$$

$$= \frac{28395.5}{59998} = 0.473\ m^3/m^2 \ < 0.50 \text{ ok}$$

Note: The concrete usage for external works and sub-structural works for foundation and basement structures are excluded in CUI computation.

Refer to the following tabulation on the details and computation required for the various structural systems.

Computation of Concrete Usage Index			**NON-RESIDENTIAL BUILDING**	
Total no. of storey for the project: 30				
Block No: A				
	Structural System	Thickness (mm) or size (mm x mm)	Volume of concrete (m^3)	Remark *
1	1st storey			
	1.1 Columns	300x300, 400x400	120	57 nos of C80 300x300 precast columns
	1.2 Beams	300x500, 200x500	320	Precast
	1.3 Slabs	200,225,250	400	Post–tensioned (Total floor area = 1,600 m^2)
	1.4 Staircases	175	93.5	Precast
	1.5 Suspended structures like planter boxes, bay windows, ledges, etc.	-	0	-
	1.6 Parapets	-	0	-
	1.7 External walls - loadbearing walls	-	0	-
	1.8 External walls – non-loadbearing walls	125	22	Precast green wall (wall area = 176 m^2)
	1.9 Internal walls – loadbearing walls	200	55	RC (wall area = 275 m^2)
	1.10 Internal walls – nonloadbearing walls	100	10	Light weight concrete (wall area = 100 m^2)
	1.11 Others (kerbs, ramps, services risers, etc.)	-	15	RC
	Total volume of concrete for this storey (m^3)		1,035.5	
	Total constructed floor area for this storey (m^2)		2,200	
2	Typical storey (2nd to roof)			
	1.1 Columns	300x300, 400x400	115	Precast
	1.2 Beams	300x500, 200x500	301.5	Precast
	1.3 Slabs	200,225,250	320	Post–tensioned (Total floor area = 1,280 m^2 per floor)
	1.4 Staircases	175	93.5	Precast
	1.5 Suspended structures like planter boxes, bay windows, ledges, etc.	-	0	-
	1.6 Parapets	-	0	-
	1.7 External walls - loadbearing walls	-	0	-
	1.8 External walls –non-loadbearing walls	125	22	Precast green wall (wall area = 176 m^2)
	1.9 Internal walls – loadbearing walls	200	50	RC (wall area =250m^2)
	1.10 Internal walls – nonloadbearing walls	100	10	Light weight concrete (wall area = 100 m^2)
	1.11 Others (kerbs, ramps, services risers, etc.)	-	0	RC
	Total volume of concrete for one storey (m^3)		912	
	Total constructed floor area for one storey (m^2)		1,926.6	
	Total volume of concrete for 2nd to 30th storey – includes roof level (m^3)		27,360	
	Total constructed floor area for 2nd to 30th storey – includes roof level (m^2)		57,798	
Total volume of superstructure concrete for this project (m^3)			28,095.5	
Total constructed floor area of superstructure for this project (m^2)			59,998	
Concrete Usage Index (CUI in m^3/m^2)			0.473	

**To indicate if the structural elements are of precast concrete, post-tensioned concrete, high strength concrete (>Grade 60) or reinforced concrete (RC) under the 'Remarks' column.*

Compliance Notes: The quantities of the concrete for all the structural and non-structural elements for each floor level are to be computed. All the elements listed in the table such as columns, beams, slabs, suspended structures (like planter boxes, bay windows and ledges, etc.), parapets, walls and others (service risers, kerbs, ramps, etc.) are to be included. The concrete used for foundation and basement works are to be excluded in CUI computation. However, in the case of raft foundation that forms part of the floor slab, half of the concrete volume will have to be accounted for in deriving the CUI.

NRBE02-1(c): Embodied carbon reporting would cover the assessment of the carbon footprint of a building or infrastructure before it becomes operational. The requirement would require the account for the upfront carbon emissions of three (3) key construction materials namely concrete, steel and glass used in building developments. The emission factors used can be based on established carbon datasets such as the Inventory of Carbon and Energy (ICE) database, the RICS Building Carbon Database.

Documentation Requirements

At Design stage :

- Generally, no supporting document requirement at this stage.

At Verification stage :

- The following documents are to be made available on-site or upon request.

NRBE02-1(a)

- Architectural and structural plan layout, elevation and sectional plans showing the existing floor and/ or wall areas that are conserved for adaptive reuse; and

Details on the extent of conservation in percentage over the total existing floor and/or wall areas.

NRBE02-1(b)

- BIM model (if applicable), architectural and structural plan layout, elevation and sectional plans showing the type of building elements/ systems used, the dimensions and sizes of all the building and structural elements; and
- Summary showing the quantity of concrete for each floor level in the prescribed tabulated format shown in the Worked Example NRBE02-1(b). Calculation showing the quantity of concrete for each floor level which should include all the concrete building elements, such as non-load bearing and architectural concrete components.

NRBE02-1(c)

- Embodied carbon footprint report which includes the computation with detailed breakdown on the grade and type of concrete, steel and glass provided and the basis of the respective emission factors used.

References

- Sustainable Construction - Guide on Concrete Usage Index published by the Building and Construction Authority (BCA)

NRBE02-2 Low Carbon Concrete

Enhance carbon reduction potential with the use of sustainable materials for construction.

Use of concrete with eco-friendly cementitious materials that are classified under CEM II to V types for at least 80% of the super-structural works by volume.

Use of recycled concrete aggregate (RCA), washed copper slag (WCS) and/or granite fines from approved sources and meet the minimum usage requirement as stated in the following Table C9.

Table C9 – Minimum Usage Requirements	
Recycled Concrete Aggregate (RCA)	1.50% X GFA
Granite fines	1.50% x GFA
Washed Copper Slag (WCS)	0.75% x GFA
Note: GFA refers to Approved Gross Floor Areas of the building development.	

Alternative construction materials that can be used as a replacement for standard building materials for non-structural application.

Guidance Notes

NRBE02-2(a): The use of concrete with considerable proportion of clinker replaced with eco-friendly cementitious materials would help reduce the overall embodied carbon in buildings. Essentially, these materials comprise Portland Cement in combination with approved industrial by-products such as Ground Granulated Blast Furnace Slag (GGBS), silica fume, fly ash and could serve as alternative binder in concrete production. These cementitious materials are classified under CEM II/III/IV/V in Table 1 of SS EN 197-1. Concrete products certified by an approved local product certification body can be considered if eco-friendly cementitious materials are required as part of the certification criteria.

Worked Example NRBE02-2(a)

Clinker content
The proposed non-residential development uses three (3) types of Grade 40 concrete with the following provision.

Concrete Grade 40	Extent of Coverage (Super-Structural work only)	Provision	Remarks
Type 1 Concrete	30% by volume	20% of GGBS which is classified under CEM II in Table 1 of SS EN 197	Ok
Type 2 Concrete	40% by volume	Certified concrete products under an approved local product certification body.	Ok, concrete products produced with eco-friendly cementitious materials classified under SS EN 197 and as certified.
Type 3 Concrete	30% by volume	CEM I with no replacement of OPC	No eco-friendly cementitious materials used.

In this instance, the use of concrete with eco-friendly cementitious materials only took up 70% of the super-structural works (by volume) which would not fulfill the overall requirement of minimum 80%.

NRBE02-2(b): Recycled concrete aggregates (RCA) is derived mainly from the crushed concrete from demolition works which can be adopted to replace natural coarse aggregates for a range of structural and non-structural application. Washed Copper Slag (WCS) on the other hand is derived by reprocessing (cleaning, washing and drying) copper slag used in the first place as an abrasive in grit blasting at the shipyard. For structural grade concrete, the use of RCA and WCS shall be limited to a maximum 20% and 10% replacement by mass of coarse/fine aggregates respectively or as approved by the relevant authorities. Locally, granite fines of which the quality and grading are in accordance with SS EN 12620 can be used as a direct substitute for fine aggregates (that is replacement of natural sand in concrete).

The RCA/WCS/Granite fines quantity (in tonnes) required for the concrete production of main building elements can be estimated based on the concrete volume and replacement rate comprising these sustainable materials and as follows :

Type of Sustainable Materials	Estimation of Quantity Requirement
Recycled Concrete Aggregate (RCA)	1.0 (tonnes/m^3) x (Concrete vol in m^3) x (RCA Replacement Rate) %
Granite fines (GF)	0.7 (tonnes/m^3) x (Concrete vol in m^3) x (GF Replacement Rate) %
Washed Copper Slag (WCS)	0.7 (tonnes/m^3) x (Concrete vol in m^3) x (WCS Replacement Rate) %

Worked Example NRBE02-2(b)

Replacement of coarse and fine aggregates
The project uses 10% replacement of coarse aggregate with RCA, 10% replacement of fine aggregate with WCS for all slabs, and 30% replacement of coarse aggregate with RCA for all external non-load bearing walls of the superstructure. The Gross Floor Areas (GFA) is 58,000 m^2. Refer to Worked Example NRBE02-1(b) on the concrete volume used for the respective building elements.

Replacement of Coarse Aggregate with Recycled Concrete Aggregates (RCA)
Minimum usage requirement for RCA = 0.015 x GFA = 0.015 x 58,000 = 870 tonnes **Total concrete volume of all slabs = 400 m^3 + 320 m^3 x 30 = 10,000m^3** **Total concrete volume of all external non-load bearing walls = 22 m^3 + (22 m^3 x 30) = 682 m^3** ***[Approximate coarse aggregate content in concrete = 1 tonne/m^3]*** **Total tonnage of RCA used for superstructure** **= [(10% x 1 tonne/m^3) x 10,000m^3] + [(30% x 1 tonne/m^3) x 682m^3] = 1,204.6 tonnes > 870 tonnes, ok**
Minimum usage requirement for WCS = 0.0075 x GFA = 0.0075 x 58,000 = 435 tonnes **Total concrete volume of all slabs = 400m^3 + 320m^3 x 30 = 10,000m^3** ***[Approximate fine aggregate content in concrete = 0.7 tonne/m^3]*** **Total tonnage of WCS used for superstructure** **= [(10% x 0.7 tonne/m^3) x 10000m^3] = 700 tonnes <435 tonnes ok**
In this example, based on the replacement of coarse aggregate with RCA and fine aggregate with WCS, it can be considered meeting one carbon reduction measure under Sustainable Construction.

NRBE02-2(c): Other than the use of eco-friendly cementitious materials, RCA, WCS and granite fines stated in NRBE02-2(a) and (b), other alternative construction materials can be considered as a replacement for standard building materials for non-structural application. However, there is a need to ensure that the alternative materials used would meet the physical, chemical and engineering characteristics for the intended application and requirements from relevant authorities, where applicable.

An example of alternative materials is NEWSand derived from municipal solid waste (MSW), which can be used to replace sand and similar aggregates for non-structural application such as footpaths, road building materials, concrete products like benches. It can be considered with no specific minimum replacement rate. However, note that it is currently a new material with limited supply source administered by the National Environment Agency (NEA).

Documentation Requirements

At Design stage:

- Generally, no supporting document submission at this stage.

At Verification stage

- The following documents are to be made available on-site or upon request.

NRBE02-2(a) and (b)

- Extract of tender specification or concrete mix design showing the cement type used and/or the detailed usage of recycled/ engineered aggregates (e.g. RCA/WCS/granite fines);
- Calculation showing the quantity of recycled/ engineered aggregates (e.g. RCA/WCS/granite fines) used for the project;
- Certificates from an approved local product certification body for concrete products/mixes that are certified and evidence of the use of eco-friendly cementitious materials in concrete production; and
- Delivery orders and details of the actual concrete mix used in the project showing the usage of clinkers/ engineered aggregates (e.g. RCA/ WCS/granite fines).

NRBE02-2(c)

- Extract of tender specification or confirmation showing the use of processed waste and the areas of its application.

References

- SS EN 197–1 – Cement - Part 1 : Composition, specifications and conformity criteria for common cement
- SS EN 12620 – Specification for Aggregates for Concrete
- Sustainable Construction : Guide on the use of Recycled Materials published by the Building and Construction Authority (BCA)

NRBE02-3 Sustainable Products

Encourage the specification and use of environmentally friendly products that are certified with Environmental Product Declaration (EPD) requirements and/or with a two-tick rating by an approved local product certification body.

The provision shall include at least three (3) building and/or Mechanical and Electrical (M&E) products for 80% of applicable areas and/or building components/systems in relation to functional spaces.

Guidance Notes

An Environmental Product Declaration (EPD) is a transparent, objective report that communicates the environmental performance and impact of a product over its life cycle. EPDs support carbon emission reduction by making it possible to compare the environmental impacts of different products and facilitate the selection of more sustainable options. For this requirement, products with EPDs that are third-party certified and in conformance with ISO 14025 and EN 15804 and/or products certified with a two-tick rating by an approved local product certification body can be considered. The extent of coverage must be at least 80% of the applicable areas/building components/systems intended for the functional spaces.

Worked Example NRBE02-3

Example of a proposed office building development with provision of the following products and coverage that meet the requirements.

Products	Extent of Coverage	Provision	Remarks
Chillers	100% Applicable to all office spaces	Two-tick rated based on the extent of environmental friendliness by an approved local product certification body	√
Timber Doors	80% of all conference rooms	With EPD that is third-party certified and in conformance with ISO 14025 and EN 15804	√
Drywall partitions	100% Applicable to all office spaces	Two-tick rated based on the extent of environmental friendliness by an approved local product certification body	√

Documentation Requirements

At Design stage :

- Generally, no supporting document submission at this stage.

At Verification stage):

- The following documents are to be made available on-site or upon request.
- Extract of tender specification and drawings showing the requirements to incorporate specific products with EPDs and/or with two-tick rating by an approved local certification body;
- Certification of EPDs or details from an approved local certification body such as the material certification standards, rating and product reference; and
- Technical product information and delivery records.

References

- SS ISO 14205 : Environmental Labels and Declarations – Type III environmental declarations – Principles and procedures
- EN 15804 : Sustainability of Construction Works – Environmental Product Declarations – Core Rules for the Product Category of Construction Products

Carbon Reduction Measures for Non-Residential Buildings

Section 3 – Sustainable Technologies

Encourage the provision of green building technologies that are oriented towards establishing low energy building consumption and smart control systems that could adapt to the users' needs and enhance building energy performance.

- NRBE03-1 Renewable Energy Sources
- NRBE03-2 Smart Building Solutions
- NRBE03-3 Green Building Technologies

NRBE03-1 Renewable Energy System

Encourage the use of an on-site renewable energy system to reduce at least 1% of the expected annual total building electricity consumption. There must be suitable means for monitoring and records of the energy generated from the system used.

Guidance Notes

The expected total building electricity consumption can be obtained either from the results or based on the estimated electricity consumption, usage pattern, operational hours of all major energy-consuming systems and equipment. For the receptacle loads, the nominal values shown in Table C8 can be adopted.

Table C10 – Nominal Values for Receptacle Loads		
Receptacle Loads	Standard	Nominal Values
Computer intensive offices	Source: ASHRAE 90.1.2013	22.0 W/m^2
General office areas		16.0 W/m^2
Large conference areas		11.0 W/m^2
Schools (Tertiary/IHL)		8.0 W/m^2
Schools (Primary/Secondary)		5.0 W/m^2
Computer room (Information Technology Equipment)	Source: ASHARE 90.4 2016	215 W/m^2

<u>Worked Example – NRBE03-1</u>

A proposed development with GFA of 86,000 m^2, operating hours per week is 55 hours at 100% occupancy rate. The expected total building electricity consumption per year is estimated to be as follows:

Total Building Electricity Consumption (TBEC) per year	
System/ Equipment	Total Annual Building Electricity Consumption (kWh)/year
Lighting – (Air-Conditioned Space)	3,094,380
Lighting- (Non-Air-Conditioned Space)	236,321
Exterior Lighting	405,800
Air-Conditioned Plant	7,924,425
Air System Fans	632,293
Mechanical Ventilation Fans	207,571
Lifts	792,966
Escalators	45,865
Receptacle Equipment (@16W/m^2)	3,936,517
Domestic Water Pump Systems	226,088
Hot Water Systems	93,789
Others	-
Total:	17,596,015

Based on the supplier's specifications on the renewable system, compute the percentage (%) replacement.

Description	kWp Installed (kWp)	Annual Yield (kWh)
Upper Roof Block A	200	240,000
Roof Block B	200	240,000
Other blocks	0	0
Total	400	480,000

Total Building Consumption (kWh)	**17,596,015**
Annual Replacement Rate	2.73% > 1% ok

Documentation Requirements

At Design stage
- Generally, no supporting document submission at this stage.

At Verification stage
- The following documents are to be made available on-site or upon request.
- As-built drawings and on-site photographs of the renewable energy systems installed;
- Technical specifications and integration reports of the installed system(s) including total capacity installed; and
- Calculation of the percentage replacement of electricity and the total annual electricity consumption of the development.

NRBE03-2 Smart Building Solutions

Encourage the provision of a minimum of two (2) smart building solutions to facilitate automation and controls over building systems for better energy management and thermal comfort. Examples of building solutions that can be considered are listed below:
Use of BACnet, Modbus or any other open protocol as the network backbone of the building management system where data points can be used to facilitate communication and integration with other building systems.

Energy portal and dashboard that helps building owners and/or tenants to better manage their energy consumption in an intuitive manner. It should comprise display metered data, trending of energy consumption (historical data) of the building and tenanted spaces on a monthly basis and other useful parameters.

Real-time remote monitoring of chiller plant system operation such as BCA Chiller Efficiency Smart Portal.

Demand controlled ventilation systems such as carbon dioxide sensors or devices to regulate the fresh air intake and ventilation based on occupants' needs.

Timer sensors/controls for lighting and/or ventilation systems in common areas and facilities.

Smart building sensors that are equipped with sensing capability, microprocessors and communication technology that can help facilitate some form of monitoring or automation.

Differential pressure switches for Air Handling Units (AHUs) that are linked to a building management system (BMS) or suitable means that can monitor the air filter condition.

Others (to be evaluated on a case-to-case basis).

Documentation Requirements

At Design stage

- Generally, no supporting document submission at this stage.

At Verification stage
- The following documents are to be made available on-site or upon request.
- Extract of tender specification or drawings showing the provision of the building solutions implemented for the project; and
- Technical specification on the systems or features used.

NRBE03-3 Green Building Technologies

Encourage the adoption of low-carbon solutions and technologies which would help reduce building energy consumption. Examples of solutions that can be considered are as follows:

Energy recovery systems for building applications
- Lifts with regenerative function
- Passive Displacement ventilation system
- Dedicated outdoor air system
- Others (to be evaluated on a case-to-case basis)

Guidance Notes

Green Building Technologies	General Information
Energy recovery systems for building applications	Energy recovery system can be integrated to minimise overall building energy demand. For example, heat recovery system that captures waste heat discharged from the air-conditioning system and transfers for water heating purpose, which otherwise is exhausted or wasted.
Lifts with regenerative function	Lifts with regenerative function can help conserve and minimise energy use. Depending on lift usage, operating speed, height of building and floors, it would typically be a viable option for larger and taller buildings.
Passive displacement ventilation system	An innovative system that uses chilled water-cooling coils to create air circulation through the natural convection process to deliver conditioned air, without mechanical fans. It taps on the principle of natural buoyancy and temperature stratification to deliver cooled air to end-users using less to no energy.
Dedicated outdoor air system	Dedicated outdoor air system (DOAS) such as precool unit can be used to condition all outdoor air (OA) for more effective cooling and ventilation control. It can enhance the opportunity to reduce the energy use for ventilation, air conditioning and fan operations as the system does not need to condition as much outdoor air (OA) as is the case with a variable air volume (VAV) system.

Documentation Requirements

<u>At Design stage</u>
- Generally, no supporting document submission at this stage.

<u>At Verification stage</u>
- The following documents are to be made available on-site or upon request.
- Brief on design intent and details of the proposed green building technologies;
- Extract of tender specification, as-built drawings and photographic evidence showing the provision and location of green building technologies implemented;
- Computation of expected energy savings over the estimated total building consumption; and
- Techanical specitifcation on the systems or features used.

Appendix A: Daylight Availability Tables and Methodology

Daylight Availability Tables and Methodology

A1 General

A1.1 In general, daylighting simulation should be carried out using computational modelling to quantify and demonstrate the availability of natural daylighting that could provide a proper and comfortable lighting level for building occupants. However, for buildings/spaces that come with standard designs and have the following building characteristics and urban parameters, the quality and availability of daylight can be quantified using the Daylight Availability Tables provided in this Appendix.

(a) Spaces that are side lit and located adjacent to the vertical fenestration.

(b) Spaces with typical room floor-to-ceiling heights between 2.5 m and 3.1 m.

(c) Simple horizontal overhang shading devices or no shading devices adopted for vertical fenestration.

(d) Relatively unobstructed by surrounding buildings and with average urban obstruction angles (AUOA) ≤ 57.25°. More explanation on the derivation of the AUOA can be found in para A3 of this Appendix.

(e) The daylight availability tables were developed using the annual climate-based daylighting metrics and take into consideration potential visual discomfort in evaluating the effectiveness of daylighting in the local context. The following terms and requirements, which describe the lighting quality of building spaces will be of relevance.

A1.2 *Daylight Autonomy ($DA_{Nlx,x\%}$)* is a daylight availability metric that defines the percentage of the occupied hours of the year when the desired illuminance level can be provided by daylight alone. It is expressed as $DA_{Nlx,x\%}$ where N lx represents the illuminance requirement in lux for a specific space and x% represents the percentage of occupied sunlit hours. For example, in the case of residential buildings, the daylight autonomy requirement set is $DA_{200lx,50\%}$ which is translated to having 200 lux (or greater) of illuminance for 50% of the occupied sunlit hours (from 7:00 am to 10:00 am and from 4:00 pm to 7:00 pm) for a specific space of interest.

A1.3 *Useful Daylight Illuminance Exceeded ($UDIe_{3000lx,10\%}$)* is a daylight availability metric that describes the frequency at which daylight illuminance levels exceed an acceptable daylight illuminance threshold of 3000 lux for more than 10% of occupied hours in a year.

A1.4 *Daylit area* refers to the floor area that is illuminated by sufficient daylight that meets the daylight autonomy requirement set for indoor spaces. For example, in the context of residential buildings, daylit areas refer to the floor areas where daylight autonomy, $DA_{200\,lx,50\%}$ are met.

A1.5 *Overlit area* refers to the floor area that is illuminated by high levels of daylight that would potentially result in visual discomfort (glare) for occupants. In this requirement, the area of a space where daylight illuminance level is equal to or greater than 3000 lx for more than 10% of occupied hours in a year is denoted by $UDIe_{3000\,lx,10\%}$, are considered overlit.

Specific Daylight Autonomy Requirements for the various types of occupied spaces are as follows:

S/N	Space Occupancy Type	Daylight Autonomy requirement	Occupied sunlit hours every day of the year for analysis
1	Offices and Institutional spaces	$DA_{500lx,50\%}$	8:00 am to 5:00 pm
2	Industrial, sports facilities, retail areas	$DA_{300lx,50\%}$	8:00 am to 5:00 pm
3	Hotel and residential style occupancy	$DA_{200lx,50\%}$	7:00 am to 10:00 pm 4:00 pm to 7:00 pm
4	Residential Buildings – Dwelling Units	$DA_{200lx,50\%}$	7:00 am to 10.00 am 4:00 pm to 7:00 pm

Note (1) – For all cases, the overlit areas with Useful Daylight Illuminance Exceeded ($UDIe_{3000lx,10\%}$) are to be accounted for in determining the quality of daylight provision.

Note (2) – As the DA_{Nlx} and $UDIe_{3000lx}$ are defined as a percentage of occurrence over an occupied period of a building, this period must be explicitly defined and use for daylight analysis as stated in this table.

Note (3) – Daylight availability tables will not be applicable for buildings or spaces with unusual occupancy schedules.

A2 Daylight Availability Tables and Methodology for Standard Designs

A2.1 The Daylight Availability tables were derived from more than 13,000 different combinations of building characteristics and urban parameters with a conglomeration of 4,000 simulated results using a reference shoebox model. The simulation results provided in these tables can be used to determine the effective daylighting for buildings/spaces with standard designs as highlighted in para A1.

A2.2 There are three (3) Daylight Availability tables for each space occupancy type. The specific Daylight Autonomy and respective occupied hours are as stipulated below:

Daylight Availability Table Reference	Space Occupancy Type	Daylight Autonomy requirement	Occupied sunlit hours
DT1-1 to DT1-3	Offices and Institutional spaces including schools	$DA_{500lx,50\%}$	8:00 am to 5:00 pm
DT2-1 to DT2-3	Industrial, Sports facilities, Retail areas	$DA_{300lx,50\%}$	8:00 am to 5:00 pm
DT3-1 to DT 3-3	Residential, Hotel and Service Apartments	$DA_{200lx,50\%}$	7:00 am to 10:00 pm 4:00 pm to 7:00 pm

A2.3 These tables provide information on the daylight availability expressed in term of the depth of the effective daylit areas (in blue shade) and highlights the areas that have potential risks of overlit (in red and pink shade). The daylight availability results shown in the table have considered the overlit areas with $UDIe_{3000\ lx,\ 10\ \%}$ and if the percentage of these areas takes up more than 15% of the occupied spaces before deriving the effective daylit areas.

In short,

Effective daylit areas *= Daylit areas with* $DA_{Nlx,50\%}$ *- Overlit areas with* $UDIe_{3000\ lx,10\ \%}$

where the overlit areas must be less than 15% of the occupied spaces.

A2.4 Average Urban Obstructing Angle (AUOA)

The Average Urban Obstructing Angle (AUOA) describes the average portion of the sky blocked by surrounding obstructions such as neighbouring buildings. It can be determined by considering the height of the surrounding obstructions and the height of the specific floor level with reference to the ground level as well as the distance apart and can be expressed in the following formula.

$$AUOA = arctan\left(\frac{H - h}{W}\right)$$

where

H: Average urban height of the surrounding obstructions in meters measured from the ground

h: The height of the respective space's floor level above ground

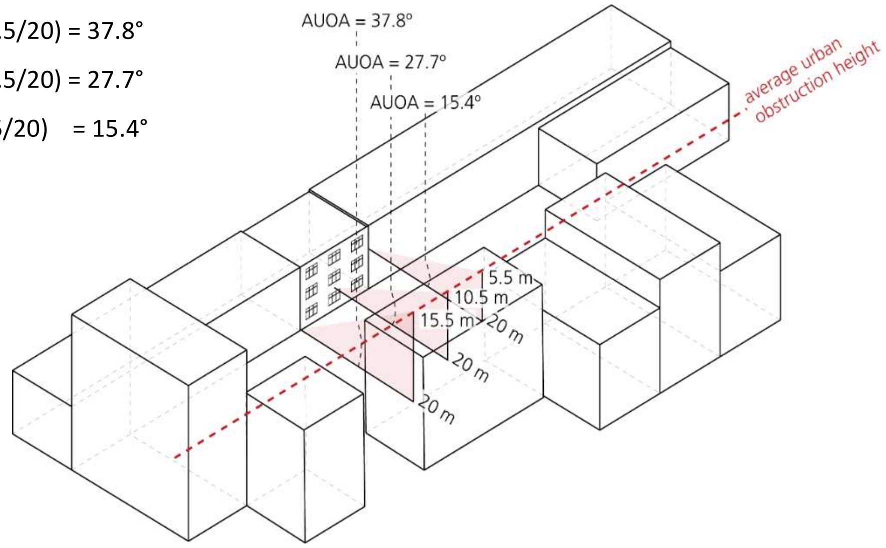
W: Width of the street or the distance between the building and its surrounding obstructions.

A2.5 The following diagram shows an example of the derivation of the average urban obstruction angle for three floors of a building. For example, based on the average urban obstruction height of 15.5 m, the building-to-building distance of 20 m with respect to the height of the respective floor level above ground, the AUOA is 37.8° and so forth. Spaces with AUOA of more than 57.25°are not likely to have quality daylighting and hence, there is no daylight availability table for such spaces. Other than AUOA, there are four other parameters that are important and pertinent before the Daylight Availability Tables can be used to determine the depth of the daylit areas and as listed in para A2.6 to A2.9.

AUOA = arctan (15.5/20) = 37.8°

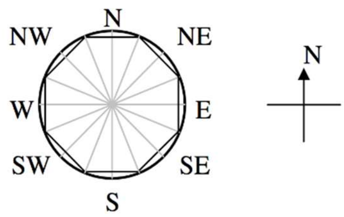
AUOA = arctan (10.5/20) = 27.7°

AUOA = arctan (5.5/20) = 15.4°



A2.6 Orientation *(refers to vertical axis on the right-hand side of daylight availability table)*

The daylight availability expressed in terms of the depth of the daylit areas is grouped based on the eight (8) major cardinal directions in which the façade is orientated. The selection of the façade orientation should be within 11.25° of the given orientation shown in the tables.



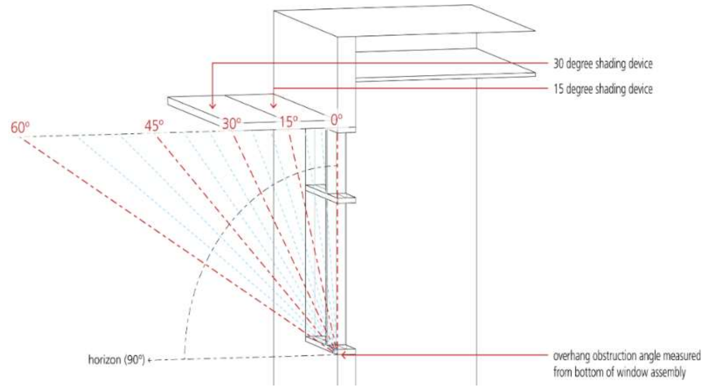
A2.7 Overhang Obstruction Angle (OOA) *(refers to horizontal axis on the top of daylight availability table)*

The OOA is the angle describing the portion of the sky blocked by a horizontal overhang. The angle is measured from the bottom of the window assembly, i.e. from the zenith (directly overhead) to the outside edge of the shading device.

$$OOA = arctan\left(\frac{H_w}{P}\right)$$

H_w is the height of the windows of the space, while P is the length of the shading device.

The diagram below depicts the measurement of the overhang obstruction angle from the bottom of window sill:



Within each table, the daylight availability results are broadly classified by the Overhang Obstruction Angle (OOA) in three groupings that are 0°, 15° and 30°. The selection of the OOA will be based on the nearest value to the OOA of the overhang design.

A2.8 Visible Light Transmittance (T_{vis}) *(refers to vertical axis on the left-hand side of daylight availability table)*

Visible light transmittance (T_{vis}) is the percentage of visible light that passes through a glazing surface such as a window at normal incidence. A higher value of T_{vis} represents greater visible light transmittance. There are six (6) options of Visible Light Transmittance (T_{vis}) for selection (that is 25%, 35%, 45%, 55%, 65% and 75%). In general, the T_{vis} can be obtained from the glazing specification and the selection of T_{vis} would be based on the nearest value to the specification or design intent.

A2.9 Window-to-Wall Ratio *(refers to horizontal axis at the bottom of daylight availability table)*

Window-to-wall Ratio (WWR) in this context is the percentage of glazing areas relative to its exterior wall envelope areas.

$$WWR = \frac{\sum Area\ of\ Glazing\ Panes}{Total\ Exterior\ Wall\ Envelope\ Areas} \times 100$$

There is a list of 10 WWRs included in the Daylight Availability Tables (that is 10%, 20%, 26%, 32%, 39%, 43%, 52%, 60%, 70%, and 87%). The selection of WWR would be based on the nearest value to the designed WWR from this list.

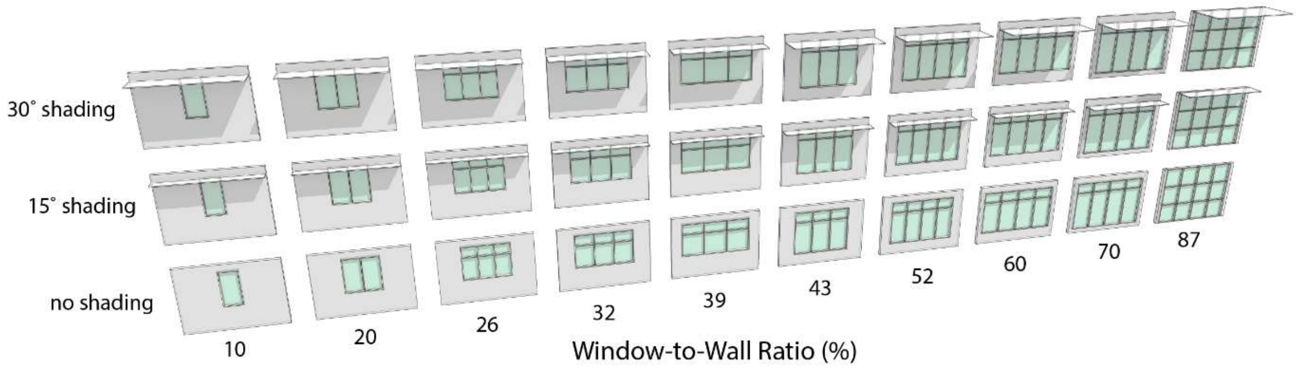


Illustration of the façade geometric parameters of various WWR and Shading provision with the respective OOA

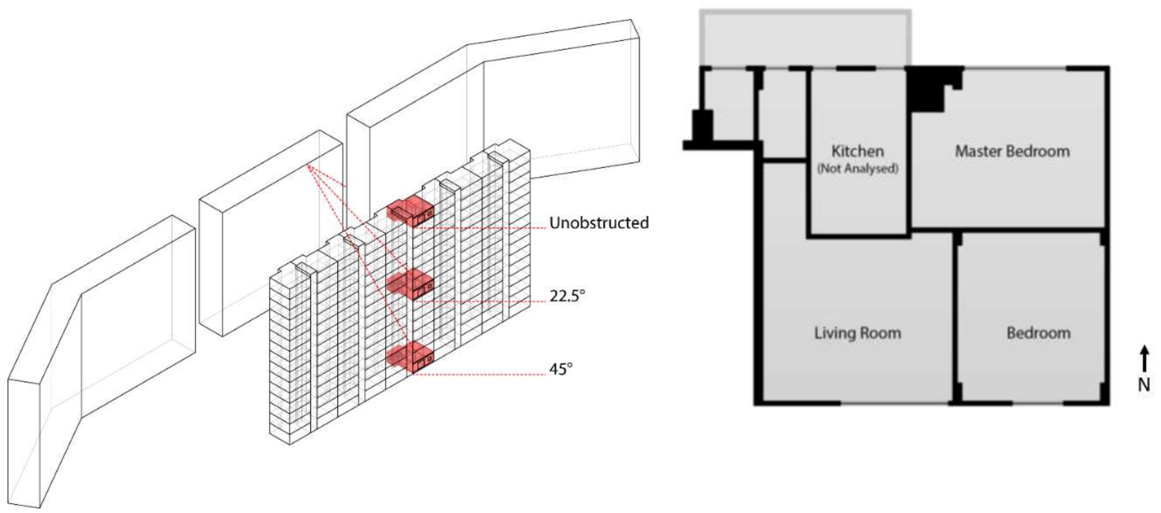
A3 Guidance and Limitation on the Use of Daylight Availability Tables

While the Daylight Availability tables can help eliminate the need for daylight simulations for standard designs, there are limitations that should be considered and are as follows:

- *Potential underestimation of the daylighting provision in spaces with more than one glazed façade or window openings* - As the daylight availability tables document only the daylit area for single-sided lit spaces, there would be added daylighting sources which are not accounted for. In such a situation, there would be a need to consider daylight availability by way of daylighting simulation to ensure proper and comfortable lighting levels for building occupants. For spaces that are located adjacent to two glazed facades abutting at corners, the daylight availability for such spaces could be discounted for simplicity.

- *Applicability limited to stipulated floor-to-ceiling heights* – As the daylight availability tables are derived based on the floor-to-ceiling height of spaces that are within 2.5 m - 3.1m, these tables would not be suitable means in determining effective daylighting if the floor-to-ceiling height is not within the stipulated range.

<u>Worked Example for Residential Building Development</u>
Proposed residential development with one block of 15-storey residential apartments with sky obstruction from neighbouring building at its south-facing façade. The typical floor layout of the apartment units is as shown below.



In this instance, the Daylight Availability Tables can be used as the respective sky obstructions posed by neighbouring buildings fall within the limit (i.e. the AUOA is 57.25). Three (3) unit types representing the different urban contexts are selected for analysis.

In summary,

Unit Type 1 can represent the units from Level 1 to 5 with Significant Obstruction Urban Context that is AUOA of 45° (i.e. ranging from 33.75° to 57.25°);

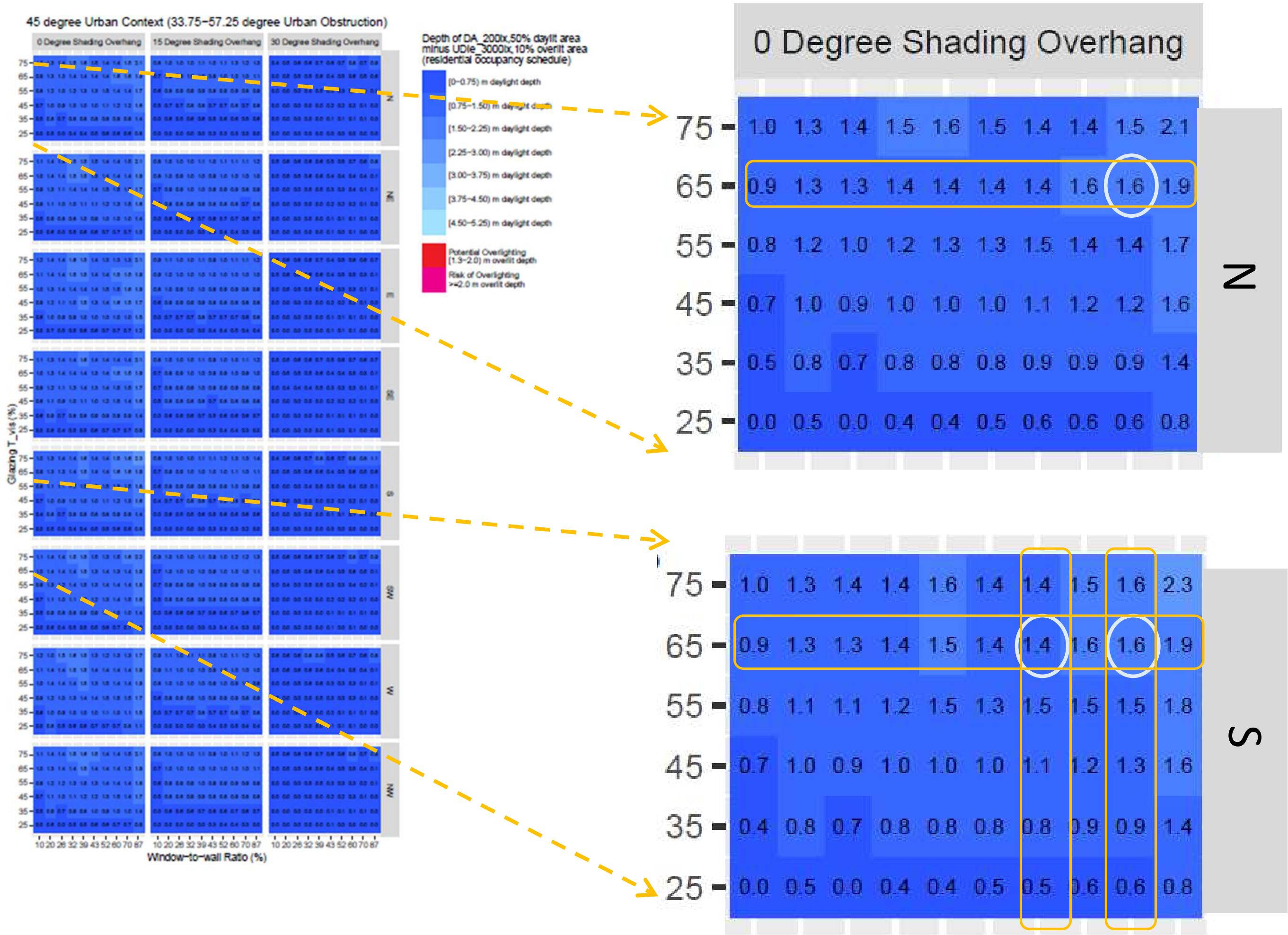
Unit Type 2 can represent the units from Level 6 to 10 with Moderate Obstruction Urban Context that is AUOA of 22.5° (i.e. ranging from 11.25° to < 33.75°); and

Unit Type 3 can represent the units from Level 11 to 15 which are Unobstructed Urban Context (i.e. ranging from 0° to < 11.25°).

Based on building and façade design, the key parameters of these typical units are as follows:

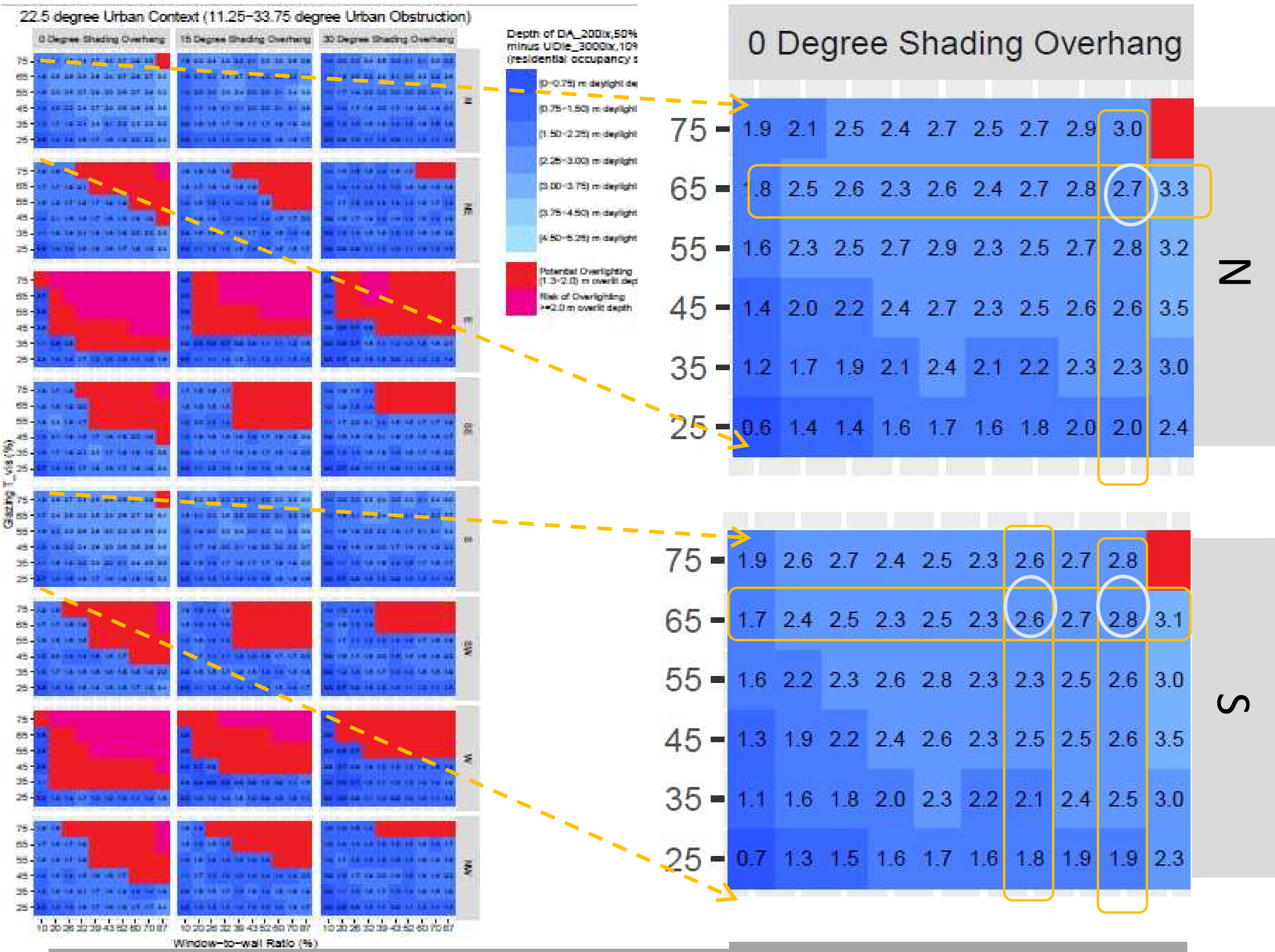
Habitable Spaces	Floor Areas (m^2)	Room Width (m)	Orientation of Vertical Fenestration adjacent to the space	Overhang Obstruction Angle (OOA)	Visible Light Transmittance (Tvis) (%)	Window to Wall Ratio (WWR) (m^2)
Master Bedroom	14.7	4.2	North-facing	0°	65	0.7
Living Room	16.4	4.1	South-facing	0°	65	0.7
Bedroom	11.2	3.2	South-facing	0°	65	0.5

(a) Unit Type 1 representing the Units from Level 1 to 5 with Significant Obstruction Urban Context that is AUOA of 45° (i.e. ranging from 33.75° to 57.25°), the depth of effective daylight areas can be derived from Daylight Availability Table DT3-3 as illustrated below:



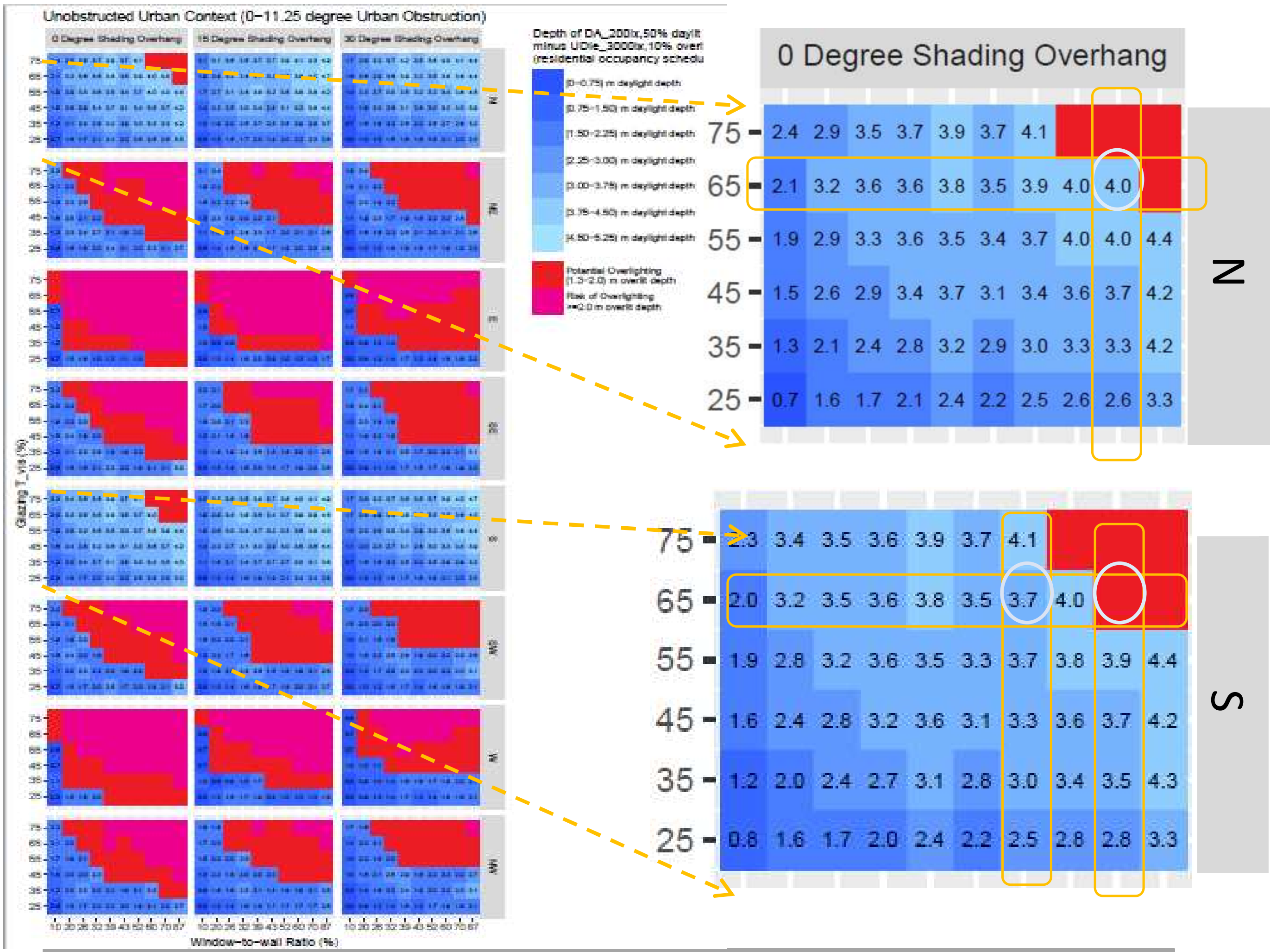
Unit Type 1 representing Level 1 to 5 (50 Units) (with Significant Obstruction Urban Context that is AUOA of 45°)				
Habitable Spaces	Floor Areas (m^2)	Room Width (m^2)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
Master Bedroom	14.7	4.2	1.6	6.7
Living Room	16.4	4.1	1.6	6.6
Bedroom	11.2	3.2	1.4	4.5
Total Areas :	**42.3**		Total Effective Daylit areas:	17.8
$$\textit{Total Daylit Area for each dwelling unit} = \frac{DaylitArea_{Room1} + DaylitArea_{Room2} + \cdots + DaylitArea_{RoomN}}{\sum FloorAreas\ of\ each\ dwelling}$$			Percentage of effective daylit areas: 42.1% < min 60% requirement	

(b) Unit Type 2 can represent the units from Level 6 to 10 with Moderate Obstruction Urban Context that is AUOA of 22.5° (i.e. ranging from 11.25° to < 33.75°), the depth of effective daylight areas can be derived from Daylight Availability Table DT3-2 as illustrated below.



Unit Type 2 representing Level 6 to 10 (50 Units) (with Moderate Obstruction Urban Context that is AUOA of 22.5°)				
Habitable Spaces	Floor Areas (m^2)	Room Width (m^2)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
Master Bedroom	14.7	4.2	2.7	11.3
Living Room	16.4	4.1	2.8	11.5
Bedroom	11.2	3.2	2.6	8.3
Total Areas:	**42.3**		Total Effective Daylit areas:	31.1
Percentage of effective daylit areas: 73.5% > min 60% requirement				

(c) Unit Type 3 representing the units at Level 11 to 15 that are relatively unobstructed, the depth of effective daylit areas can be derived from the Daylight Availability Table DT3-1 as illustrated below:



Unit Type 3 representing Level 11 to 15 (50 Units) (with Unobstructed Urban Context)				
Habitable Spaces	Floor Areas (m^2)	Room Width (m^2)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
Master Bedroom	14.7	4.2	4.0	16.8
Living Room	16.4	4.1	Not qualified as daylit areas as there is potential risks of overlit of more than 15% of room areas	0
Bedroom	11.2	3.2	3.7	11.8
Total Areas :	**42.3**		Total Effective Daylit areas:	28.6
Percentage of effective daylit areas: 67.6% > min 60% requirement				

Note that for residential building development, the effective daylight provision should at least cover 25% of the total number of dwelling units where 60% of the habitable spaces within these units are effective daylit.

In summary,

Unit Description	No. of Dwelling Units	% of effective daylit areas	No. of dwelling units with 60% of habitable spaces with effective daylighting
Unit Type 1 representing Level 1 to 5 ***(with Significant Obstruction Urban Context that is AUOA of 45°)***	50	42.1% < min 60% requirement	0
Unit Type 2 representing Level 6 to 10 ***(with Moderate Obstruction Urban Context that is AUOA of 22.5°)***	50	73.5% > min 60% requirement	50
Unit Type 3 representing Level 11 to 15 ***(with Unobstructed Urban Context)***	50	67.6% > min 60% requirement	50
Total	150		100

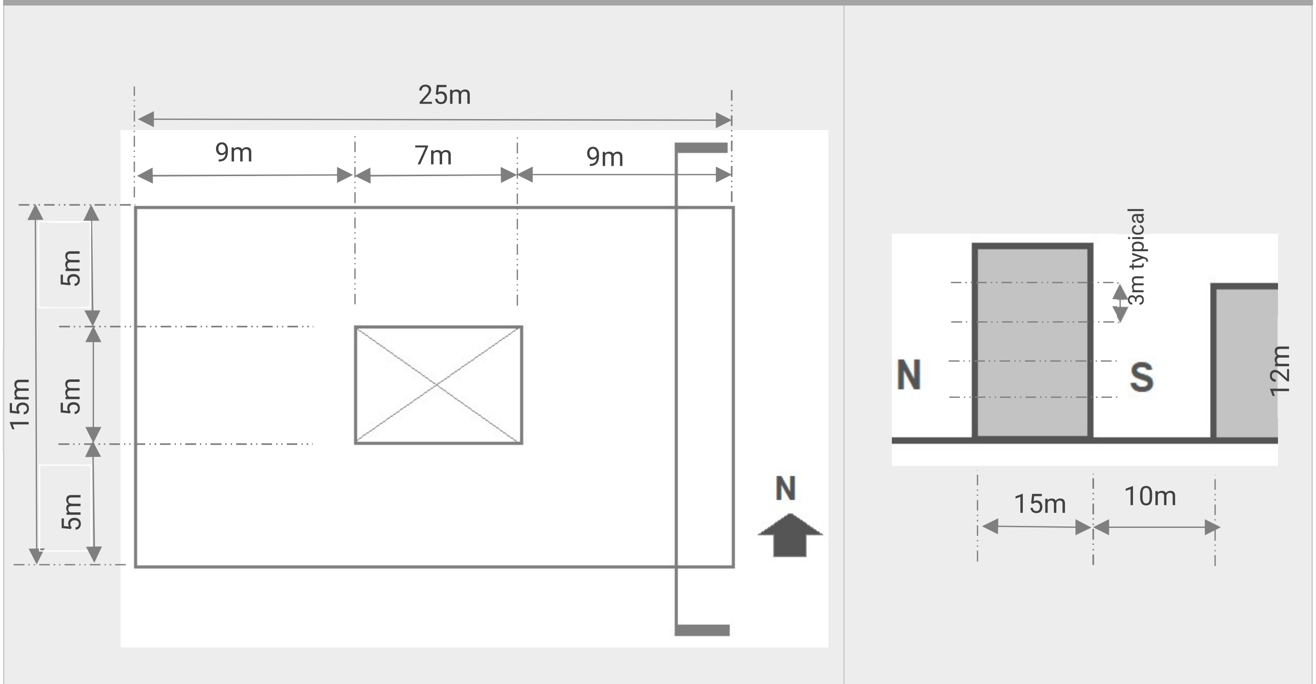
Percentage of dwelling units with 60% of habitable spaces with effective daylighting = 100 units / 150 units = 66.7% > 25% min ok

Worked Example for Non-Residential Building

Proposed non-residential development with one block of 5-Storey office with sky obstruction from neighbouring building at its south-facing façade. The simplified elevation, typical floor layout and façade design parameters of the office are as shown below.

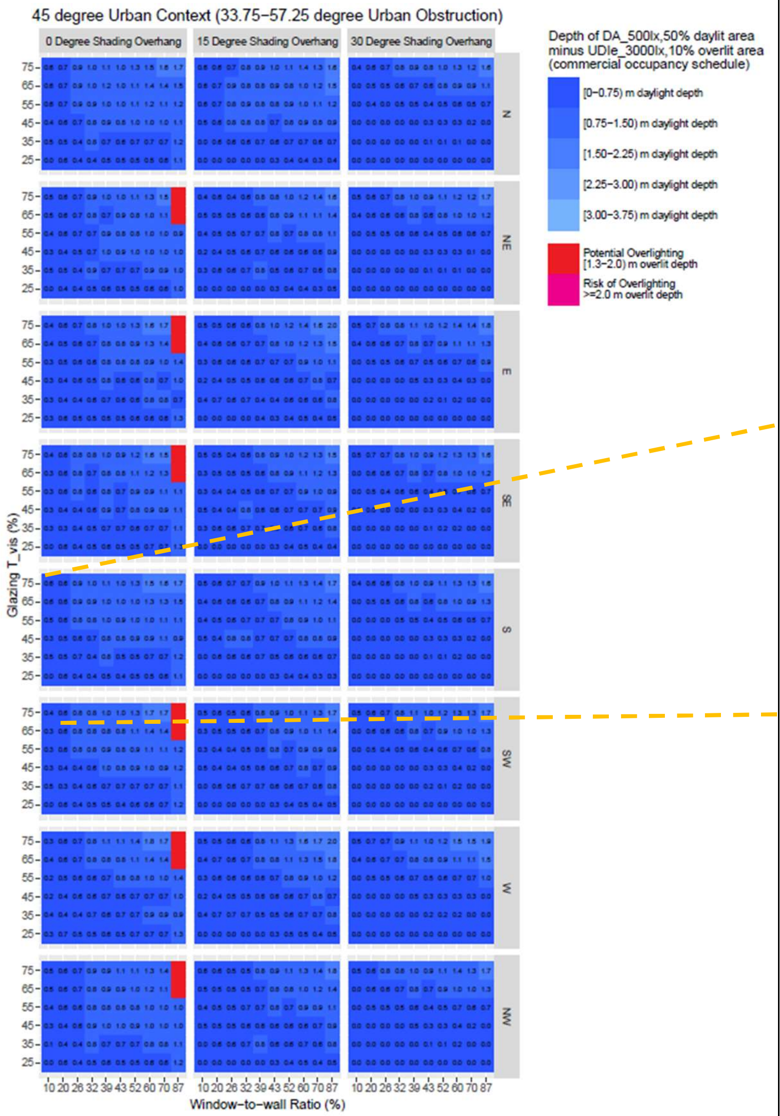
In this example, daylight from the air well and non-applicable area are excluded for simplicity.

Plan	Elevation



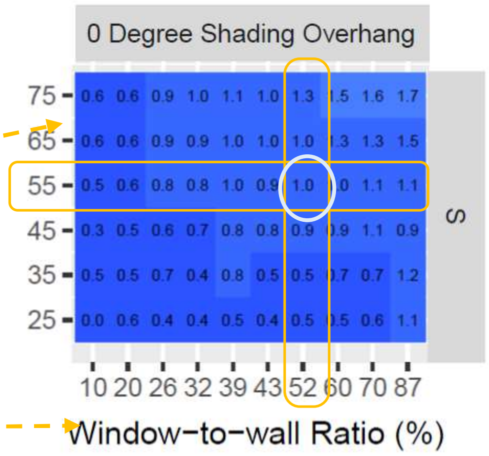
Level	Orientation of Vertical Fenestration	Overhang Obstruction Angle (OOA)	Visible Light Transmittance (Tvis) (%)	Window to Wall Ratio (WWR) (%)	Obstruction angle from adjoining block
1	South	0	55	52	50
2	South	0	55	52	42
3	South	0	55	52	31
4	South	0	55	52	17
5	South	0	55	52	0
1 to 5	North	15	55	52	0
1 to 5	East	15	55	10	0
1 to 5	West	15	45	20	0

Level 1 & 2- South-facing fenestration- Average Urban Obstruction Angle (AUOA) of 45°

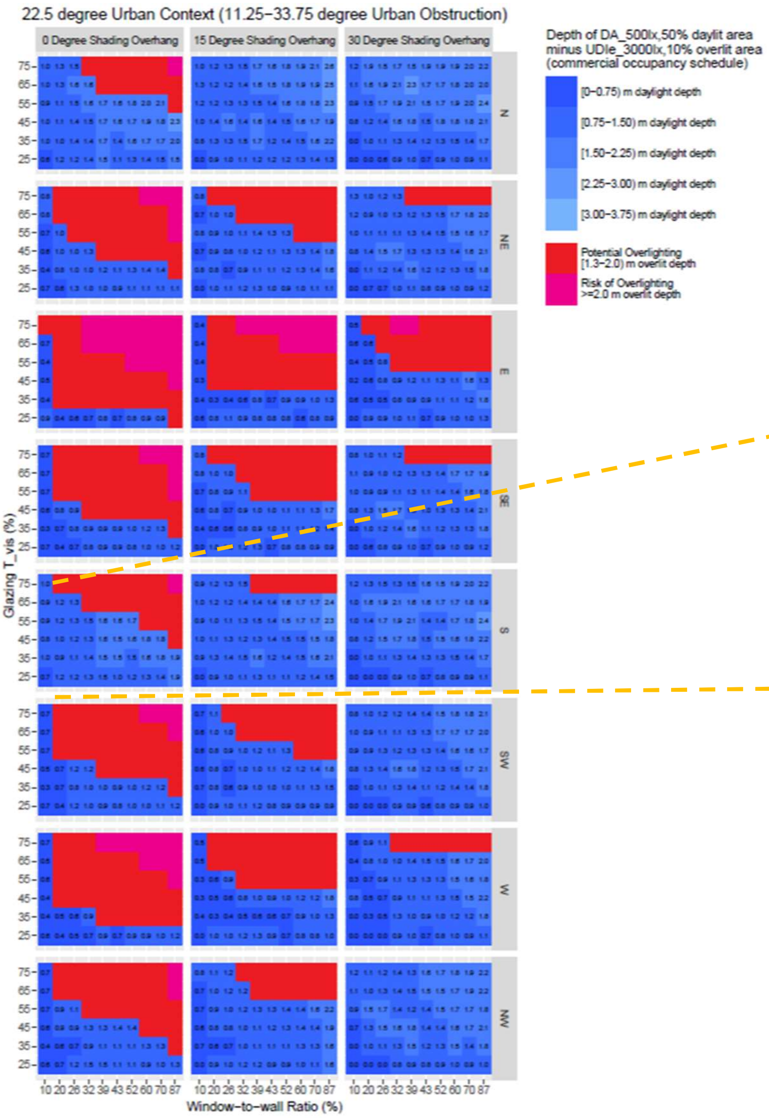


Daylight Availability Table DT 1-3

For Office and Institutional spaces including Schools

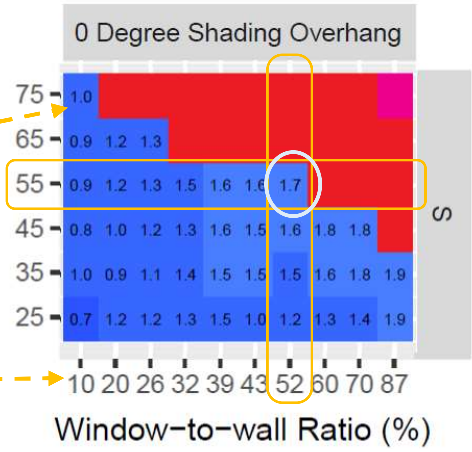


Level 3 & 4- South-facing fenestration- Average Urban Obstruction Angle (AUOA) of 22.5°

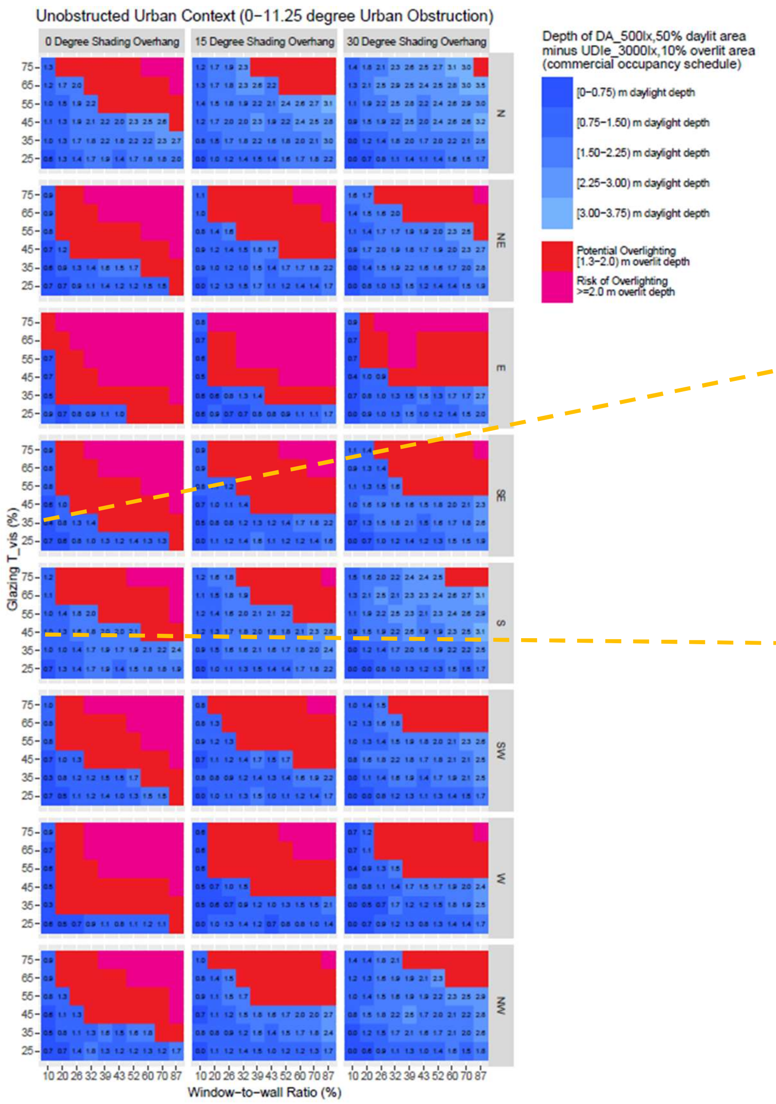


Daylight Availability Table DT1-2

For Office and Institutional spaces including Schools

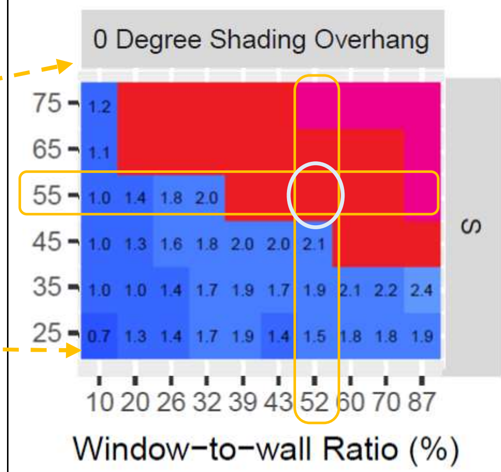


Level 5- South-facing fenestration- Average with Unobstructed Urban Context

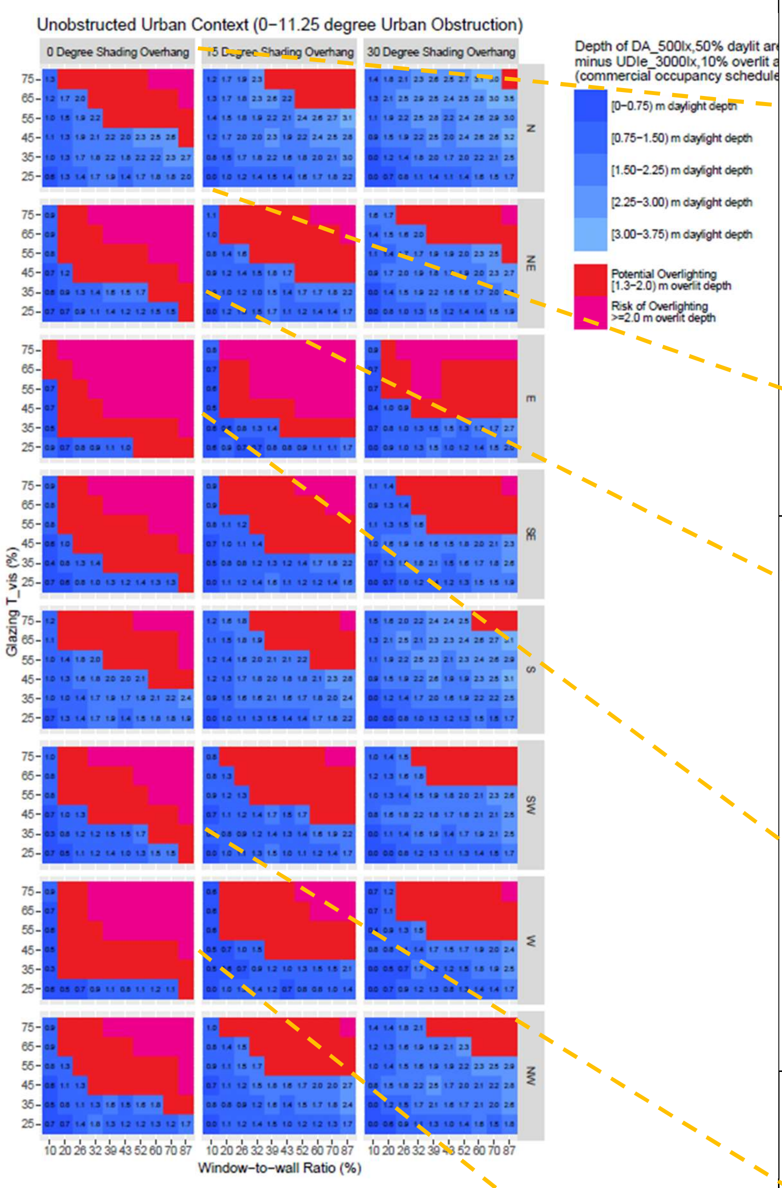


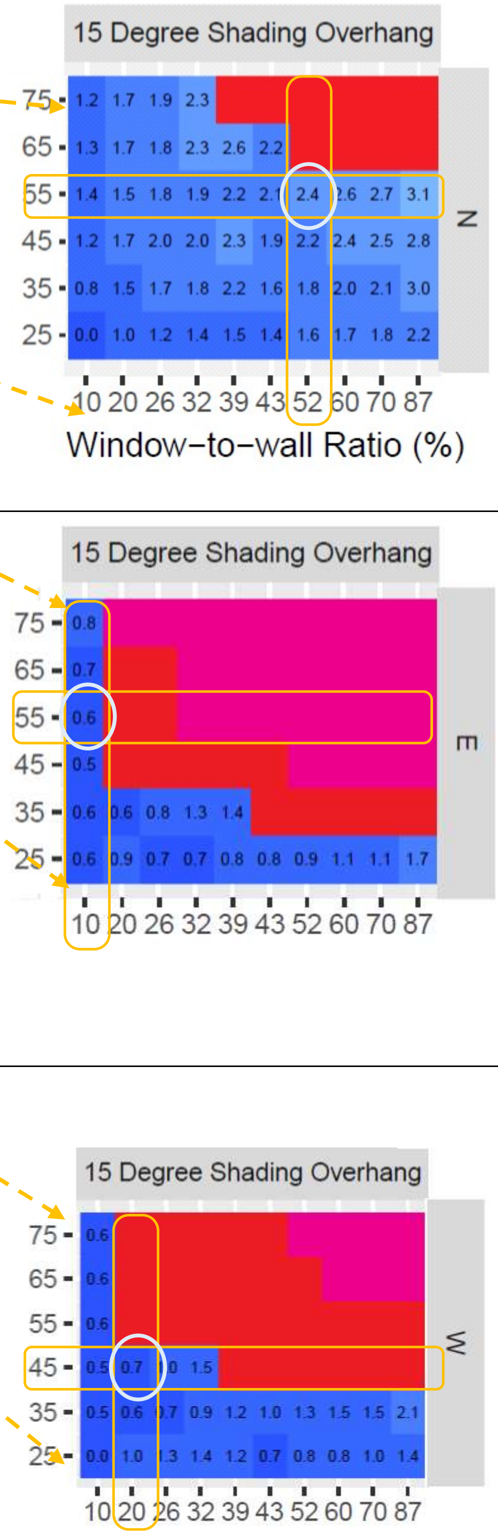
Daylight Availability Table DT1-1

For Office and Institutional spaces including Schools



Level 1 to 5- North. East & West facing fenestration- Average Urban Obstruction Angle (AUOA) of 22.5°





Daylight Availability Table DT1-1

For Office and Institutional spaces including Schools

Level 1- Office area (with Significant Obstruction Urban Context that is AUOA of 45°)				
Orientation of Vertical Fenestration	Floor Areas (m^2)	Daylit Room Width (m)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
N	340	9.92	2.4	23.81
S		9.92	1.0	9.92
W		11.6	0.7	8.12
E		11.6	0.6	6.96
			Area daylit	48.81

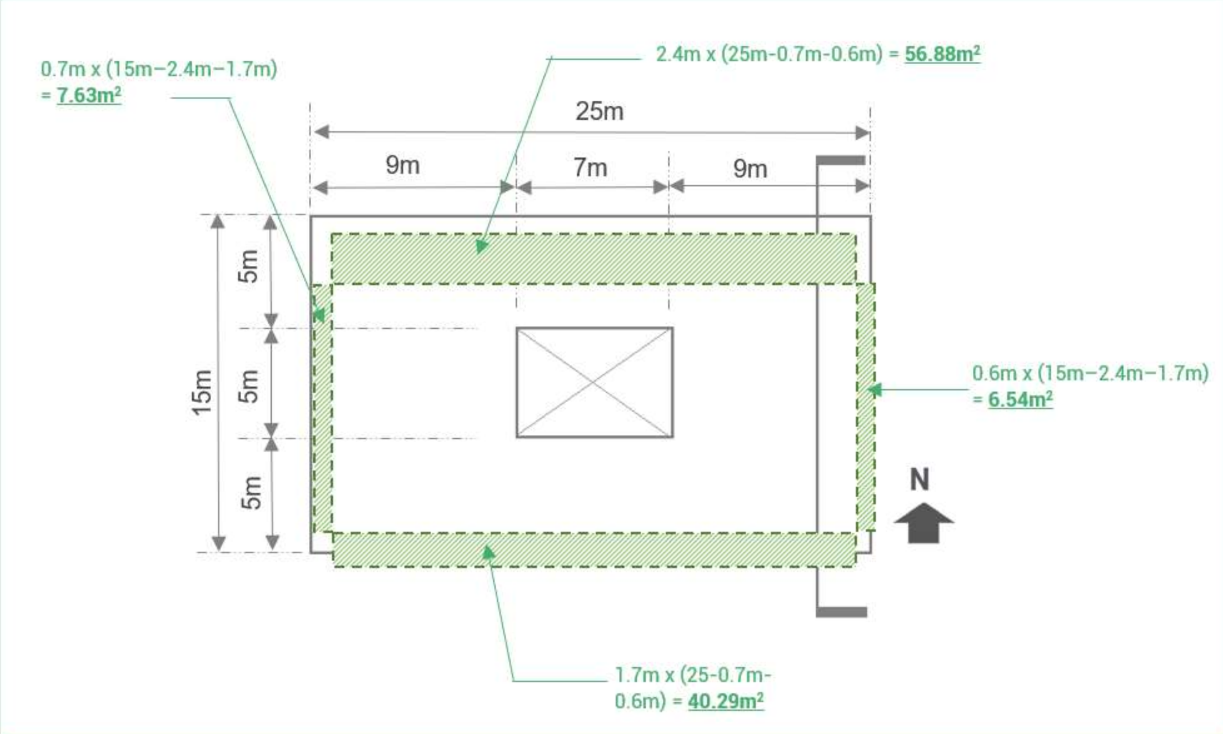
Level 2- Office area (with Significant Obstruction Urban Context that is AUOA of 45°)				
Orientation of Vertical Fenestration	Floor Areas (m^2)	Daylit Room Width (m)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
N	340	9.92	2.4	23.81
S		9.92	1.0	9.92
W		11.6	0.7	8.12
E		11.6	0.6	6.96
			Area daylit	48.81

Level 3- Office area (with Significant Obstruction Urban Context that is AUOA of 45°)				
Orientation of Vertical Fenestration	Floor Areas (m^2)	Daylit Room Width (m)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
N	340	23.7	2.4	56.88
S		23.7	1.7	40.29
W		10.9	0.7	7.63
E		10.9	0.6	6.54
			Area daylit	111.34

Level 4- Office area (with Significant Obstruction Urban Context that is AUOA of 45°)				
Orientation of Vertical Fenestration	Floor Areas (m^2)	Daylit Room Width (m)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
N	340	23.7	2.4	56.88
S		23.7	1.7	40.29
W		10.9	0.7	7.63
E		10.9	0.6	6.54
			Area daylit	111.34

Level 5- Office area (with Significant Obstruction Urban Context that is AUOA of 45°)				
Orientation of Vertical Fenestration	Floor Areas (m^2)	Daylit Room Width (m)	Depth of Effective Daylit Areas from Daylight Availability Table (m)	Effective Daylit Areas (m^2)
N	340	25	2.4	56.88
S		25	0	0.00
W		12.6	0.7	7.42
E		12.6	0.6	6.36
			Area daylit	70.66

In Summary	
Total daylit area for the block:	390.96m^2
Total floor area:	1700.0m^2
Percentage daylit floor area:	23%



Marking out example for the calculation for Level 3 (Level 4 has similar results)

Other Base Sustainability Requirements for Existing Buildings

ENRB01 Building Energy Performance

Intent

Reduce energy demand associated with key building services and equipment during operation.

Applicability & Scope

Applicable to existing buildings with mechanical and/or electrical equipment and systems. This section specifies the minimum energy efficiency requirements for the following systems.

(a) Building cooling systems that serve an aggregate air-conditioned area > 500 m^2;
(b) Lighting systems for interior spaces, building facades and landscape;
(c) Mechanical ventilation systems for normally occupied spaces and car parks, where applicable; and
(d) Vertical transportation system, where applicable.

Requirement

The compliance with the requirement shall be demonstrated either by way of energy audit based on the methodology detailed in ENRB01-1 or by meeting the enhanced energy performance standards set for the key building systems as detailed in ENRB01-2.

ENRB01-1 Whole Building Approach via Energy Audit

For the Whole Building Approach via Energy Audit, the minimum energy efficiency requirements can be complied with via the building's total yearly electricity consumption and Energy Usage Index (EUI). The EUI of the building shall not exceed the benchmark set for the various building categories stipulated in the GM International Energy Efficiency Technical Guide, Table 1B Pathway 1.

In addition, the Total System Efficiency (TSE) of the building cooling system must also be within the minimum stipulated limit set in Pathway 2, Fixed Metrics. TSE refers to the combined system efficiency of the chilled water plant and air distribution systems.

ENRB01-2 System Level Approach via Enhanced Energy Performance Standards

Alternatively, the System Level Approach shall be adopted where all enhanced energy performance standards set for the following key building systems are to be complied with.

(a) Building cooling systems
(b) Lighting systems for interior spaces, building facades and landscape;
(c) Mechanical ventilation systems for normally occupied spaces and car parks, where applicable; and
(d) Vertical transportation system, where applicable.

ENRB01-2(a) Air-Conditioning System

To reduce energy required to provide and distribute conditioned air within the space using energy-efficient air-conditioning system.

The Total System Efficiency (TSE) which is the combined system efficiency of the chilled water plant or condenser unit, and air distribution systems shall not exceed the limits set in the section on "8. Air Conditioning Total System Efficiency (Non-Residential Buildings)".

ENRB01-2(b) Lighting System

To reduce energy required to illuminate interior spaces with proper lighting levels. Refer to the section on "12. Lighting Power Budget"

ENRB01-2(c) Mechanical Ventilation System

To reduce energy required to supply and distribute fresh air within the space using energy-efficient mechanical ventilation systems and controls. Refer to the section on "13. Mechanical Ventilation".

ENRB01-2(d) Vertical Transportation System

To reduce energy consumption from vertical transportation such as lifts and escalators by adopting energy-efficient technologies and control. Refer to the section on "11. Vertical Transportation System".

ENRB02 Measurement and Verification (M&V) Instrumentation

Intent

Facilitate energy management and monitoring of the operating system efficiency of air-conditioning systems.

Applicability & Scope

Applicable to existing buildings with central chilled water plant and/or Variable Refrigerant Flow (VRF) systems that serve an aggregate conditioned floor area of 2000 m^2 or more.

Base Requirement

A building shall be equipped with means to facilitate monitoring and improvement in the efficiency of the building cooling systems.

ENRB02-1 Instrumentation for Chilled Water Air-conditioning System

Refer to "1. Permanent Instrumentation for Measurement and Verification" for "(i) Chilled Water Air Conditioning System".

ENRB02-2 Instrumentation for Variable refrigerant Flow (VRF) System

Refer to "1. Permanent Instrumentation for Measurement and Verification" for "(ii) Variable Refrigerant Flow (VRF) System"

ENRB03 Real-Time Remote Monitoring of Chiller Plant Operation

Intent

Facilitate real-time monitoring of chiller plan system operation.

Applicability & Scope

Existing Buildings with chiller plant systems

Requirement

A building shall be designed and equipped with means to facilitate energy measurement and management in real-time remotely. The provision of a web-based control system with remote access and functionality to monitor the chiller system operation and efficiency with diagnostic alerts will be required.

Documentation Requirements

- Technical specification of the functionality of the web-based control system; and
- Site demonstration of the features for remote monitoring.

ENRB04 Energy Utilisation Reporting

Intent

Facilitate trending and analysis of the building energy consumption profile and pattern for review and energy improvement.

Applicability & Scope

Generally applicable

Requirement

Sustainable practices that facilitate review of building consumption and energy improvement plan and measures. There must have evidence of energy use monitoring of the building over the last three (3) years. The trends of the EUI which is the Annual Total Building Energy Consumption (kWh)/GFA(m^2) must be included as part of the review process.

Guidance Notes

The building's Energy Use Intensity (EUI) for the past 3 years shall be calculated based on actual utility bills. Any abnormal trends or significant increase in EUI should be investigated and corrective actions should be carried out to address any wastage.

Calculation of EUI = TBEC / GFA where

TBEC : Total building energy consumption (kWh/year)

GFA : Gross floor area (exclude car park area) (m2)

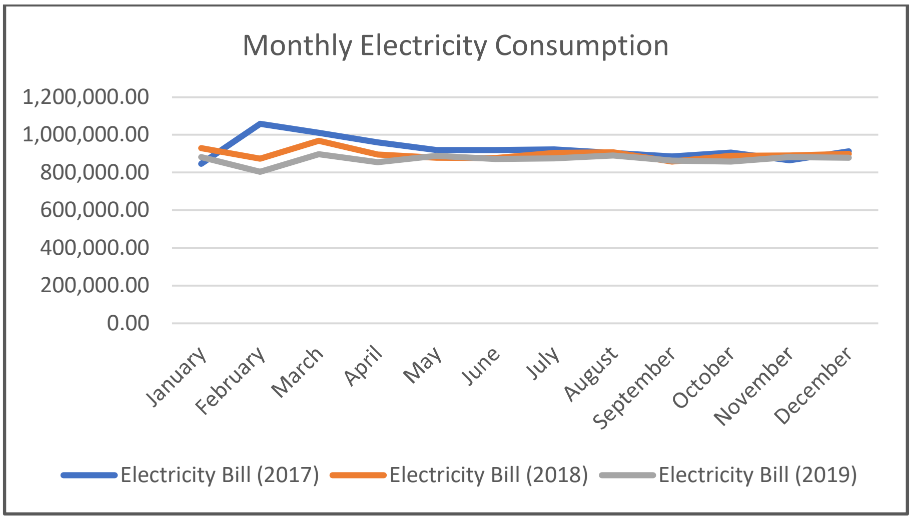
Worked Example ENRB04

An existing building with GFA of 31,540 m^2 and the following energy consumption data.

Month	Electricity Bill (2017)	Electricity Bill (2018)	Electricity Bill (2019)
January	846,332.05	928,990.22	881,538.18
February	1,059,170.28	872,425.01	803,967.48
March	1,009,784.15	969,407.75	898,125.78
April	959,061.17	895,217.92	854,398.27
May	918,719.73	877,730.64	888,123.20
June	918,339.21	876,166.72	871,571.00
July	922,716.52	903,425.78	874,511.78
August	903,851.85	907,715.70	890,246.84
September	885,180.49	858,509.93	863,458.04
October	904,567.52	888,244.20	858,307.30
November	865,289.02	890,177.01	881,028.54
December	911,383.18	898,669.48	878,565.07
TOTAL (kWh/yr)	11,104,395.15	10,766,680.34	10,443,841.48

EUI Calculation

Indicators	2017	2018	2019
Total (kWh/yr)	11,104,395.15	10,766,680.34	10,443,841.48
GFA (m^2)	31,540	31,540	31,540
EUI (kWh/yr/m^2)	352.07	341.37	331.13
Deviation (%)	-	- 3.04%	- 3%



Documentation Requirements

- Energy utilisation report with energy consumption and EUI trends over the past three (3) years; and
- Energy improvement plan and measures to be included, where relevant.

ENRB05 Indoor Temperature

Intent

Minimise incidences of overcooling and energy wastage. of Facilitate trending and analysis of the building energy consumption profile and pattern for review and energy improvement.

Applicability & Scope

Generally applicable to air-conditioned spaces

Requirement

Sustainable operation practices that minimise energy wastage and facilitate better thermal comfort for building occupants. There must have effective control to ensure that the normal dry-bulb temperature for indoor spaces is maintained at 23^{o}C and above.

Documentation Requirements

IAQ surveillance audit report (hardcopy and softcopy in excel template) endorsed by an accredited laboratory.

Reference

SS 553 – Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.

ENRB06 Indoor Air Quality (IAQ) Surveillance Audit

Intent

Ensure a comfortable and healthy indoor environment for occupants through the testing and evaluation of IAQ parameters within an occupied air-conditioned space.

Applicability & Scope

Generally applicable to air-conditioned premises where air-conditioning is used intermittently or continuously. Not applicable for hospitals, polyclinics and laboratories.

Requirement

A building is maintained to provide a good indoor environment for building occupants. There shall be an Indoor Air Quality (IAQ) surveillance audit conducted and the results of the IAQ parameters must be within the acceptable range.

Guidance Notes

An IAQ surveillance audit can be conducted based on the indicative methods according to SS 554 : 2016 Code of Practice for Indoor Air Quality for Air-Conditioned Buildings

Documentation Requirements

IAQ surveillance audit report (hardcopy and softcopy in excel template) endorsed by an accredited laboratory.

Reference

SS 554 - Code of Practice for Indoor Air Quality for Air-conditioned Buildings.

Carbon Reduction Measures for Existing Non-Residential Buildings

Section 1 – Sustainable Features

Encourage incorporation of cost-effective green features and passive strategies to minimise overall building consumption and to improve on indoor thermal comfort.

- ENRBE01-1 Building Envelope Enhancement
- ENRBE01-2 Natural Ventilation Strategies

ENRBE01-1 Building Envelope Enhancement

Enhance building envelope performance to minimise heat gain to internal spaces for better indoor thermal comfort with any of the following provisions:

(a) Façade design with Envelope Thermal Transmittance Value (ETTV) of not more than 45 W/m^2 when replaced.

(b) Application of cool materials that are certified by an approved local product certification body for 80% of all external walls of the existing buildings or applicable roof areas.

(c) Provision of innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, film technology, parametric façade for at least 20% of the fenestration areas.

Guidance Notes

ENRBE01-1(a): The Envelope Thermal Transfer Value (ETTV) is to be determined using the methodology set out in the Code on Envelope Thermal Performance for Buildings and shall not exceed 45 W/m^2.

ENRBE01-1(b): Cool materials in this context refer to surface coating, paints, tiles that come with high solar reflectance and infrared emissivity properties and are certified by an approved local product certification body. The extent of application shall cover at least 80% of all external walls of the existing building blocks or applicable roof areas.

Worked Example ENRBE01-1(b)

Example of an existing building with application of cool paints on external wall areas

<table>
<tr><th>Block Description</th><th>Total Applicable External Wall Areas (m^2)</th><th>Areas with cool materials (m^2)</th><td rowspan="5">Extent of coverage =
16500/22500 *100 = 80.5% ok

Note: The green wall areas can be excluded in the computation.</td></tr>
<tr><td>Blk 1</td><td>4500</td><td>3500</td></tr>
<tr><td>Blk 2</td><td>6000</td><td>5000</td></tr>
<tr><td>Blk 3</td><td>10000</td><td>8000</td></tr>
<tr><td>Total:</td><td>20500</td><td>16500</td></tr>
</table>

Example of an existing building development with application of cool paints on roof areas

Block Description	Total roof areas (m^2)	Non-Applicable Areas (m^2)	Total Applicable Roof Areas (m^2)	Roof Areas with cool materials (m^2)
Blk 1	5000	400	4600	3100
Blk 2	4000	400	3600	3500
Blk 3	5000	500	4500	4000
	14000	1300	12,700	10600
Extent of coverage = 10600/12700*100 = 83.5% ok				
Note: Non-applicable areas can include green roofs and areas beneath large equipment like cooling towers, water tanks or photovoltaic (PV) panels where the application of cool materials may not be relevant.				

ENRBE01-1(c): Innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, film technology, parametric façade for at least 20% of the fenestration areas.

<u>Worked Example ENRBE01-1(c)</u>

Example of a proposed single existing building using a combination of Building Integrated Photovoltaic (BIPV) system and film technology to enhance the building envelope performance design.

Innovative Solutions	**Areas of Application (m^2)**	
Film Technology	2000	Total Fenestration Areas = 20500 Extent of coverage = 5000/20500 = 24% ok
BIPV system	3000	
Total areas of application	5000	

Document Requirements

<u>ENRBE01-1(a)</u>

- ETTV computation;
- Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant for the computation of the ETTV; and
- Architectural plan layouts and elevations showing the mode of ventilation and location for various spaces including air-conditioning areas.

<u>ENRBE01-1(b)</u>

- Extracts from tender specifications showing the requirement to incorporate cool materials for the specific wall or roof areas; and
- Certification details of the cool materials used, technical product information, delivery orders, confirmation on the extent of application and coverage.

<u>ENRBE01-1(c)</u>

- Extract from tender specifications showing the requirements on the specific façade technology or solutions and test report where applicable; and
- Elevation drawings and details showing the areas where the façade technology or solutions are used and confirmation on the extent of application and coverage.

ENRBE01-2 Naturally Ventilated Building Design

Reduce energy demand for cooling and ventilation by enhancing the space layout design with added provision of naturally ventilated spaces. It may entail conversion and re-design of existing conditioned spaces to be naturally ventilated, where appropriate. A minimum coverage of 5% in any of the following areas will be required.

- Lift lobbies
- Corridors
- Staircases
- Atriums
- Toilets
- Others

Guidance Notes

As these spaces are generally typical in terms of areas, the extent of coverage can be based on the number or respective areas of the applicable spaces that are naturally ventilated for simplicity.

For example, an existing building with 20 toilets and out of which 2 were re-designed to be naturally ventilated. In this case, the extent of coverage will be 10% which meets the minimum requirement of 5%.

Documentation Requirements

- Architectural plan layouts showing the applicable areas with highlights of those that are re-designed to be naturally ventilated; and
- Tabulation showing the total number/areas and percentage of applicable areas that are naturally ventilated.

Related Information

Natural Ventilation: Under the Approved Document – Section G – Ventilation regulated under the Building Control Regulations, there are specific requirements in relation to natural ventilation, to protect people from loss of amenity due to lack of fresh air. There are requirements on the minimum size of openable windows or other openings as well as their location to ensure adequate ventilation is provided in a building.

ENRBE01-3 Sustainable Products

Encourage the specification and use of environmentally friendly products that are certified with Environmental Product Declaration (EPD) requirements or two-tick rating by an approved local product certification body.

The provision shall include at least two (2) building products and/or Mechanical and Electrical (M&E) systems/equipment for 80% of applicable functional spaces or building components/system.

Guidance Notes

An Environmental Product Declaration (EPD) is a transparent, objective report that communicates the environmental performance and impact of a product over its life cycle. EPDs support carbon emission reduction by making it possible to compare the environmental impacts of different products and facilitate the selection of more sustainable options. For this requirement, products with EPDs that are third-party certified and in conformance with ISO 14025 and EN 15804 and/or products certified with a two-tick rating by an approved local product certification body can be considered. The extent of coverage must be at least 80% of the applicable areas/building components/systems within the functional spaces.

Worked Example ENRBE01-3

Example of a proposed office building development with provision of the following products and coverage that meet the requirements.

Products	Extent of Coverage	Provision	Remarks
Building cooling system	100% for building operation	Two-tick rated based on the extent of environmental friendliness by an approved local product certification body	√
Drywall partition	100% Applicable to the Management office	With EPD that is third-party certified and in conformance with ISO 14025 and EN 15804	√

Documentation Requirements

- Extract of tender specification and drawings (if applicable) showing the requirements to incorporate specific products with EPDs or two-tick rated by an approved local certification body;
- Certification of EPDs or details from an approved local certification body such as the material certification standards, rating and product reference; and
- Technical product information and delivery records.

References

- SS ISO 14205 : Environmental Labels and Declarations – Type III environmental declarations – Principles and procedures
- EN 15804 : Sustainability of Construction Works – Environmental Product Declarations – Core Rules for the Product Category of Construction Products

Carbon Reduction Measures for Existing Non-Residential Buildings

Section 2 – Sustainable Operation and Management

Facilitate smart monitoring and integration of sustainability management practices to maximise operational efficiency and carbon reduction opportunities.

- ENRBE02-1 Electrical Submetering
- ENRBE02-2 Maintenance of Building Cooling System Performance
- ENRBE02-3 User Engagement Plan

ENRBE02-1 Electrical Submetering

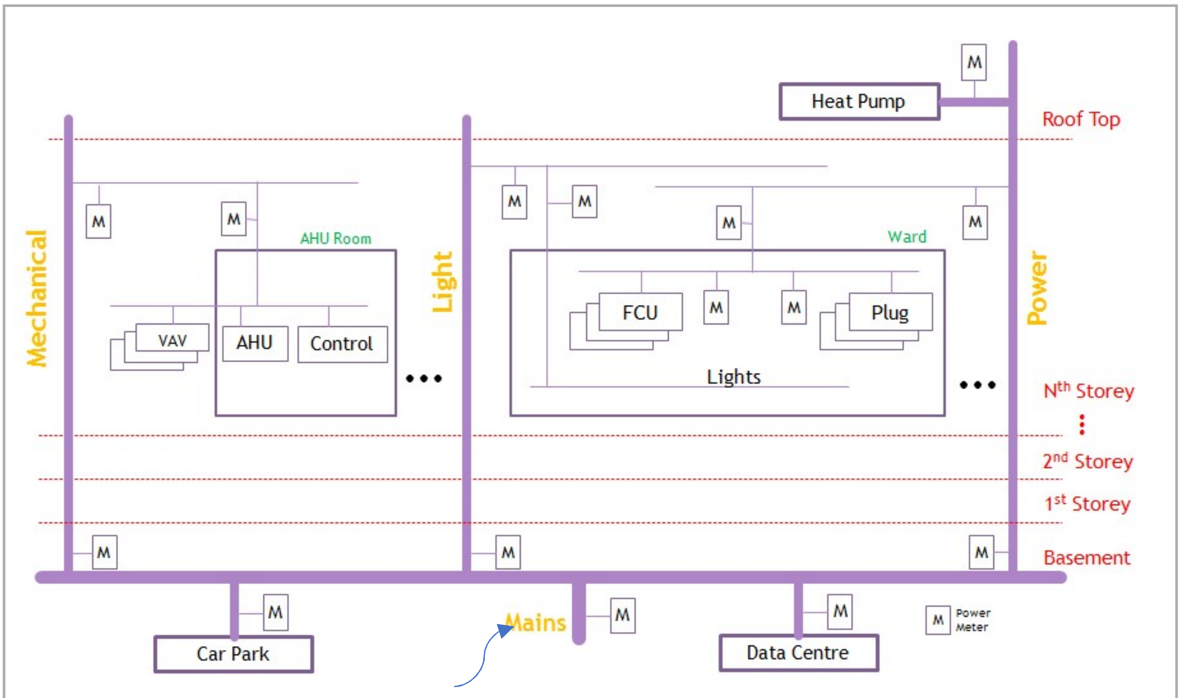
Facilitate measurement and monitoring of major energy end uses for energy management and audit. The provision shall come in the form of separate electrical sub-meters for the sub-systems as listed below. The sub-metering for these systems is to be equipped with data logging capability to communicate energy consumption and metered data to a monitoring system that can store, measure and trend energy use data and comply with the specifications set out for any of the following systems when upgrade:

Sub-Systems for Metering	
Lifts and escalators	More than 5 numbers or sets or with a sum of all feeders > 50 kVA.
Mechanical ventilation systems	Total subsystem's load > 15 kW Sub-metering applicable to individual fan system motors that are more than 1.5 kW in the following areas: • Normally Occupied Spaces • Mechanical and Electrical (M & E) Plant Rooms • Car Parks
Centralised hot water supply system	> 50 kW thermal heating capacity
General power supply and lighting systems	Sub-metering for tenancy areas and owners' premises are to be separated. The sub-circuits serving these areas can be provided on sub-system level basis and/or per floor level.
Note(1): Sub-metering provision for chilled water plant, variable refrigerant flow (VRF) systems and air distribution systems are covered under ENRB02. Note(2): If there is a need to cater to high plug loads or process loads exceeding 50 kVA, please provide separate sub-metering for these specific areas to better manage and audit the building energy consumption.	

Guidance Notes

An example of a sub-metering arrangement for a hospital is as follows:

- Each major energy load areas: data centre, car park, heat pump
- Each major energy use: light, plug load (power)
- Air distribution sub-system (VAV, AHU, FCU)
- Each floor and ward



Private main meter to record the total building energy consumption

Documentation Requirements

- Sub-system equipment, power meter and current transducer specifications;
- As-built electrical single-line diagrams showing the location of the power meters;
- As-built design of main switchboards (MSBs) and power distribution boxes (DBs); and
- Evidence of the remote capability and link to a BMS/EMS system.

ENRBE02-2 Maintenance of Building Cooling System Performance

Ensure adequate access space provisions for building cooling system performance can be maintained after a system upgrade.

The access space provisions for the following equipment are to comply with either the service clearances as per manufacturers' specification or the specifications set out in ENRBE02-2(a) to ENRBE02-2(d), whichever governs.

ENRBE02-2(a) Chillers

Access space provisions are as follows:

(a) Clearance of 2.0 m or more at the front of chiller unit piping section for tube maintenance and cleaning, repair and replacement of bigger components;

(b) Clearance of 1.2 m or more between the chillers measured from plinth to plinth for regular maintenance; and

(c) Clearance of 1.5 m or more above the chiller for maintenance, overhaul or replacement.

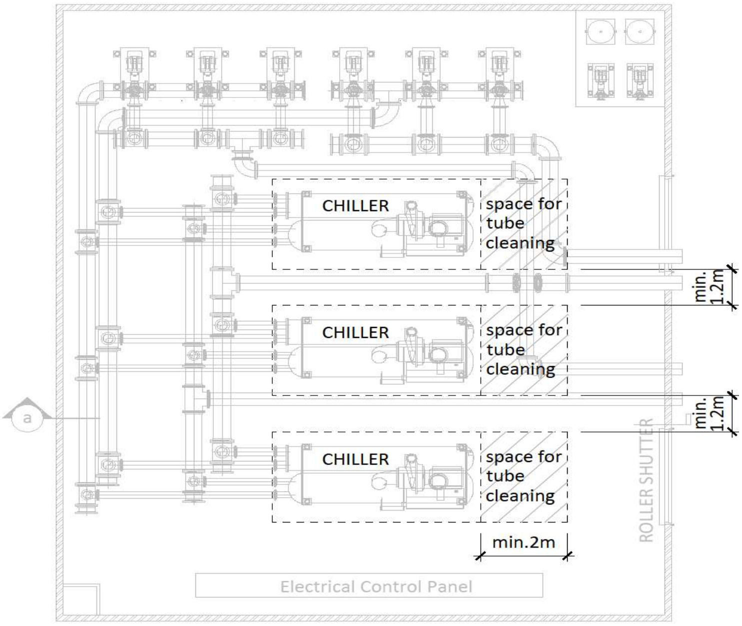


Figure A1 – Access space for the chillers

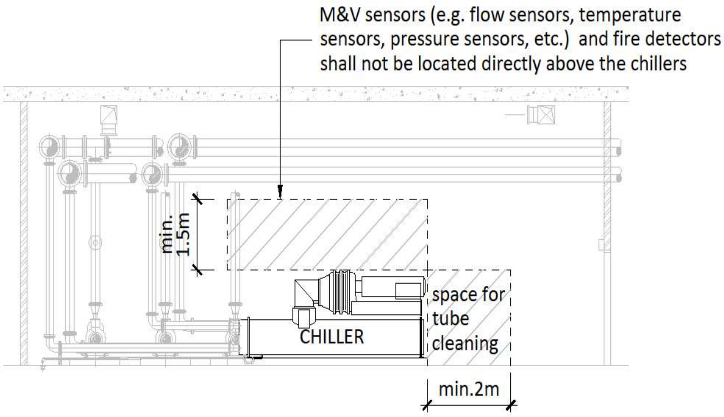


Figure A2 – Head room requirements for the chillers

Documentation Requirements

- Architectural/mechanical plan drawings indicating the chiller plant location.

- ACMV chiller plant layout drawing showing the access space provisions or tender specifications indicating the access space provisions;
- Shop drawing/as-built chiller plant layout and sectional drawing indicating the access space provisions as per the actual equipment selection; and
- Photographs showing the clear access space provisions for chiller plant equipment including M&V sensors.

ENRBE02-2(b) Pump Systems

Access space provisions are as follows:

(a) Except for the areas where the pipes are connected, clearance of 0.6 m or more is to be provided around the pump for regular maintenance; and

(b) Clear headroom of 1.0 m or more above the pump and motor to facilitate maintenance, overhaul or replacement.

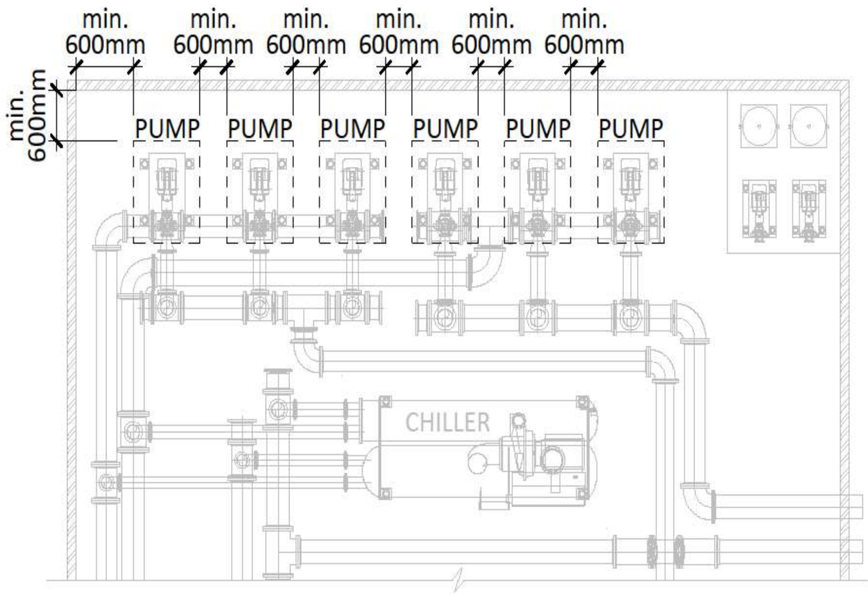


Figure A3 – Access space for the pump systems

Documentation Requirements

- Chiller plant layout drawing with access space provisions and headroom requirement;
- Tender specification indicating the access space provisions for chilled water pumps and condenser water pumps;
- Shop drawings/as-built drawings highlighting the space and headroom provision for pumps with dimensions as per the actual equipment selection; and
- Photographs showing the provision of access space and headroom.

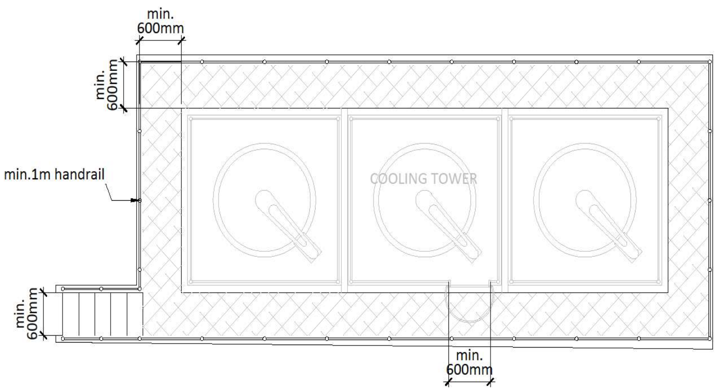
ENRBE02-2(c) Cooling Towers

Maintenance provisions are as follows:

(a) Provision of maintenance platform, stairs and catwalks of 600 mm width or more with handrails around the cooling towers and access to the level for periodic maintenance and the inspection of water basin and fill media; and

(b) Clear distance of 2.0 m or more from the top of cooling towers to the location of the trellis, where applicable.

Note(1): Proper clearances on all sides of the cooling tower should be provided in accordance with the manufacturer's technical recommendation to ensure the heat rejection performance of cooling towers is not affected or should not be less than the lateral width of the cooling tower, whichever governs.



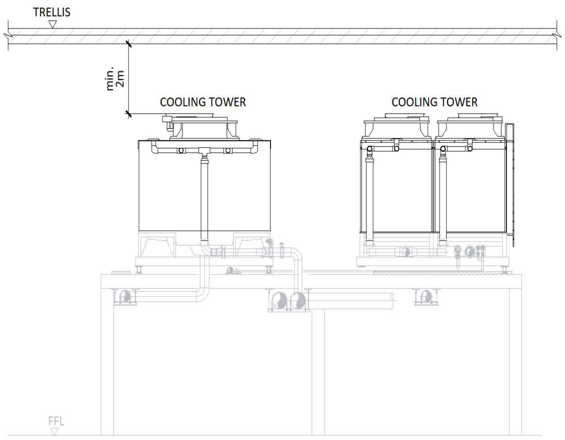


Figure A5 – Clear space requirement from top of cooling towers to location of trellis

Documentation Requirements

- ACMV plan drawing showing the requirement on the maintenance platform;
- Tender specifications indicating the maintenance platform requirements;
- ACMV shop drawing/as-built drawings indicating the permanent stairs and catwalk around the cooling tower; and
- Photographs showing the catwalk and maintenance platform installed.

ENRBE02-2(d) Air Distribution Systems

Maintenance provisions are as follows:

(a) Air handling units (AHU) of cooling capacity greater than 35 kW shall be floor mounted as stipulated in SS 553.

(b) For AHUs that are floor mounted, the access space provisions are as follows:

(i) AHU access – Provide minimum 1.0 m clearance from the AHU room door entrance to the AHU for general maintenance;

(ii) Cooling coil pipe and filter access – Provide minimum 800 mm clearance after pipe connection to facilitate cooling coil cleaning and filter access;

(iii) Fan access – Provide minimum 800 mm clearance for fan/motor access and maintenance (if the access is not from the cooling coil connection side); and

(iv) AHU side and back clearance – Provide minimum 600 mm clear width for general access and maintenance.

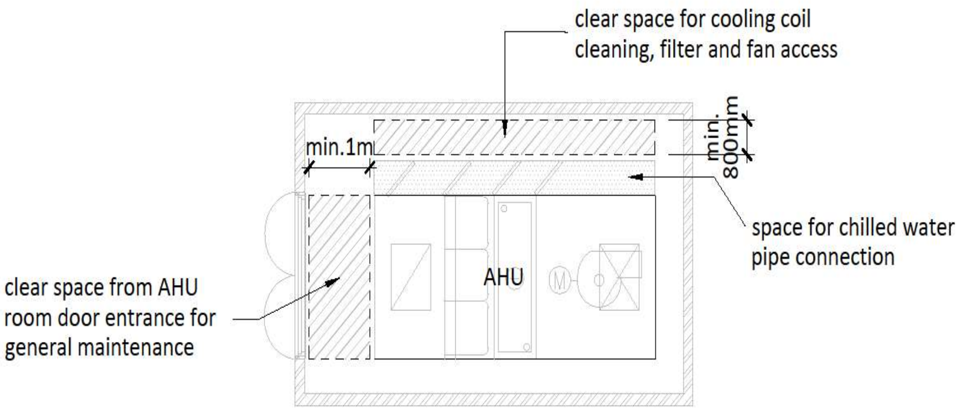


Figure A6 – Space provisions for Air Handling Units

Note: All AHUs of cooling capacity greater than 35 kW shall be floor mounted

Documentation Requirements

- Tender specifications indicating the access/space provisions for air handling units (AHUs);
- As-built drawings/shop drawings (including plan drawing/section) highlighting the AHU room access space provision; and
- Photographs showing the space provisions

References

- Design for Maintainability Guide on Non-Residential Buildings published by Building and Construction Authority
- Maintainability Section under the Green Mark 2021 Framework

ENRBE02-3 User Engagement Plan

Encourage the provision of user engagement plans and strategies that facilitate users' involvement and contribution in reducing the overall carbon footprint. It should have a combination of minimum of two (2) strategic approaches from the listing below:

- Green education
- Green related activities and programmes
- Green fit-out guidelines
- Green Lease
- Others (to be assessed on a case to case basis)

Guidance Notes

Examples of the engagement plan that can be considered and as follows:

Green Education
• Green Building User Guide Dissemination of green building user guide to all tenants with a detailed overview of the green features and sustainable practices employed in the building and their environmental benefits. The guide should include recommendations on how the users could properly operate or utilise these green features as well as other sustainable practices that they can undertake within their premises. • Green Corner Green Corner should be dedicated to the education and promotion of green building elements and environmental sustainability. It should be located in a prominent area, easily accessible and noticeable to all tenants, building occupants and visitors.
Green Related Activities and Programmes for Building Occupants, Tenants or Public
• Activities such as Earth Hour, exhibitions, seminars, talks on environmental sustainability • Incentive programmes for tenants meeting measurable outcome • Promotional efforts to encourage tenants to take up sustainability-related certification
Green Fit-Out Guidelines
• Provision of Green Fit-out Guidelines which should include recommendations to assist the tenants in making sustainable fit-out decisions and to be disseminated to the relevant tenant management and personnel.
Green Lease
• Green Lease agreement with tenants which establish the agreed environmental objectives and building performance

Documentation Requirement

- *Green Building User Guide*: Official green building user guide and evidence of its dissemination to the respective parties and building occupants.
- *Green Corner*: Photographic evidence of the Green Corner.
- *Green-related Activities*: Documentation such as promotional articles including brochures, pamphlets, emails, photographs of the green-related events.
- *Green Fit-Out Guidelines*: Official green fit-out guidelines and evidence of its dissemination to the building occupants/tenants.
- *Green Lease*: Official tenancy agreement with Green Lease and compliance procedures incorporated, complete with evidence of its application to the specific tenants. Other documents include the list of tenants, net lettable areas and details of tenants with Green Lease.

Carbon Reduction Measures for Existing Non-Residential Buildings

Section 3 – Sustainable Technologies

Encourage provision of green building technologies that are oriented towards establishing low energy building consumption and smart control systems that could adapt to the users' needs and enhance building energy performance.

- ENRBE03-1 Renewable Energy Sources
- ENRBE03-2 Smart Building Solutions
- ENRBE03-3 Green Building Technologies

ENRBE03-1 Renewable Energy System

Encourage the use of on-site renewable energy sources to reduce the use of electricity by at least 1% of the annual total building electricity consumption. There must be suitable means for monitoring and records of the energy generated from the system used.

Guidance Notes

The average annual total building electricity consumption of the building excluding tenants' electricity consumption shall be used to determine if the provision of on-site renewable energy sources meets the minimum requirement of 1%.

<u>Worked Example – ENRBE03-1</u>

An existing building development with multiple blocks with GFA of 120,000 m^2 and the following electricity consumption.

Month	Monthly Electricity Consumption (kWH/mth)		
	2017	**2018**	**2019**
Jan	1,211,742	2,182,720	2,302,892
Feb	1,417,844	2,140,469	2,019,043
Mar	1,304,704	2,011,638	2,021,604
Apr	1,518,710	2,241,270	2,301,516
May	1,619,952	2,123,190	2,152,914
Jun	1,721,194	2,345,117	2,331,292
Jul	1,850,377	2,173,922	2,217,904
Aug	2,188,679	2,220,098	2,372,013
Sep	2,143,945	2,171,360	2,248,731
Oct	2,231,941	2,118,413	2,218,344
Nov	2,264,791	2,221,515	2,229,759
Dec	2,149,503	2,034,892	2,277,345
Total Yearly Electricity Consumption (kWH/year)	**21,623,382**	**25,984,604**	**26,693,355**
Average Total Building Electricity Consumption (TBEC) per year	**24,767,114**		

Based on the supplier's specifications on the renewable system, compute the percentage (%) replacement.

Description	kWp Installed (kWp)	Annual Yield (kWh)
Upper Roof Block A	200	240,000
Roof Block B	200	240,000
Other blocks		0
Total	400	480,000

Total Building Consumption (kWh)	24,767,114
Annual Replacement Rate	1.93% > 1% ok

Documentation Requirements

- As-built drawings and on-site photographs of the renewable energy systems installed.
- Technical specifications and integration reports of the installed system(s) including total capacity installed; and
- Calculation of the percentage replacement of electricity and the total annual electricity consumption of the development.

ENRBE03-2 Smart Building Solutions

Encourage the provision of a minimum of two (2) smart building solutions to facilitate automation and controls over building systems for better energy management and thermal comfort. Examples of building solutions that can be considered are listed below:

- Use of BACnet, Modbus or any other open protocol as the network backbone of the building management system where data points can be used to facilitate communication and integration with other building systems.
- Energy portal and dashboard that helps building owners and/or tenants to better manage their energy consumption in an intuitive manner. It should comprise display metered data, trending of energy consumption (historical data) of the building and tenanted spaces on a monthly basis and other useful parameters.
- Demand controlled ventilation systems such as carbon dioxide sensors or devices to regulate the fresh air intake and ventilation based on occupants' needs.
- Timer sensors/controls for lighting and/or ventilation systems in common areas and facilities.
- Smart building sensors that are equipped with sensing capability, microprocessors and communication technology that can help facilitate some form of monitoring or automation.
- Differential pressure switches for Air Handling Units (AHUs) that are linked to a building management system (BMS) or suitable means that can monitor the air filter condition.
- Others (to be evaluated on a case to case basis).

Documentation Requirements

- Extract of tender specification or drawings showing the provision of the building solutions implemented for the project; and
- Technical specification on the systems or features used.

ENRBE03-3 Green Building Technologies

Encourage the adoption of low-carbon solutions and technologies which would help reduce building energy consumption. Examples of solutions that can be considered are as follows:

- Energy recovery systems for building applications
- Lifts with regenerative function
- Passive Displacement ventilation system
- Dedicated outdoor air system
- Others (to be evaluated on a case-to-case basis)

Guidance Notes

Green Building Technologies	General Information
Energy recovery systems for building applications	Energy recovery system can be integrated to minimise overall building energy demand. For example, heat recovery system that captures waste heat discharged from the air-conditioning system and transfers for water heating purpose, which otherwise is exhausted or wasted.
Lifts with regenerative function	Lifts with regenerative function can help conserve and minimise energy use. Depending on lift usage, operating speed, the height of building and floors, it would typically be a viable option for larger and taller buildings.
Passive displacement ventilation system	An innovative system that uses chilled water-cooling coils to create air circulation through natural convection process to deliver conditioned air, without mechanical fans. It taps on the principle of natural buoyancy and temperature stratification to deliver cooled air to end-users using less to no energy.
Dedicated outdoor air system	Dedicated outdoor air system (DOAS) such as precool unit can be used to condition all outdoor air (OA) for more effective cooling and ventilation control. It can enhance the opportunity to reduce the energy use for ventilation, air conditioning and fan operations as the system does not need to condition as much outdoor air (OA) as is the case with a variable air volume (VAV) system.

Documentation Requirements

- Brief on design intent and details of the proposed green building technologies.
- Extract of tender specification, as-built drawings and photographic evidence showing the provision and location of green building technologies implemented;
- Computation of expected energy savings over the estimated total building consumption; and
- Technical specification on the systems or features used.