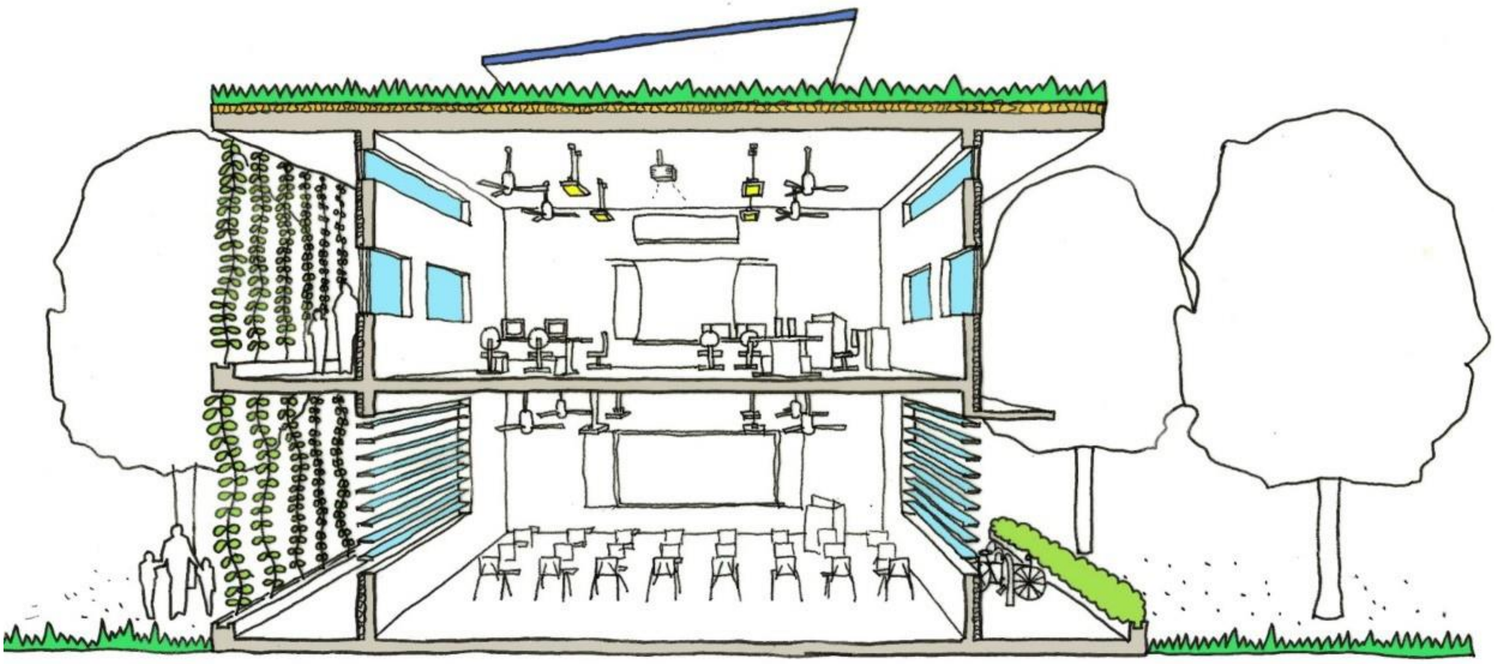
BCA GREEN MARK

GM NRB: 2015

GREEN MARK FOR NON-RESIDENTIAL BUILDINGS NRB: 2015

including Hawker Centres, Healthcare Facilities, Laboratory Buildings and Schools



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Green Mark Non-Residential Buildings NRB : 2015 Revision Log

Revision	Description	Date Effective
R0	Launch for Pilot	02/09/2015
R1	Revised Version for Implementation	31/08/2016
R2	Revised Version for Implementation: Minor wording amendments to: Pg 9, 15, 19, 22 - 24, 29, 32, 34, 37, 42, 53-55, 58, 62, 69, 71 - 74, 76	02/11/ 2016
R3	Revised Version to include annexes for specific building types Hawker Centres, Healthcare Facilities, Laboratory Buildings and Schools. Alternate option for scoring of Energy related items and other minor changes. Revision 3.1: Minor amendments made on 1 Nov 2019. Revision 3.2: Combine technical guide and criteria as single document and include ACT Annex on 15 Feb 2020.	01/08/2018

Introduction

What is BCA Green Mark?

The Building and Construction Authority (BCA) Green Mark scheme was launched in 2005 and is an internationally recognised green building rating system tailored for the tropical climate. Green Mark sets parameters and establishes indicators to guide the design, construction and operation of buildings towards increased energy effectiveness and enhanced environmental performance.

BCA Green Mark comprises a number of distinct rating tools that together holistically rate the built environment for its environmental performance. These include:

- **New Buildings**: Non-Residential, Residential, Data Centres and Landed Housing
- **Existing Buildings**: Non-Residential, Residential, Data Centres and Schools
- **User Centric**: Office Interior, Retail, Supermarket, Restaurant and Laboratories
- **Beyond Buildings**: Districts, Parks, and Infrastructure

Introducing Green Mark NRB: 2015

Green Mark for Non-Residential Buildings NRB: 2015 is the 5th edition of the Green Mark scheme for new non-residential buildings, such as commercial (office, retail and hotel), industrial and institutional buildings as well as specialised buildings Hawker Centres, Healthcare Facilities, Laboratories and Schools. This version delivers:

- A streamlined rating scheme that addresses sustainability in a more balanced and holistic manner.
- Greater emphasis on climatically contextual design, energy effectiveness, health and wellbeing of building occupants, smart buildings, and a systematic approach to addressing embodied energy and resource usage.
- Recognition of the design processes which respond to site context and facilitate sustainability considerations at the early project stages where there is the greatest opportunity for low cost, high reward options to be implemented.
- A collaborative framework with more than 130 industry members and academics involved in the setting of metrics, assessment methods and performance levels.

The Green Mark NRB: 2015 Criteria should be read in conjunction with the following accompanying handbooks and tools:

- Green Mark NRB: 2015 Technical Guide and Requirements
- BCA Carbon Calculator (Carbon Submission Form) (go.gov.sg/cc)
- BCA Energy Performance Points Calculator

Why Green Mark NRB: 2015?

Green Mark provides a consistent method to assess and verify buildings for their overall environmental performance, assisting project teams to deliver a more sustainable built environment and encouraging best practices and market transformation. It is a design guide that can be referenced to understand the attributes of what makes buildings truly sustainable. Green Mark NRB: 2015 aims to further stretch building outcomes to substantially reduce the environmental impacts and increase the life-cycle quality of projects. Moreover, it provides a platform to recognise and make mainstream the leadership needed to drive creative, organisational & technical improvements to the overall environmental credentials of projects.

Outcomes of Green Mark NRB: 2015

The indicators within the Green Mark criteria are mapped to internationally recognised sustainability outcomes. Driving these outcomes through the Green Mark scheme can ensure buildings awarded under Green Mark will truly be high quality environmentally sustainable developments for our current and future generations.

Climate
Buildings should demonstrate emissions reduction and resilience to the effects of climate change.

Resources
As stewards of the earth's resources, buildings should use resources in an efficient manner to reduce its environmental footprint over the building life cycle.

Wellbeing
Liveable built environments are vital for our health and well-being.

Ecology
Buildings should consider their wider impact on the biosphere through the integration of nature and protection of natural systems including flora and fauna.

Assessment Process

The BCA Green Mark Certification Process is as follows:

Application

- Submittal of application with relevant supporting documents for certification upon finalisation of building design.
- Upon acceptance of application and fee payable, a BCA Green Mark Assessor will be assigned for the duration of the project.

Assessment

- To be conducted when design and documentary evidences are ready.
- Comprises design and documentary reviews to verify if the building project meets the intents of the criteria and certification level; as well as the prerequisite requirements.
- For projects with potential BCA Green Mark Gold^{PLUS} and Platinum rating, a presentation to BCA panel for evaluation is required.

Verification

- To be conducted upon project completion.
- Includes review of delivery records, updated documents on green features and building energy performance data. Site inspection and measurement will be conducted.
- For projects with BCA Gold^{PLUS} and Platinum rating, energy savings based on the actual building operating data and parameters will be required to ascertain the energy performance of the building.

Green Mark NRB: 2015 Ratings

The environmental performance of a building development shall be determined by the numerical scores (i.e Green Mark points) achieved in accordance with the applicable criteria using the scoring methodology and the prerequisite requirements on the level of building performance as specified in this Green Mark scheme document. Under this assessment framework, points are awarded for incorporating sustainable design features and practices, which would add up to a final Green Mark Score. Depending on the level of building performance and Green Mark Score, the building development will be eligible for certification under one of the ratings, namely BCA Green Mark Gold, Gold^{PLUS} or Platinum. The design of the building development shall also meet all the relevant mandatory requirements regulated under the Building Control Regulations.

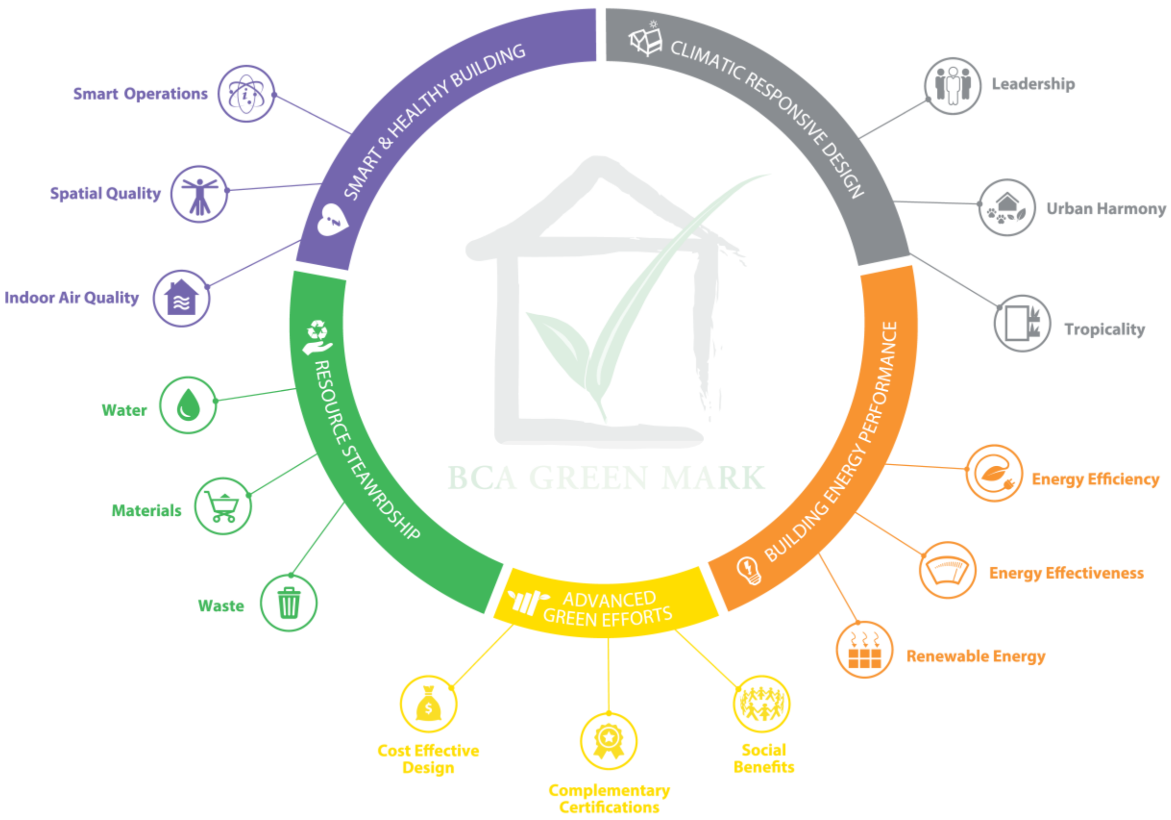
The Green Mark Score of the building design is the total of all the numerical scores assigned based on the degree of compliance with the applicable criteria. The following table states the corresponding Green Mark Score to attain the respective Green Mark ratings. Buildings must also fulfil their respective pre-requisite requirements to be awarded Green Mark. The total points scored include the bonus points scored under Advanced Green Efforts, as well as in the respective Annexes for buildings classified as hawker centres, healthcare, laboratories or schools.

BCA Green Mark Award Rating Scores

Green Mark Rating	Green Mark Score
Green Mark Platinum	70 and above
Green Mark Gold^{PLUS}	60 to < 70
Green Mark Gold	> 50 to < 60

Criteria Overview

To dovetail the criteria with the sustainable outcomes of Green Mark NRB: 2015, the criteria has been re-structured into 5 sections, with 16 criteria and 52 sustainability indicators. Each of the 4 main sections is equally weighted in terms of points. The total point is 140 points, inclusive of 20 points from Section 5: *Advanced Green Efforts* as well as additional credits scored under Annexes for specialised building types : hawker centres, healthcare facilities, laboratory buildings and schools.



Within the main criteria, criteria within the grey boxes with the 'Advanced Green Efforts' icon are scored under *5.1 Enhanced Performance*.

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GM NRB: 2015 Criteria Summary

Prerequisite Requirements
Prerequisites P.1 to P.15: Parked under main criteria
Minimum Points Prerequisites
Energy Modeling Prerequisite

Elective Requirements	
Part 1 - Climatic Responsive Design	**30 points**
P.1 Envelope and Roof Thermal Transfer	
P.2 Air Tightness and Leakage	
P.3 Bicycle Parking	
1.1 Leadership	**10 points**
1.1a Climatic & Contextually Responsive Brief	1 point
1.1b Integrative Design Process	4 points
4D, 5D & 6D BIM (Advanced Green Efforts)	*3 points*
1.1c Environmental Credentials of Project Team	2 points
1.1d User Engagement	3 points
1.2 Urban Harmony	**10 points**
1.2a Sustainable Urbanism	Up to 5 points
(i) Environmental Analysis	2 pts
Creation of possible new ecology and natural ecosystems (Advanced Green Efforts)	*1 pt*
(ii) Response to Site Context	3 pts
(iii) Urban Heat Island (UHI) Mitigation	1 pt
(iv) Green Transport	1.5 pts
1.2b Integrated Landscape and Waterscape	Up to 5 points
(i) Green Plot Ratio (GnPR)	3 pts
GnPR ≥ 5.0 (Advanced Green Efforts)	*1 pt*
(ii) Tree Conservation	1 pt
(iii) Sustainable Landscape Management	1.5 pts
(iv) Sustainable Storm Water Management	1 pt
1.3 Tropicality	**10 points**
1.3a Tropical Façade Performance	3 points
Low heat gain façade (Advanced Green Efforts)	*1 pt*
Greenery on the East and West Façade (Advanced Green Efforts)	*1 pt*
Thermal Bridging (Advanced Green Efforts)	*1 pt*
1.3b Internal Spatial Organisation	3 points
1.3c Ventilation Performance	4 points
Wind Driven Rain Simulation (Advanced Green Efforts)	*1 pt*

Part 2 – Building Energy Performance	30 points
P.4 Air Conditioning Total System and Component Efficiency	
P.5 Lighting Efficiency and Controls	
P.6 Vertical Transportation Efficiency	
2.1 Energy Efficiency	**22 points**
Option 1: Energy Performance Points Calculator	
2.1a Air Conditioning Total System Efficiency	5 points
2.1b Lighting System Efficiency	3 points
2.1c Carpark System Efficiency	2 points
2.1d Receptacle Efficiency	1 points
2.1e Building Energy	11 points
Further Improvement in Design Energy Consumption (Advanced Green Efforts)	*2 pts*
Option 2: Performance-Based Computation	
2.1f Space Conditioning Performance	10 points
Efficient space conditioning energy design (Advanced Green Efforts)	*1 pt*
2.1g Lighting Performance	6 points
Efficient lighting design (Advanced Green Efforts)	*1 pt*
2.1h Building System Performance	6 points
Additional Energy Efficient Practices and Features (Advanced Green Efforts)	*2 pts*
2.2 Renewable Energy	**8 points**
2.2a Solar Energy Feasibility Study	0.5 point
2.2b Solar Ready Roof	1.5 points
2.2c Adoption of Renewable Energy	6 points
Further Electricity Replacement by Renewables (Advanced Green Efforts)	*5 pts*
Part 3 – Resource Stewardship	**30 points**
P.7 Water Efficient Fittings	
3.1 Water	**8 points**
3.1a Water Efficient Systems	3 points
(i) Landscape irrigation	1 pt
(ii) Water Consumption of Cooling Towers	2 pts
Better Water Efficient Fittings (Advanced Green Efforts)	*1 pt*
3.1b Water Monitoring	2 points
(i) Water Monitoring and Leak Detection	1 pt
(ii) Water Usage Portal and Dashboard	1 pt
3.1c Alternative Water Sources	3 points

3.2 Materials	18 points
3.2a Sustainable Construction	8 points
(i) Conservation and Resource Recovery	1 pt
(ii) Resource Efficient Building Design	4 pts
Use of BIM to calculate CUI (Advanced Green Efforts)	*1 pt*
(iii) Low Carbon Concrete	Up to 3 pts
Use of Advanced Green Materials (Advanced Green Efforts)	*1 pt*
3.2b Embodied Carbon	2 points
Provide Own Emission Factors with Source Justification (Advanced Green Efforts)	*1 pt*
Compute the Carbon Footprint of the Entire Development (Advanced Green Efforts)	*2 pt*
3.2c Sustainable Products	Up to 8 points
(i) Functional Systems	8 pts
(ii) Singular Sustainable Products outside of Functional Systems	2 pts
Sustainable Products with Higher Environmental Credentials (Advanced Green Efforts)	*2 pts*
3.3 Waste	**4 points**
3.3a Environmental Construction Management Plan	1 point
3.3b Operational Waste Management	3 points
Part 4 – Smart & Healthy Building	**30 points**
P.8 Thermal Comfort	
P.9 Minimum Ventilation Rate	
P.10 Filtration Media for Times of Pollution	
P.11 Low Volatile Organic Compound (VOC) Paints	
P.12 Refrigerants	
P.13 Sound Level	
P.14 Permanent Instrumentation for the Measurement and Verification of Chilled Water Air-Conditioning Systems	
P.15 Electrical Sub-Metering & Monitoring	
4.1 Indoor Air Quality	**10 points**
4.1a Occupant Comfort	2 points
(i) Indoor Air Quality (IAQ) Surveillance Audit	1 pt
(ii) Post Occupancy Evaluation	0.5 pt
(iii) Indoor Air Quality Display	0.5 pt
Indoor Air Quality Trending (Advanced Green Efforts)	*2 pts*
4.1b Outdoor Air	3 points
(i) Ventilation Rates	1.5 pts
(ii) Enhanced Filtration Media	1 pt
(iii) Dedicated Outdoor Air System	0.5 pt
4.1c Indoor Contaminants	5 points
(i) Local Exhaust and Air Purging System	2 pts
(ii) Ultraviolet Germicidal Irradiation (UVGI) System	0.5 pt
(iii) More Stringent VOC Limits for Interior Fittings and Finishes	2 pts
(iv) Use of Persistent Bio-cumulative and Toxic (PBT) free lighting	0.5 pt
Zero ODP Refrigerants with Low Global Warming Potential (Advanced Green Efforts)	*1 pt*

4.2 Spatial Quality	**10 points**
4.2a Lighting	Up to 6 points
(i) Effective daylighting for common areas	2 pts
(ii) Effective daylighting for occupied spaces	4 pts
(iii) Quality of Artificial Lighting	1 pt
4.2b Acoustics	2 points
(i) Sound Transmission Reduction	0.5 pt
(ii) Acoustic Report	1.5 pt
4.2c Wellbeing	Up to 2 points
(i) Biophilic Design	3 pts
(ii) Universal Design (UD) Mark	1 pt
4.3 Smart Building Operations	**10 points**
4.3a Energy Monitoring	3 points
(i) Energy Portal and Dashboard	2 pts
(ii) BAS and Controllers with Open Protocol	1 pt
Permanent M&V for VRF Systems (Advanced Green Effort)	*2 pts*
Permanent M&V for Hot Water systems (Advanced Green Efforts)	*1 pt*
4.3b Demand Control	3 points
(i) ACMV Demand Control	2 pts
(ii) Lighting Demand Control	1 pt
(iii)Carpark Guidance System	0.5 pt
4.3c Integration and Analytics	3 points
(i) Basic Integration and Analytics	0.5 pt per feature
(ii) Advanced Integration and Analytics	1 pt per feature
Additional Advanced Integration and Analytical Features (Advanced Green Effort)	*1 pt*
4.3d System Handover and Documentation	1 point
Expanded Post Occupancy Performance Verification by a 3rd Party (Advanced Green Effort)	*2 pts*
Energy Performance Contracting (Advanced Green Effort)	*1 pt*
Part 5 – Advanced Green Efforts	**20 points**
5.1 Enhanced Performance	Up to 15 points
5.2 Complementary Certifications	1 point
5.3 Demonstrating Cost Effective Design	2 points
5.4 Social Benefits	2 points
Annexes for specialised buildings	**10 to 15 points**
Annex 1: Energy Efficiency Features for Specialised Building [Hawker Centres]	15 points
Annex 2: Energy Efficiency Features for Specialised Building Healthcare Facilities]	10 points
Annex 3: Energy Efficiency Features for Specialised Building [[Laboratories]	10 points
Annex 4: Energy Efficiency Features for Specialised Building [Schools]	10 points

GM NRB:2015 Summarised Criteria

Part 1 – Climatic Responsive Design	Green Mark Points

P.1 Envelope and Roof Thermal Transfer

	Gold	Gold^{PLUS}	Platinum
ETTV (W/m^2)	45	40	38

Maximum Thermal Transmittance for roof			
Roof Weight Group	Weight Range (kg/m^2)	A/C Bldg (A/C areas > 500m^2)	Non A/C Bldg (A/C areas ≤500m^2)
		Maximum U-value (W/m^{2}K)	
Light	< 50	0.5	0.8
Medium	50 to 230	0.8	1.1
Heavy	> 230	1.2	1.5

Green Mark Points: Prerequisite

P.2 Air Tightness and Leakage

Comply with SS 212: 2007 – Specification for Aluminium Alloy Windows and SS 381: 1996 (2007) – Materials and Performance Tests for Aluminium Curtain Walls

Green Mark Points: Prerequisite

P.3 Bicycle Parking

Meet the minimum quantity of bicycle parking lots required for the development, in line with URA circular *URA/PB/2018/03-DCG (or prevailing circular)* and *LTA's Code of Practice - Street Work Proposal Relating to Development Works (or prevailing COP)*

Green Mark Points: Prerequisite

1.1 Leadership

1.1a Climatic & Contextually Responsive Brief

Create climatic and culturally responsive brief including target setting

Green Mark Points: 1 point
(Up to 1 point for 1.1a)

1.1b Integrative Design Process

(i) Demonstrate Integrated design process — 2 points

- Appointment of all relevant consultants early in the design phase
- Identification of responsible parties within the team to implement relevant sustainability goals and targets
- Detailing of sustainable design methodology action plans and progress
- Addressing of opportunities and challenges with integrative team strategies to achieve the targets
- Organising of design charrettes at key stages within the project design

Rating	Gold	Gold^{PLUS}	Platinum
Min point for 1.1b	-	2 pts	

(ii) Involve Facility Manager (FM) in the design stage and incorporating his inputs into design. — 1 point

(iii) Use of BIM — 1 point

(Up to 4 points for 1.1b)

1.1c Environmental Credentials of Project Team

This pertains to the appointment of environmental specialists at building design, construction and operations stages.

Green Individuals:

- Green Mark Accredited Professional [GMAP] or Green Mark Accredited Professional (Facilities Management) [GMAP (FM)] — 0.25 point with at least one GMAP or GMAP(FM)
- Green Mark Advanced Accredited Professional [GMAAP] or Green Mark Advanced Accredited Professional (Facilities Management) [GMAAP (FM)] — 0.5 point with at least one GMAAP or GMAAP(FM)

(Up to 0.5 point for Green Individuals)

Green and Gracious Builder:

- The main builder is a BCA Certified Green and Gracious Builder. — 0.25 point for Certified or Merit; or 0.5 point for Excellent or Star rating

(Up to 0.5 point for Green & Gracious Builder)

Green Companies:

- Following companies with ISO14001 certification: Architect, M&E Engineer, C&S Engineer, Developer and Main Contractor. — 0.25 point each per consultant type IS014001
- SGBC Green Services Certified Firm. — 0.25 point each

(Up to 1.5 points for Green Companies)

(Up to 2 points for 1.1c)

Part 1 – Climatic Responsive Design	Green Mark Points
1.1d User Engagement	
Provision of relevant information and guidance to building occupants so that they can contribute positively to the reduction of the building's environmental impact	
• Building user guide • Sustainability Education Corner • Sustainability Awareness & Education Programme • Green fit out guidelines	0.5 point each
• Displaying Green Mark credential	1 point each (Green fit out guidelines is required for all ratings. Display of Green Mark credential is required for Platinum projects)
• Green lease	
➢ ≥ 25% of the net lettable area	1 point
➢ ≥ 60% of the net lettable area	3 points
	(Up to 3 points for 1.1d)
1.2 Urban Harmony – Part A	
1.2a Sustainable Urbanism	
Minimise environmental impact to the surroundings through site analysis	
(i) Environmental Analysis	
• Environmental Study	1 point
• Comprehensive Environmental Impact Assessment (EIA) by 3rd party	2 points (Up to 2 points)
(ii) Response to Site Context	
• Level 1 site analysis and design that demonstrates sensitivity to the site condition	1 point
• Level 2 site analysis optimised design with at least 2 types of iterative simulations	3 points (Up to 3 points)
(iii) Urban Heat Island (UHI) Mitigation	
• ≥ 50% site coverage (at plan view) with mitigation measures	0.5 point
• ≥ 80% site coverage (at plan view) with mitigation measures	1 point (Up to 1 point)
(iv) Green Transport	
• Provision of electrical vehicle charging and parking infrastructure for vehicles or to facilitate electric car-sharing service (at least 1 lot per 100 lots (Up to 5 lots)	0.5 point each
• Meet the prevailing lower bound requirement by of 'Range Based Car Parking Standard (RCPS)' based on development type and parking zone published by LTA.	
• Provision of bicycle lots over and above requirements stated in URA circular *URA/PB/2018/03-DCG (or prevailing circular)* and *LTA's Code of Practice - Street Work Proposal Relating to Development Works (or prevailing COP)* with at least 1 bicycle parking lot per 1,500m² of GFA (Up to 30 lots)	
• Additional features to promote bicycle usage (at least 2 features to score)	**(Up to 5 points for 1.2a)**

Part 1 – Climatic Responsive Design	Green Mark Points
1.2 Urban Harmony – Part B	

1.2b Integrated Landscape and Waterscape

Integrate a verdant landscape and waterscape into their building design, to enhance the biodiversity around the development and provide visual relief to building occupants and neighbours.

(i) Greenery Provision

GnPR	Points
0.5 to <1.0	0.5
1.0 to <2.0	1.0
2.0 to <3.0	2.0
3.0 to <4.0	2.5
≥ 4.0	3.0

(ii) Tree Conservation

- Preservation of existing trees on-site — 0.5 point
- Replant an equivalent number of similar or native species of equivalent LAI — 0.5 point

(iii) Sustainable Landscape Management

- Certified under NParks Landscape Excellence Assessment Framework (LEAF) certification — 1.5 point
- Adoption of native species of greenery > 50% of the flora selected — 0.5 point
- Provision of landscape management plan — 0.5 point

(Up to 1.5 point for 1.2biii)

(iv) Sustainable Stormwater Management

- Certified under PUB Active, Beautiful and Clean Waters (ABC Waters) certification — 1 point
- Treatment of stormwater run-off
  - ≥ 10% of run-off of total site area — 0.5 point
  - ≥ 35% of run-off of total site area — 1 point

(Up to 1 point for 1.2biv)

(Up to 5 points under 1.2b)

Rating	**Gold**	**Gold**PLUS	**Platinum**
Min point for 1.2b	-	Commercial, Healthcare – 2 pts Others – 1 pt	

1.3 Tropicality	

1.3a Tropical Façade Performance

Holistic consideration of façade performance can reduce direct sunlight into the building and minimise thermal heat gain, enhancing indoor comfort and lowering the energy for conditioning the indoor environment.

Simulation Method

Overall Weighted Values	**Industrial Buildings**	**Other building types**
Window U-Value	5.4 W/m²K	2.8 W/m²K
Wall U-Value	1.5 W/m²K	0.7 W/m²K
Overall Envelope U-value	2.4 W/m²K	1.6 W/m²K
Window-to-Wall Ratio (Each façade)	0.2	0.4
Total Effective Glass Shading Coefficient (SC_1 x SC_2)	0.6	0.4
Roof U-Value	1.1 W/m²K	0.8 W/m²K
Sky light/ Roof window U-Value	4.3 W/m²K	2.2 W/m²K
RTTV (where there are sky lights for AC areas)	50 W/m²K	50 W/m²K

1 point for meeting notional façade stated
1 point for every 5% heat load reduction

Part 1 – Climatic Responsive Design	Green Mark Points

Non-Simulation Checklist for Industrial Buildings

Overall Weighted Values	Baseline	Points for meeting or reduction from baseline
Envelope U-Value (Up to 2 pts)	2.4 W/m^{2}K	0.5 points for every 0.4 W/m^{2}K reduction
WWR (Excludes Façade openings/ voids) (Up to 2 pts)	0.2	0.5 pt for meeting baseline 0.5 pt for every 0.05 reduction
Glass Shading Coefficient (SC1) (Up to 2 pts)	0.5	1 pt for meeting baseline 0.5 pt for every 0.05 reduction from baseline
Effective Sun Shading (Up to 2 pts)	-	1 pt for ≥10% effectiveness (N & S) 1 pt for ≥ 30% effectiveness (East and West)
Roof U-Value (Up to 2 pts)	1.0 W/m^{2}K	0.5 pt for every 0.1 W/m^{2}K reduction
Sky light/ Roof window U-Value (Up to 1 pt)	4.0 W/m^{2}K	0.5 pt for meeting baseline 1 pt for U-Value of 2 W/m^{2}K

Non-Simulation Checklist for Other Buildings Types

Overall Weighted Values	Baseline	Points for meeting or reduction from baseline
Envelope U-Value (Up to 2 pts)	1.6 W/m^{2}K	0.5 pt for meeting baseline 0.5 points for every 0.2 W/m^{2}K reduction
WWR (Excludes Façade openings/ voids) (Up to 2 pts)	0.4 (E & W facades not to exceed 0.3)	1 pt for meeting baseline 0.5 pt for every 0.05 reduction
Glass Shading Coefficient (SC1) (Up to 2 pts)	0.4	0.5 pt for meeting baseline 0.5 pt for every 0.05 reduction from baseline
Effective Sun Shading (Up to 2 pts)	-	1 pt for ≥ 10% effectiveness (N & S) 1 pt for 30% effectiveness (East and West)
Roof U-Value (Up to 1 pt)	0.8 W/m^{2}K	1 pt for meeting baseline
Sky light/ Roof window U-Value (Up to 0.5 pt)	2.2 W/m^{2}K	0.5 pt for meeting baseline

(Up to 3 points under 1.3a)

<u>1.3b Internal Spatial Organisation</u>

Adopting passive design strategies in the internal spatial organisation of a building provides opportunities to enhance building performance.

(i) Location of non-air-conditioned spaces, e.g. lift cores, staircases, toilets, electrical plantrooms etc that covers

- 1/3 of the east and west facades — 0.5 point
- 2/3 of the east and west facades — 1 point

(Up to 1 point)

(ii) Prorating the number of transient common spaces, e.g. toilets, staircases, corridors, lift lobbies and atriums by the mode of ventilation against the total number of applicable spaces

Point scored =

$$\frac{\text{No. of NV spaces x 2 + No. of MV spaces x 0.5 + No. of AC spaces x 0}}{\text{Total no. of spaces}}$$

(Up to 2 points)

(Up to 3 points under 1.3b)

<u>1.3c Ventilation Performance</u>

Naturally ventilated functional areas should be effectively designed to be thermally comfortable and healthy for the building occupants.

Part 1 – Climatic Responsive Design	Green Mark Points
(i) Ventilation Performance Checklist • Openings towards prevailing wind directions	0.1 point for every 10% of units or rooms with openings facing towards the prevailing winds (North & South) (Up to 1 point)
• Depth of room vs opening <table><tr><th>Ventilation</th><th>Non-Atria</th><th>Atria*</th></tr><tr><td>Single sided ventilation</td><td>W ≤ 2H</td><td>W ≤ 3H</td></tr><tr><td>Cross ventilation</td><td>W ≤ 5H</td><td>W ≤ 7.5H</td></tr></table>*A factor of 1.5 can be applied to the W-H ratio for atria. Atria are typically higher than surrounding floors (double volume or greater).	≥50% of applicable spaces – 1 point ≥70% of applicable spaces – 2 points (Up to 2 points)
(ii) Full Ventilation Simulation	<table><tr><th rowspan="2">Wind velocity</th><th rowspan="2">Thermal Comfort</th><th colspan="2">Air Quality</th><th rowspan="2">Points</th></tr><tr><th>Air Change Rate</th><th>Air Exchange Efficiency</th></tr><tr><td>0.2 m/s</td><td>-</td><td>-</td><td>-</td><td>3</td></tr><tr><td>0.4 m/s</td><td>-1.0 < PMV < +1.0</td><td>≥ 4</td><td>≥ 1</td><td>4</td></tr><tr><td>0.6 m/s</td><td>-0.8 < PMV < +0.8</td><td>≥ 10</td><td>≥ 1.2</td><td>4</td></tr></table>**(Up to 4 points under 1.3c)**<table><tr><th>Rating</th><th>Gold</th><th>Gold^{PLUS}</th><th>Platinum</th></tr><tr><td>Min point for 1.3c</td><td>-</td><td colspan="2">4 pts • Gold^{PLUS} – 0.4 m/s • Platinum – 0.6 m/s *Complementary methods to compliance are available as described in *1.3c*</td></tr></table>

Part 2 – Building Energy Performance	Green Mark Points

P.4 Air Conditioning Total System and Component Efficiency

Green Mark Rating	Air Cooled Chilled-Water System/ Unitary Air-Conditioning System		Water Cooled Chilled Water System		District Cooling System (DCS)
	Peak Building Cooling Load (RT)				
	<500	≥500	<500	≥500	
	Minimum DSE ηt (kW/RT)				
Gold	NA *(0.9, N.A.)*	NA	*NA (0.75, N.A.)*	NA *(0.67, NA)*	0.9 *(0.65, N.A.)*
Gold^{PLUS}	1.10 *(0.85, 0.25)*		*0.95 (0.7, 0.25)*	0.9 *(0.65, 0.25)*	0.9 *(0.65, 0.25)*
Platinum	1.03 *(0.78, 0.25)*		*0.93 (0.67, 0.25)*		

(ηc, ηa) shall meet their respective thresholds.

ηc: System kW/ton excluding the air distribution equipment or DCS system kW/ton

ηa: Air distribution equipment kW/ton

$\eta_t = \eta_c + \eta_a$

Green Mark Points: Prerequisite

P.5 Lighting Efficiency and Controls

Comply with SS 530 : 2014 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment.

Green Mark Points: Prerequisite

P.6 Vertical Transportation Efficiency

Lifts and escalators shall be equipped with AC variable voltage and variable frequency (VVVF) motor drive and sleep mode features.

Green Mark Points: Prerequisite

2.1 Energy Effiicency

Option 1: Energy Performance Points Calculator

Section 2.1a to 2.1e

2.1a Air Conditioning Total System Efficiency

The use of energy efficient air-conditioning systems can optimise their total system performance, and reduce the energy needed to produce and distribute conditioned air into building spaces.

Peak Building Cooling Load (RT)	Baseline for Total Design System Efficiency (kW/RT)
<500 RT	1.08
≥500RT	0.98

For district cooling plants under Path B scenario, where the plant is excluded from the computation, the baseline reference for the building air distribution equipment can be taken as 0.28 kW/ton for the purposes of points computation here.

Points scored = 0.2 x % improvement from baseline
(Computed by Energy Performance Points Calculator)

(Up to 5 points for 2.1a)

2.1b Lighting System Efficiency

The use of energy efficient lighting can reduce the energy needed to illuminate a space.

Baseline: SS 530: 2014 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment
Design to comply with SS 531 – 1: 2006 (2013)– Code of Practice for Lighting of Workplaces

Points scored = 0.1 x % improvement from baseline
(Computed by Energy Performance Points Calculator)

(Up to 3 points for 2.1b)

2.1c Carpark System Efficiency

The use of energy efficient carpark ventilation and lighting systems can reduce the energy needed for carpark operations.

Points scored = 0.05 x % improvement from baseline
(Computed by Energy Performance Points Calculator)

(Up to 2 points for 2.1c)

2.1d Receptacle Load Efficiency

The use of energy efficient receptacle equipment can reduce their energy consumption.

Points scored = 0.025 x % improvement from baseline x % of functional areas
(Computed by Energy Performance Points Calculator)

(Up to 1 point for 2.1d)

2.1e Building Energy

Encourage effective design of building systems to reduce building's overall energy consumption.

$$Points\ scored = \frac{\%\ improvement\ from\ baseline}{3}$$

(Computed by Energy Performance Points Calculator)

(Up to 11 point for 2.1e)

Part 2 – Building Energy Performance	Green Mark Points
Option 2: Performance-Based Computation	**Section 2.1f to 2.1h**

2.1f Space Conditioning Performance

Efficient use of energy to maintain a thermally acceptable indoor environment, by effective design of natural ventilation, energy efficient mechanical ventilation and air-conditioning systems.

Proration based on mode of ventilation in functional spaces

Natural Ventilation

As per scoring

Mechanical Ventilation

Systems	Constant Volume & Variable Volume	
Fan systems with nameplate motor power	≥ 4kW	< 4kW
Option 1: Fan system motor nameplate	0.35	No baseline
Option 2: Fan system input *Applicable pressure drop adjustments can be considered based on SS553 in accordance to GM NRB: 2015 Technical Guide and Requirements, subjected to BCA's evaluation	0.3	0.17

Air-conditioning

Efficient air-conditioning system

Peak Building Cooling Load (RT)	Baseline for Total Design System Efficiency (kW/RT)
<500 RT	1.08
≥500RT	0.98

*TDSE refers to combined efficiency of the cooling and air distribution components

*For district cooling plants under Path B scenario, where the plant is excluded from the computation, the baseline reference for the building air distribution equipment can be taken as 0.28 kW/ton for the purposes of points computation here.

Total points scored =
% of NV areas x points scored under NV + % of MV areas x points scored under MV + % of AC areas x points scored under AC

Natural Ventilation

Points scored = 6 points for design for NV + scoring in section 1.3c
(Up to 10 points)

Mechanical Ventilation

Points scored = 0.15 x % improvement from baseline stated in SS553
(Up to 10 points)

Air-Conditioning

Efficient air-conditioning system
Points scored = 0.4 x (% improvement from baseline)
(Up to 9 points)

(Up to 10 point for 2.1f)

2.1g Lighting System Performance

The use of energy efficient lighting can reduce the energy needed to illuminate a space.

Baseline: SS 530: 2014 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment

Design to comply with SS 531 – 1: 2006 (2013)– Code of Practice for Lighting of Workplaces

Points scored = 0.17 x (% improvement from baseline)

(Up to 6 point for 2.1g)

2.1h Building Systems Performance

Encourage effective design of building systems other than space conditioning systems and lighting systems to reduce building's overall energy consumption

(i) Receptacle Load Efficiency

Receptacle loads	Nominal Values
Computer Intensive Office	$22W/m^2$
General office areas	$16W/m^2$
Large conference areas	$11W/m^2$
Schools (Tertiary/IHLs)	$8W/m^2$
Schools (Primary/Secondary)	$5W/m^2$
Server/Computer rooms	$540W/m^2$

Points scored = 0.05 x (% improvement from baseline) x (% of functional areas)
(Up to 2 points)

(ii) Car Park Ventilation Energy

Mode of ventilation		Points
Natural Ventilation		1.5 points
Mechanical Ventilation	Without CO sensor/without Fume Extract	Point scored = 0.015 x % improvement from baseline (Up to 1 point)
	With CO sensor / Fume Extract	+ 0.25 points

(Up to 1.5 points)

<table>
<tr><th>Part 2 – Building Energy Performance</th><th>Green Mark Points</th></tr>
<tr><td>(iii) Energy Use Intensity

(iv) Energy Efficient Practices and Features</td><td>0.5 point for meeting 25th percentile EUI as per prevailing BCA Building Energy Benchmarking Report (BEBR)
(Up to 0.5 point)

Points scored = 0.5 x (% improvement from baseline total building consumption)
(Up to 2 points)

(Up to 6 point for 2.1h)</td></tr>
<tr><th>2.2 Renewable Energy</th><th></th></tr>
<tr><td>2.2a Solar Energy Feasibility Study
The evaluation of a building footprint's potential in harnessing solar energy can raise awareness on viable solar opportunities in the development and assist building developers in their decision making to adopt photovoltaics.</td><td>0.5 point for provision of solar feasibility report
(Up to 0.5 point)

(Up to 0.5 point for 2.2a)
(Required for all ratings with building's footprint ≥1,000m²)</td></tr>
<tr><td>2.2b Solar Ready Roof
Designing roofs to be ready for photovoltaic installation facilitates ease of their deployment should building developers decide to do so at later stages of a project/ during building operation.</td><td>0.5 point each for achieving
• Structural readiness
• Electrical readiness
• Spatial readiness
(Up to 1.5 points)

(Up to 1.5 point for 2.2b)</td></tr>
<tr><td>2.2c Adoption of Renewable Energy
On-site generation of renewable energy can reduce the building development's power consumption from the grid and carbon emissions.</td><td>
<table>
<tr><th>Expected Energy Use Intensity (EUI) [kWh/m²/yr]</th><th>% Replacement of Building Electricity Consumption by Renewable Energy</th></tr>
<tr><td>≥ 220</td><td>1 point for every 0.5%</td></tr>
<tr><td>50 ≤ EUI < 220</td><td>1 point for every 1.25%</td></tr>
<tr><td>< 50</td><td>1 point for every 2.5%</td></tr>
</table>

(Up to 6 point for 2.2c)</td></tr>
</table>

<table>
<tr><th>Part 3 – Resource Stewardship</th><th>Green Mark Points</th></tr>
<tr><td>P.7 Water Efficient Fittings
Meet minimum requirements stated in table
<table>
<tr><th>Type of Water Fittings</th><th>Prescribed Minimum WELS rating</th><th>Applicable Areas</th></tr>
<tr><td rowspan="2">Basin Taps & Mixers</td><td>3 Ticks WELs rating</td><td>Public/ staff/ school toilets</td></tr>
<tr><td>2 Ticks WELs rating</td><td>Other areas</td></tr>
<tr><td>Sink Taps & Mixers</td><td>2 Ticks WELs rating</td><td>All areas</td></tr>
<tr><td>Shower Taps, Mixers or Showerheads</td><td>2 Ticks WELs rating</td><td>Public/ staff/ school shower facilities</td></tr>
<tr><td>Dual Flush Flushing Cisterns</td><td>2 Ticks WELs rating</td><td>All areas</td></tr>
</table></td><td>Prerequisite</td></tr>
<tr><th>3.1 Water</th><th></th></tr>
<tr><td>3.1a Water Efficient Systems
The design of water efficient mechanical systems and strategies can minimise potable water consumption in building operations.

(i) Landscape Irrigation
• Every 25% of the landscape areas that are served by water efficient irrigation systems with features such as automatic sub-soil drip irrigation system with moisture or rain sensor control.
• Every 20% of the landscape areas that comprises drought tolerant plants.

(ii) Water Consumption of Cooling Towers
• Cooling tower water treatment system with 7 or more cycles of concentration (CoC) with effective filtration system.
• Provision of devices that recovers waste heat from the condensers and helps reduce the water requirement needed to remove heat through the cooling towers.</td><td>0.5 point each
(Up to 1 point)

1 point each
(Up to 2 points)

(Up to 3 points for 3.1a)</td></tr>
<tr><td>3.1b Water Monitoring
Better control and monitoring can facilitate setting of consumption reduction targets. Making the monitored information accessible to end users can facilitate user engagement programmes and promote behavioural changes with regard to water management and use.
(i) Water monitoring and leak detection
• Private meters
• Smart remote metering system

(ii) Water Usage Portal and Dashboard
• Display metered data, trending of water consumption (historical data) and relevant parameters
• Display monthly water consumption of 50th percentile line of the tenants/space within the buildings. The information could also include 25th and 75th percentile line.</td><td>0.5 point each
(Up to 1 point)

0.5 point each
(Up to 1 point)

(Up to 2 points for 3.1b)</td></tr>
<tr><td>3.1c Alternative Water Sources
The use of alternative water sources can reduce potable water consumption for general application and use.
• AHU condensate collection where > 50% of total condensate is collected
• NEWater supply
• On-site recycled water
• Rainwater harvesting</td><td>1 point each
(Up to 3 points)

(Up to 3 points for 3.1c)</td></tr>
</table>

Part 3 – Resource Stewardship	Green Mark Points

3.2 Materials

3.2a Sustainable Construction

To encourage the adoption of building designs, building structures and construction practices that are environmentally friendly and sustainable.

(i) Conservation and Resource Recovery

- The existing structures are conserved and not demolished.
- The existing structures are demolished with an enhanced demolition protocol, where a recovery rate of > 35% crushed concrete waste from the demolished building is sent to approved recyclers with proper facilities.

1 point for either case

(Up to 1 point for 3.2a(i))

(ii) Resource Efficient Building Design

- Concrete Usage Index (CUI)

Project's CUI (m^3/m^2)	Points
≤ 0.60	0.5
≤ 0.50	1.0
≤ 0.45	1.5
≤ 0.40	2.0
≤ 0.35	2.5

(Up to 2.5 points)

- Adoption of sustainable building systems

List of Sustainable Building Systems

- ➢ Pre-stressed Concrete Elements
- ➢ Hollow Core or Voided Concrete Elements
- ➢ Light Weight Concrete Elements
- ➢ High Strength Concrete Elements (Concrete grade >60MPa)
- ➢ Structural Steel Elements
- ➢ Composite Structural Elements
- ➢ Engineered Timber Elements
- ➢ Prefabricated Prefinished Volumetric Construction units
- ➢ Precast Concrete Elements
- ➢ Leave-in Formwork
- ➢ Others (to be accepted by BCA on case-by-case basis)

Total coverage area	Points
< 50%* of CFA	0.5
≥ 50% of CFA	1.0
≥ 75% of CFA	1.5

* no computation required with adoption of any sustainable building systems

(Up to 1.5 points)

(Up to 4 points for 3.2a(ii))

(iii) Low Carbon Concrete

Clinker Content

Use of concrete containing clinker ≤ 400 kg/m^3 for grades up to C50/60 for ≥ 80% of the applicable superstructural concrete by volume

Concrete Categories*	Points
Uncertified concrete	0.5
SGBC-certified 1-Tick concrete	1.0
SGBC-certified 2-Tick concrete	1.5
SGBC-certified 3-Tick and 4-Tick concrete	2.0

Replacement of coarse and fine aggregates

The usage should not fall below 1.5% x GFA for RCA and/ or 0.75% x GFA for WCS for points scoring.

0.5 point for every 5% replacement by mass of coarse and fine aggregates with recycled concrete aggregates (RCA) and/ or washed copper slag (WCS) from approved sources for the superstructure concrete mix.

(Up to 3 points for 3.2a(iii))

(Up to 8 points for 3.2a)

Rating	Gold	Gold^{PLUS}	Platinum
Min point for 3.2a	0.5 pt	2 pts	3.5 pts

3.2b Embodied Carbon

This involves the computation of the carbon footprint of the development and the building life cycle analysis to better quantify the environmental impact of a building and raise awareness among key decision makers.

1 point for declaration of Concrete, Glass and Steel

0.25 point per material for Declaration of additional materials (Up to 1 point)

(Up to 2 points for 3.2b)

Rating	Gold	Gold^{PLUS}	Platinum
Min point for 3.2b	-	1 pt	1 pt

Part 3 – Resource Stewardship	Green Mark Points

3.2c Sustainable Products

Encourage the specification of resource efficient and environmentally friendly products for use in the fit-out of a building, taking a functional system approach to focus on greening major fit-out materials whilst allowing for flexibility in design as well as recognising designs with optimal/ minimal material use.

(i) Functional Systems

Specification and use of green products certified by approved local certification bodies, namely the Singapore Green Building Council and the Singapore Environment Council, within the 6 main functional system categories

Non-Speculative Buildings/ Speculative Buildings with Tenanted Areas Included

Functional System Category	Base Group (Score this group prior to score for Finishes Group)	Finishes Group
	Coverage: ≥ 80% for external wall & roofing Coverage: ≥ 60% for the rest	Coverage: ≥ 80% for external wall & roofing Coverage: ≥ 60% for the rest
External Wall	1 pt	2 pt
Internal Wall	1 pt	2 pt
Flooring	1 pt	2 pt
Doors	1 pt	0.5 pt*
Ceiling	0.5 pt	0.5 pt
Roofing	0.5 pt	0.5 pt

* refers to supporting accessories for doors

Speculative Buildings with Tenanted Areas Excluded

Functional System Category	Base Group (Score this group prior to score for Finishes Group)	Finishes Group
	Coverage: ≥ 80%	Coverage: ≥ 80%
External Wall	1 pt	2 pt
Internal Wall	0.5 pt	1 pt
Flooring	0.5 pt	1 pt
Doors	0.5 pt	0.25 pt*
Ceiling	0.25 pt	0.25 pt
Roofing	0.5 pt	0.5 pt

* refers to supporting accessories for doors

(Up to 8 points)

(ii) Singular Sustainable Products outside of Functional Systems

To encourage the use of sustainable products that do not fall into the functional systems such as

- Hardscape - Includes items such as composite timber decking, outdoor equipment, pre-cast kerbs and drains, wheel stoppers in car parks, drainage cells etc.
- Building services and M&E products - Mechanical, electrical and plumbing equipment or products such as chillers, circuit boards, transformers, water pipes

Singular products category	Coverage ≥ 80%
Hardscape, building services and M&E products certified by an approved local certification body	0.25 point per product

(Up to 2 points)

(Up to 8 points for 3.2c)

Rating	Gold	Gold^PLUS	Platinum
Min point for 3.2c	2 pts	3 pts	4 pts

3.3 Waste

3.3a Environmental Construction Management Plan

An effective and holistic management plan can facilitate better environmental performance of the construction process and promote waste minimisation.

1 point

(Up to 1 point for 3.3a)

3.3b Operational Waste Management

Appropriate collection and recycling provisions can facilitate the segregation of recyclable consumer waste at source. Provisions for the treatment of horticultural or wood waste for buildings with landscaping can promote their reuse and recycling as well.

Part 3 – Resource Stewardship	Green Mark Points
1 point each • Facilities for the collection and storage of different recyclables such as paper, glass, metal and plastic in commingled or sorted form. • Facilities or systems for food waste to be treated and recycled, for buildings generating large volumes of food waste. • Facilities or systems for the placement of horticultural or wood waste for recycling. 0.5 point each • Provision of separate chute for recyclables, beyond code compliance*. • Provision of Pneumatic Waste Conveyance System (PWCS), beyond code compliance*. *NEA's Code of Practice on Environmental Health (or prevailing code)	1 point each 0.5 point each **(Up to 3 point for 3.3b)**

Part 4 – Smart and Healthy Building	Green Mark Points
P.8 Thermal Comfort The normal design dry-bulb temperature for comfort air-conditioning shall be within 23ºC - 25ºC, and resultant relative humidity ≤ 65% in accordance with SS 553 : 2016 - Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.	Prerequisite
P.9 Minimum Ventilation Rate The building's air-conditioning and mechanical ventilation systems shall be designed to provide appropriate minimum quantum of outdoor air rates as stated in Table 1 and Table 5 of SS 553 : 2016.	Prerequisite
P.10 Filtration Media for Times of Pollution AHUs or dedicated outdoor air units in the building shall be designed to accommodate fine dust filters of least a rating of Minimum Efficiency Reporting Value (MERV) 14 (ASHRAE 52.2: 2012) or F8 (EN779: 2012), when the outdoor pollution level is in the unhealthy range in accordance with MOH's guidelines, as stipulated in SS 553 : 2016.	Prerequisite
P.11 Low Volatile Organic Compound (VOC) Paints Low VOC paints certified by an approved local certification body shall be used for at least 90% of the total painted internal wall areas.	Prerequisite
P.12 Refrigerants Air conditioning systems shall use refrigerants with ozone depleting potential (ODP) of 0 or global warming potential (GWP) of less than 100. A refrigerant leak detection system shall also be installed in critical areas of plant rooms containing chillers and/ or other equipment using refrigerants.	Prerequisite
P.13 Sound Level The relevant equipment as aforementioned shall be designed to comply with the recommended ambient sound levels in Table 4 of SS 553 : 2016.	Prerequisite
P.14 Permanent Instrumentation for the Measurement and Verification of Chilled Water Air-Conditioning Systems Permanent instrumentation to monitor chilled water plant (water cooled and air-cooled system) efficiency shall also be provided. The installed instrumentation shall have the capability to calculate resultant efficiency (i.e. kW/RT) within 5% of its true value, in accordance with ASHRAE Guideline 22 and AHRI Standard 550/590. Each measurement system shall include the sensor, any signal conditioning, the data acquisition system and wiring connecting them.	Prerequisite

Part 4 – Smart and Healthy Building	Green Mark Points

P.15 Electrical Sub-Metering & Monitoring

Subsystem measurement devices with remote capability shall be provided, linked to a monitoring system and measure and trend energy consumption data of:

- Each of the following energy sub systems:

Use (Sum of all loads)	Sub-systems thresholds
Lift & escalator	Sum of all feeders > 50 kVA
Heater, including heat pump	> 50 kWth
Process loads	Connected loads > 50 kVA Connected gas or district services load > 75 kW
Mechanical ventilation	The subsystem's load > 15kW
VRF systems (CUs, FCUs)	No threshold

- Each tenancy or floor, as well as high energy load areas exceeding 50kVA such as car park, data centres, IT closets and process areas.

Prerequisite

4.1 Indoor Air Quality

4.1a Occupant Comfort

The testing and evaluation of indoor air quality parameters is crucial to ensure occupant comfort. Engaging building occupants completes the feedback loop, and is essential for the management and improvement of operational practices in high-performing green buildings.

(i) Indoor Air Quality (IAQ) Surveillance Audit
Committed to conduct an IAQ surveillance audit within one year after occupancy or after reasonable occupancy has been reached. The audit shall be conducted by an accredited laboratory under Singapore Accreditation Council with respect to the recommended IAQ parameters and acceptable limits stated in Table 1 of SS554: 2016, based on Indicative methods or reference methods.

0.5 point for indicative method
1 point for reference method
(≥0.5 pt required for all ratings)

(ii) Post Occupancy Evaluation
Committed to conduct Post Occupancy Evaluation (POE) questionnaire, with appropriate corrective actions if required, within a year after building occupancy or after reasonable occupancy has been reached.

0.5 point

Rating	Gold	Gold[PLUS]	Platinum
Min point for 4.1a(ii)	-	0.5 pt	

(iii) Indoor Air Quality Display
Provision of display panels for temperature and relative humidity information at each floor/ tenancy, to raise awareness among building occupants on the internal conditions of the space.

0.5 point

(Up to 2 point for 4.1a)

4.1b Outdoor Air

Provision of adequate and proper ventilation in conditioned spaces to prevent build-up in the concentration of contaminants.

(i) Ventilation Rates

- Measurement and monitoring of outdoor airflow volume in accordance with desired ventilation rates.

0.5 point for precool units (e.g. PAHUs and PFCUs)
1 point for all AHUs and FCUs

- Use of demand control ventilation strategies such as carbon dioxide sensors or equivalent devices to regulate the quantity of fresh air and ventilation in accordance with the space requirements.

0.5 point

(Up to 1.5 point)

<table>
<tr><th>Part 4 – Smart and Healthy Building</th><th>Green Mark Points</th></tr>
<tr><td>(ii) Enhanced Filtration Media
Permanent provision of Minimum Efficiency Rating Value (MERV 14, ASHRAE 52.2 or F8/ EN779 class of filter or equivalent).</td><td>0.5 point for all PAHUs
1 points for all PAHUs and AHUs
(Up to 1 point)
<table><tr><th>Rating</th><th>Gold</th><th>GoldPLUS</th><th>Platinum</th></tr><tr><td>Min point for 4.1b(ii)</td><td>-</td><td colspan="2">0.5 pt</td></tr></table></td></tr>
<tr><td>(iii) Dedicated Outdoor Air System
Provision of a dedicated outdoor air system, such as precool units, to encourage effective treatment of outdoor air for cooling and dehumidification.</td><td>0.5 point

(Up to 3 point for 4.1b)</td></tr>
<tr><td>4.1c Indoor Contaminants
Indoor contaminant pollution control at source and air treatment strategies can safeguard the health of building occupants.

(i) Local Exhaust and Air Purging System
• Local isolation and exhaust systems to remove the source of pollutants
• Air purging system to replace contaminated indoor air with outdoor fresh air</td><td>1 point each
(Up to 2 points)</td></tr>
<tr><td>(ii) Ultraviolet Germicidal Irradiation (UVGI) System
Provision of UVGI system in AHUs and FCUs to control airborne infective microorganisms.</td><td>0.5 point</td></tr>
<tr><td>(iii) More Stringent VOC Limits for Interior Fittings and Finishes
Specification and use of products certified SGBP Very Good or above, of which the VOC emission rate standards meet more stringent VOC emission limits.</td><td><table><tr><th>Functional System</th><th>Points
(VOC content within a Functional System for ≥ 80% of applicable areas must be SGBP Very Good or above)</th></tr><tr><td>External Wall</td><td>1 pt</td></tr><tr><td>Internal Wall</td><td>1 pt</td></tr><tr><td>Internal Flooring</td><td>1 pt</td></tr><tr><td>Ceiling</td><td>1 pt</td></tr><tr><td>Doors</td><td>0.5 pt</td></tr><tr><td>Other Systems: Fixed furniture/ system furniture</td><td>0.5 pt</td></tr></table>(Up to 2 points)</td></tr>
<tr><td>(iv) Use of Persistent Bio-cumulative and Toxic (PBT) free lighting</td><td>0.5 point for ≥ 90% of light fittings in the project.
<table><tr><th>Rating</th><th>Gold</th><th>GoldPLUS</th><th>Platinum</th></tr><tr><td>Min point for 4.1c(iv)</td><td>-</td><td colspan="2">Healthcare - 0.5 pt</td></tr></table>
(Up to 5 point for 4.1c)</td></tr>
<tr><td>4.2 Spatial Quality</td><td></td></tr>
<tr><td>4.2a Lighting
Natural lighting has been linked to the positive mental wellbeing of building occupants. It connects enclosed indoor environments with the external natural environment. In the tropics, special care must be taken to maximise effective daylight while minimising visual discomfort and maintaining the façade’s thermal efficiency.

(i) Effective daylighting for common areas
Prorating the number of daylit transient common spaces with effective automatic lighting controls against the total number of applicable spaces.
Note: Each toilet is counted as 0.5.</td><td>Points scored = 1.5 x (% count with daylighting for toilets, staircases, corridors, lift lobbies and atriums)
+ 0.5 x (% areas of carpark with daylighting or having no carpark.)
(Up to 2 points for 4.2ai)</td></tr>
</table>

Part 4 – Smart and Healthy Building	Green Mark Points

(ii) Effective daylighting for occupied spaces

Percentage of occupied spaces with access to effective daylighting

Points are computed based on the percentage of total occupied areas that can achieve the specific Daylight Autonomy (DA) requirement of DAN lx,50% (without overlighting), as outlined in the Green Mark NRB: 2015 Technical Guide and Requirements Annex B: Effective Daylighting Simulation and Pre-Simulated Daylight Availability Tables Methodology and Requirements. Effectively daylit areas shall be integrated with automated lighting controls.

Pre-Simulation Daylight Availability Tables or Daylight Simulation

Percentage	Points
15 to < 35 %	0.5
35 to < 55 %	1
55 to < 75 %	2
≥75%	3

(Up to 3 points)

Effective Mitigation of Overlit Areas

Pre-Simulation Daylight Availability Tables: Adoption of suitable mitigation strategies for overlit spaces

or

Daylight Simulation: mitigation measures to effectively address overlighting are included into the simulation model in accordance with Annex B

1 point

(Up to 4 points for 4.2aii)

(iii) Quality of Artificial Lighting

Low impact item

- Good light-output over life with a minimum lifespan rating of L70 ≥ 50,000 life hours
- Lighting designed to avoid flicker and stroboscopic effects, by using high frequency ballasts for fluorescent luminaries and LED lighting with ≤ 30% flicker
- Meeting the minimum colour rendering index (Ra or CRI) in Clause 5 of SS 531 – 1 : 2006 (2013) – Code of Practice for Lighting of Workplaces

High impact item

- LED Luminaires certified under SGBP scheme

0.5 point each for low impact item
1 point for high impact item

(Up to 1 point for 4.2aiii)

(Up to 6 points for 4.2a)

4.2b Acoustics

An improved acoustical performance for normally occupied spaces can enhance the aural comfort of its occupants, facilitating communication, reducing unwanted sound and aiding in speech privacy.

(i) Sound Transmission Reduction

Projects that demonstrate that the acoustic performance of the internal partitions between adjoining spaces will be constructed to achieve the following performance levels:

0.5 point

Description	Sound Transmission Class (STC)
Between general office spaces	40 - 50
Spaces where confidential speech are required/ Between mechanical and equipment spaces and occupied spaces:	50 – 60

(ii) Acoustic Report

1.5 points can be scored for an acoustic design and verification report adhering to the requirements in the GM NRB: 2015 Technical Guide and Requirements.

1.5 point

(Up to 2 points for 4.2b)

4.2c Wellbeing

The state of being comfortable, healthy or happy. Nurturing, healing and inclusive spaces can enhance the building occupant and user’s environment, and overall wellbeing.

Part 4 – Smart and Healthy Building	Green Mark Points
(i) Biophilic Design • Provision of accessible sky gardens, sky terraces, internal courtyards and rooftop gardens as areas for respite. • Building design that adopt biomimicry designs. • The provision for at least 5% of the common areas or functional spaces to have fixed indoor planting. • Building design that takes after any natural shapes and forms/ creates ecological attachment to the place. • Provision of images of nature for 5% of common areas. (ii) Universal Design (UD) Mark	1 point each 0.5 point each 0.25 point each (Up to 3 points) Certified/Gold – 0.5 point Gold^{PLUS}/Platinum – 1 point **(Up to 2 points for 4.2c)**
4.3 Smart Building Operations	
4.3a Energy Monitoring 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. (i) Energy Portal and Dashboard • Display metered data, trending of energy consumption (historical data) and relevant parameters • Display monthly energy consumption of 50th percentile line of the tenants/space within the buildings. The information could also include 25th and 75th percentile line. (ii) BAS and Controllers with Open Protocol Use of BACnet, Modbus or any other non-proprietary protocol as the network backbone for the building management system, with the system being able to provide scheduled export of a set of any chosen data points to commonly used file formats.	1 point each (Up to 2 points) 1 point **(Up to 3 points for 4.3a)**
4.3b Demand Control Using occupancy based controls to monitor the usage of spaces and vary temperature, ventilation and lighting demand while maintaining room temperature effectiveness, good indoor environmental quality and lighting quality, can significantly reduce building energy consumption. The energy savings from such controls can be taken into account under the Energy Performance Points Calculator under Part 2 Building Energy Performance. (i) ACMV Demand Control • Binary sensing controls ➢ ≥ 80% of all transient areas ➢ ≥ 80% of all occupied areas • Occupancy-based sensing controls (for VAV systems) ➢ ≥ 80% of all transient areas ➢ ≥ 80% of all occupied areas	0.5 point each (Up to 1 point) 0.5 point each (Up to 1 point)

<table>
<tr><th>Part 4 – Smart and Healthy Building</th><th>Green Mark Points</th></tr>
<tr><td>(ii) Lighting Demand Control
Use of occupancy/ vacancy sensors to moderate brightness of the luminaries for :
➢ ≥ 80% of all transient areas
➢ ≥ 80% of all occupied areas

(iii) Carpark Guidance System</td><td>0.5 point each
(Up to 1 point)

0.5 point
(Up to 3 points for 4.3b)</td></tr>
<tr><td>4.3c Integration and Analytics
The innovative and integrative use of data can optimise workflow or attain persistence of high performance and energy efficiency in a building. Basic integration and use of sensor data can optimise and operate the building in an informed and effective manner. The use of advanced integration and analytics can provide enhanced efficacy in lowering energy use, increase asset reliability, and improve the user experience.

<table>
<tr><th>Basic Features</th><th>Advanced Features</th></tr>
<tr><td>• Use adaptive control algorithms
• Exception handling by identifying systems that deviates from expected performance/setting
• Detect equipment that run outside intended hours or settings
• Monitor equipment condition for preventive maintenance
• Basic fault detection and diagnostics (FDD) of sensors by finding failed or improperly operating sensors or actuators</td><td>• Whole system optimisation using a network of HVAC equipment
• Integration of sub-systems to optimise resource use or improve user experience
• Use of Building Information Modelling (BIM) or similar applications that provide location-based visualisation of multiple sensors
• Participate in a Demand Response programme with electricity retailer</td></tr>
</table>
</td><td>0.5 point each for Basic Features and
1 point each for Advanced Features
(Features displayed via
BMS, BAS, website or mobile app)

(Up to 3 points for 4.3c)</td></tr>
<tr><td>4.3d System Handover and Documentation
Proper system verification and handover of higher-order functional and system level performance of buildings control systems, mechanical systems and electrical systems. The project shall demonstrate a commitment to comply to verification requirements and show evidence of relevant schedules and documentation.</td><td>1 point
<table>
<tr><th>Rating</th><th>Gold</th><th>Gold^{PLUS}</th><th>Platinum</th></tr>
<tr><td>Min point for 4.3d</td><td>-</td><td colspan="2">1 pt</td></tr>
</table>

(Up to 1 point for 4.3d)</td></tr>
</table>

Part 5 – Advanced Green Efforts	Green Mark Points
5.1 Enhanced Performance	
5.1 Enhanced Performance Credits Advanced Green Efforts indicators that are highlighted within the Green Mark NRB: 2015 criteria, or for other outcome beyond what is specified, based on high, medium and low impact items. Enhanced performance indicators within criteria	

Advanced Green Efforts Under Part 1 Climatic Responsive Design	Green Mark Points
1.1b Integrative Design Process 4D, 5D & 6D BIM ➢ 4D (Time) BIM ➢ 5D (Cost) BIM ➢ 6D (Facilities Management) BIM	1 point each (Up to 3 points)
1.2a Sustainable Urbanism Creation of possible new ecology and natural ecosystems	1 point
1.2b Integrated Landscape and Waterscape GnPR ≥ 5	1 point
1.3a Tropical Façade Performance Low heat gain façade ➢ ETTV < 35W/m^2	1 point
Vertical Greenery on the East and West Façade ➢ For more than 30% of east and west façade areas ➢ For more than 15% of east and west façade areas	1 point 0.5 point
Thermal Bridging Use of thermal break /insulating profiles certified by approved local certification bodies	1 point
1.3c Ventilation Performance Wind Driven Rain Simulation	1 point
Advanced Green Efforts under Part 2 Building Energy Performance	
Option 1: Energy Performance Points Calculator **2.1e Building Energy** Further Improvement in Design Energy Consumption ➢ Additional improvement of the design energy consumption against the notional reference above maximum credit scored under 2.1e Building Energy based on the same formula.	$Points\ scored = \frac{\%\ improvement\ from\ baseline}{3} - 11$ (Up to 2 points)
Option 2: Performance-Based Computation **2.1f Space Conditioning Performance** Efficient Space Conditioning Energy Design Achieve highly efficient air-conditioning design ➢ Achieving 0.70kW/ton TDSE ➢ Achieving 0.65kW/ton TDSE	0.5 point 1 point (Up to 1 point)
2.1g Lighting System Performance Efficient Lighting Design Achieve highly efficient air-conditioning design ➢ 0.5 point for 40% improvement ➢ 1 point for 50% improvement	0.5 point 1 point (Up to 1 point)

Part 5 – Advanced Green Efforts	Green Mark Points
2.1h Building Systems Performance Additional Energy Efficient Practices and Features ➢ Additional improvement from baseline total building consumption above maximum credit scored under 2.1h(iv) Energy Efficient Practices and Features based on the same formula.	Points scored $= \frac{\left(\frac{\%\ improvement\ from\ baseline}{total\ building\ consumption}\right) - 4\%}{3}$ (Up to 2 points)
2.2c Adoption of Renewable Energy Further Electricity Replacement by Renewables ➢ Additional percentage electricity replacement by renewable energy above maximum credit scored under 2.2c Adoption of Renewable Energy based on the same formula.	Expected Energy Use Intensity (EUI) [kWh/m²/yr] / % Replacement of Building Electricity Consumption by Renewable Energy: ≥ 220: 1 point for every 0.5% (beyond 3%) 50 ≤ EUI < 220: 1 point for every 1.25% (beyond 7.5%) < 50: 1 point for every 2.5% (beyond 15%) (Up to 5 points)
Advanced Green Efforts under Part 3 Resource Stewardship	
3.1a Water Efficient Systems Better Water Efficient Fittings Demonstrate the use of better WELS rated water efficient fittings ➢ Use of better WELS rated water efficient fittings for 100% of basin taps & mixer and dual flush flushing cisterns ➢ Use of better WELS rated water efficient fittings for 100% of applicable water fittings as prescribed in P.7 whilst ensuring user requirements are not compromised.	0.5 point 1 point (up to 1 point)
3.2a(ii) Resource Efficient Building Design Use of BIM to calculate CUI ➢ BIM is used to compute CUI	1 point
3.2a(iii) Low Carbon Concrete Use of Advanced Green Materials ➢ Use of SGBC-certified 4-Tick concrete ➢ Use of SGBC-certified reinforcement bars for structural reinforced concrete elements, for more than 80% of the applicable superstructure elements by volume.	0.5 point each (Up to 1 point)
3.2b Embodied Carbon Provide Own Emission Factors with Source Justification ➢ Provision of own material emission factors Compute the Carbon Footprint of the Entire Development ➢ Computation of the carbon footprint of the entire development and a detailed carbon footprint report based on all the materials used within the development.	0.25 pt per material (Up to 1 point) 2 points
3.2c Sustainable Products Sustainable Products with Higher Environmental Credentials ➢ Use of products certified to higher tiers of environmental performance (per product).	Singapore Green Building Product Certification Rating / Points per product (≥ 80% of the applicable use): Very Good (2-ticks): 0.25 Excellent (3-ticks): 0.5 Leader (4-ticks): 1.0 (Up to 2 points)

Part 5 – Advanced Green Efforts	Green Mark Points
Advanced Green Efforts under Part 4 Smart and Healthy Building	
4.1a Occupant Comfort Indoor Air Quality Trending ➢ Provision for monitoring and trend logging of temperature and relative humidity through a centralised system. ➢ Provision for monitoring and trend logging of common indoor air pollutants, such as formaldehyde, at each floor.	0.5 point 1.5 point (Up to 2 points)
4.1c Indoor Contaminants Zero ODP Refrigerants with Low Global Warming Potential ➢ Zero ODP **and** GWP < 750 ➢ Zero ODP **and** GWP < 10	0.5 point 1 point (Up to 1 point)
4.3a Energy Monitoring Permanent M&V for VRF Systems Provision of permanent measuring instruments for monitoring of energy efficiency performance of Variable Refrigerant Flow (VRF) condensing units and air distribution subsystem.	2 points
Permanent M&V for Hot Water Systems Incorporation of Permanent Measurement and Verification for hot water systems, with performance requirement similar to P.14, for central hot water system.	1 point
4.3c Integration and Analytics Additional Advanced Integration and Analytical Features Additional advanced integration and analytical features above maximum credit scored under 4.3c(ii) Advanced Integration and Analytics	1 point
4.3d System Handover and Documentation Expanded Post Occupancy Performance Verification by a 3rd Party Owner engages an independent competent professional to verify the operational performance and provide recommendations on system performance enhancement, conducted within one year from the building's TOP.	0.5 point can be scored per energy subsystem (Up to 2 points)
Energy Performance Contracting Engagement an Energy Performance Contracting (EPC) firm (accredited by SGBC) to implement and deliver energy efficiency, renewable energy and/or energy recovery projects with an energy performance contract wherein the EPC firm's remuneration is based on demonstrated energy savings. Operational system efficiency should be guaranteed over a minimum of 3 years.	1 point
Other enhanced performance indicators	2 points for high impact items 1 point for medium impact items 0.5 point for low impact items **(Up to 15 points for 5.1)**

Part 5 – Advanced Green Efforts	Green Mark Points
5.2 Complementary Certifications	
5.2 Complementary Certifications Project demonstrates that it is certified through a local or international complementary certification or rating tool that assesses the project beyond the environmental indicators within Green Mark NRB: 2015.	1 point **(Up to 1 point for 5.2)**
5.3 Demonstrating Cost Effective Design	
5.3 Demonstrating Cost Effective Design Demonstration of cost effective or cost neutral design beyond the norm through a detailed quality surveyor's report of the building.	1 point for cost effective design 2 points for cost neutral design **(Up to 2 points for 5.3)**
5.4 Social Benefits	
5.4 Social Benefits Projects that demonstrate their social benefits or how social sustainability has been incorporated into the project, beyond core functionality of the building. This can (but not limited to) include efforts that demonstrate enhanced considerations to further wellbeing, welfare, community integration as well as the purchase of clean energy (e.g. solar energy) through third party leasing contracts.	0.5 point for each distinct benefit **(Up to 2 points for 5.4)**

0. Pre-requisites

The pre-requisites for Green Mark NRB: 2015 sets the minimum environmental considerations that a project shall demonstrate based on industry norms. All pre-requisites listed as follows must be fulfilled in order to be eligible to score Green Mark points in the 5 Green Mark sections

Pre-requisites Directory for P.1 to P.15

P.1 to P.15 are parked under the criteria sections. They must be fulfilled by all projects targeting certification.

Section	Pre-Requisites
1. Climatic Responsive Design	P.1 – P.3
2. Building Energy Performance	P.4 – P.6
3. Resource Stewardship	P.7
4. Smart and Healthy Building	P.8 – P.15

Minimum Criteria Points Requirements

Indicator	Pre-Requisite Requirement	Minimum Points Requirement		
		Gold	Gold^{PLUS}	Platinum
1.1b	Integrative Design Process	-	2 pts	
1.1d	User Engagement	Green Fit-out Guideline - 1 pt		
		-	-	Displaying GM credential – 1 pt
1.2b	Integrated Landscape and Waterscape	-	Commercial, Healthcare – 2 pts ,Others – 1 pt	
1.3c	Ventilation Performance – Ventilation Simulation For Gold^{PLUS} and Platinum projects with ≥ 2,000m^2 of naturally ventilated occupied spaces, wind speeds must meet via ventilation simulation	-	4 pts (Gold^{PLUS} – 0.4 m/s , Platinum – 0.6 m/s) *Complementary methods to compliance are available as described in *1.3c*	
2.2a	Solar Energy Feasibility Study	For buildings with a footprint ≥1,000m^2 – 0.5 pt		
3.2a	Sustainable Construction	0.5 pt	2 pts	3.5 pts
3.2b	Embodied Energy	-	1 pt	
3.2c	Sustainable Products	2 pts	3 pts	4 pts
4.1a(i)	Indoor Air Quality Audit	0.5 pt		
4.1a(ii)	Post Occupancy Evaluation	-	0.5 pt	
4.1b(ii)	Enhanced Filtration Media	-	0.5 pt	
4.1c(iv)	Use of PBT Free Lighting	-	Healthcare – 0.5 pt	
4.3d	System Handover and Documentation	-	1 pt	
Annex 2(d)	Local Energy Generation for Centralised Service Hot water Heating	-	-	Healthcare – 1 pt
Annex 2(e)	Onsite Airside Energy Recovery	-	-	Healthcare – 1 pt
Annex 3(c)	Onsite Airside Energy Recovery	-	-	Laboratory – 1 pt
Annex 4(b)	Raising Awareness on Environmental Sustainability	-	Schools – 1 pt	
Annex 4(c)	Communication of Efficiency Trends	-	Schools – 0.5 pt	

* Laboratory denote Laboratory Buildings, Healthcare denote Healthcare Facilities

All projects will need to compute Energy Efficiency Index (EEI) and Energy Use Intensity (EUI) in kWh/m^2/yr.

Legend (only digital copy is required)			
As-Built	As-built drawings and documents		Photographic evidences
	Updated calculation for changes	Purchase Summary	Summary of purchase from contractors, sub-contractors or suppliers

Energy Savings Requirements

Intent

The quantification and setting of minimum standards for energy savings of a green building can encourage an integrated approach to building design optimisation. By determining the building's energy usage based on different design options, developers can better understand their impact on total building performance and make cost effective design decisions that can maximise energy savings.

Scope

Applicable to all projects targeting Green Mark Gold^{PLUS} or Platinum rating.

Assessment

The minimum energy savings to be demonstrated for the following rating tiers are as follows:

Level of Green Mark Award	Minimum Energy Savings
Gold^{PLUS}	25%
Platinum	30%

For a building with air-conditioned area ≥ 5,000m^2, an energy model shall be used to demonstrate the building's designed energy savings compared to a prescribed reference model that reflects prevailing building standards and codes of practice. The simulation shall be conducted in accordance with the *Green Mark NRB: 2015 Technical Guide and Requirements - Annex C: Energy Modeling Methodology and Requirements*

For a building with air-conditioned areas < 5,000m^2, detailed calculations can be provided in place of energy modeling to justify the savings in energy consumption from a more efficient design.

For buildings served by existing DCS plants eligible for Path B as per the requirements outlined in the *Green Mark NRB: 2015 Technical Guide and Requirements*, the energy savings to be demonstrated (excluding the consumption of the DCS plant) are as follows:

Level of Green Mark Award	Cooling Load Savings	Energy Consumption Savings (excluding DCS plant)
Gold^{PLUS}	10%	27%
Platinum	15%	33%

For projects targeting Green Mark Gold^{PLUS} or Platinum, the Energy Use Intensity should not exceed the 50th percentile value of similar building type, stated in the annual Building Energy Benchmarking Report (BEBR). In instances where the project exceeds the EUI stated, justification shall be provided and subjected to Green Mark assessment.

1. Climatic Responsive Design

Buildings serve as structures sheltering their occupants from the variable external climate. With this consideration, the built form should be considered to maximise its response to the local tropical climate, and establish a contemporary tropical vernacular. By appreciating the site context, building designers can capitalise on the physical environment and recognise opportunities for the urban built form to maximise responsive design. Consideration of the building's human centricity and whether it is in sync with its surrounding context should also be given due account. It is paramount for such climatically contextual design to be weaved into the early thinking of building design, and this is enabled through upstream effective leadership, supported by a collaborative process of design with the partnership of relevant stakeholders.

P.1 - P.3 + POINTS PREREQUISITES 30 POINTS

1.1 Leadership (10 pts)

1.2 Urban Harmony (10 pts)

1.3 Tropicality (10 pts)

Advanced Green Efforts (9 pts)

P.1 Envelope and Roof ThermalTransfer

Intent

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

Scope

Applicable to building facades and roofs.

Assessment

Where the buildings' aggregate air-conditioned areas exceed 500 m^2, as determined in accordance with the formula set out in the *BCA Code on Envelope Thermal Performance for Buildings*, the Envelope Thermal Transfer Value (ETTV) shall not exceed the following limits:

Level of Award	Maximum ETTV
Gold	45 W/m^2
Gold^{PLUS}	40 W/m^2
Platinum	38 W/m^2

The average thermal transmittance (U-value) for the gross area of the building's roof shall not exceed the following limits:

		Buildings with aggregate air-conditioned area > 500m^2 Maximum Thermal Transmittance for roof of air-conditioned building	Buildings with aggregate air-conditioned area ≤500m^2 Maximum Thermal Transmittance for roof of non air-conditioned building
Roof Weight Group	Weight Range (kg/m^2)	Maximum U-value (W/m^2K)	
Light	< 50	0.5	0.8
Medium	50 to 230	0.8	1.1
Heavy	> 230	1.2	1.5

The limits stipulated do not apply to roofs with skylight for buildings with aggregate air-conditioned area > 500m^2. However, the Roof Thermal Transfer Value (RTTV) of such roofs, computed in accordance with the *Code on Envelope Thermal Performance for Buildings*, shall not exceed 50 W/m^2.

The roof limits stipulated do not apply to open sided sheds, linkways, covered walkways, store rooms, utility rooms, plant rooms and equipment rooms.

Definitions

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

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant to the computation of ETTV • Architectural drawings showing all the air-conditioned areas, shading device, composition of different façade or wall and roof systems. • Tender specifications and technical product information - showing the salient data of the material properties that are to be used for the façade or external wall and roof system • ETTV and Roof U-value calculation in excel format	Purchase Summary As-Built

Worked Example

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:

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

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

$ETTV_{bldg3} = 40\ W/m^2 \qquad A_{bldg} = 7500\ m^2$

$A_{devt} = 5000+6800+7500 = 19300\ m^2$

Therefore ETTV Weighted average

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

$$= \frac{(35\times5000)+(45\times6800)+(40\times7500)}{19300} = 40.46\ W/m^2\ \ (< 45 W/m^2)$$

Thus, the overall ETTV meets Gold level certification requirements.

Thermal Transmittance (U-Value) Of the Building's Roof

A development comprises 1 air conditioned block (A) and three non - air- conditioned blocks (B, C, D). The roofs are made of different material types, and the U-value of Roof D is calculated as an example as follows:

Components	Weight (kg/m^2)	Thickness b (m)	k-value (W/m K)	R-value (m^2 K/W)
Outside surface film (high emissivity)	-	-	-	0.055
325mm thick RC slab (Density: 2400 kg/m^3)	780	0.325	1.442	0.22538
50mm thick Rockwool insulation (In this example, the density of the particular rockwool used is 40 kg/m^3)	2	0.05	0.036	1.38889
Inside surface film (low emissivity) – Sloped roof 22.5°	-	-	-	0.59500
Total Weight (kg/m^2)	782			
Total R-value R_T				2.26427

Therefore, the U-value of Roof D = $1/R_T$ = 0.44 W/m^2K

After proceeding to calculate the U values of Roofs A, B and C (not shown), a summary is as follows:

Roof	Roof Weight Group	U-value of Roof (W/m^2K) (B)	Roof Area (m^2) (C)	Max U-value of Roof Type (W/m^2K) (A)	Complies?
Blk A (A/C block)	Light	0.47	6000.00	0.5	Yes
Blk B (Non A/C block)	Medium	0.53	800.00	1.1	Yes
Blk C (Non A/C block)	Heavy Type 1	0.65	600.00	1.5	Yes
Blk D (Non A/C block)	Heavy Type 2	0.44	100.00	1.5	Yes

P.2 Air Tightness and Leakage

Intent

Minimising air infiltration through the building envelope can reduce the energy required for air-conditioning and enhance occupant thermal comfort.

Scope

Applicable to all windows and curtain walls on the building envelope.

Assessment

For windows and curtain wall systems, air leakage rates shall not exceed the limit specified in *SS 212: 2007 – Specification for Aluminium Alloy Windows* and *SS 381: 1996 (2007) – Materials and Performance Tests for Aluminium Curtain Walls* respectively.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
Technical specifications showing the relevant tests and details to determine the air leakage limits rates	Testing report from an accredited laboratory

P.3 Bicycle Parking

Intent

Providing the necessary infrastructure to encourage cycling as an alternative mode of transport can reduce the energy consumption from vehicular travel.

Scope

Applicable to all building developments outlined below.

Assessment

Meet the minimum quantity of bicycle parking lots required for the development, in line with URA circular *URA/PB/2018/03-DCG (or prevailing circular)* and *LTA's Code of Practice - Street Work Proposal Relating to Development Works (or prevailing COP).*

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
Relevant plans showing proposed location of the lots	

1.1 Leadership (10pts)

The long-term sustainability of the built environment, economy and society depends on the collective leadership of building owners in driving sustainable buildings in partnership with the end users of the building. Effective leadership is needed to influence and drive creative, organizational and technical improvements to the overall environmental credentials of projects, from the initial stages of the project through to building occupation and operation. Upstream leadership can push the boundary of projects' fundamental requirements and is the key towards shifting the needle towards climatic responsive design. This is supported by an integrated design process that resonates among the stakeholders, a strong design team and a shared vision of building a sustainable development and how the vision could be achieved.

- 1.1a Climatic & Contextually Responsive Brief (1 pt)
- 1.1b Integrative Design Process (4 pts)
- 1.1c Environmental Credentials of Project Team (2 pts)
- 1.1d User Engagement (3 pts)

1.1a Climatic & Contextually Responsive Brief

Intent

Considering the constraints and opportunities for environmental sustainability to set design goals approaches early at the onset of a building project can ensure a more holistic total building performance.

Scope

Applicable to all building developments.

Assessment

1 point can be scored for a climatic and culturally responsive brief detailed with:

Target Setting and Brief: Setting of agreed achievable formal sustainability targets for the project. In addition to the project's targeted Green Mark rating, such targets should involve specific sustainable outcomes and indicators. The selection, deployment and responsibilities of the project team, builders and building operators should be detailed. This includes the identification of at least one member of the team to take the lead in coordinating sustainability efforts and tracking of the targets throughout the project phase. This could also include the client's sustainable aspirations for the project, and identification of its green potential benchmarked against similar projects.

Documentation Requirements

Design Stage
Written statements, reports, documents, correspondences and notes of discussion demonstrating the particular project's briefing process, endorsed by the client or client's representative and acknowledged by the key project team members.

1.1b Integrative Design Process

Intent

Addressing and negotiating between the various needs of all stakeholders involved in a building project to achieve common targets can result in a balanced and optimised sustainable design outcome. BIM can be used for coordination and design integration, enabling optimisation of resources and downstream building performance.

Scope

Applicable to all building developments.

Assessment

A maximum of 4 points can be scored for this section.

(i) Integrative team

2 points can be scored if the design team demonstrates an integrated design process through design charrette discussions. This encompasses the establishment of a collaborative framework for the project team during the briefing and design phases to encourage value-added contributions and constructive discussions. This process, which should be conducted in a consultative and non-hierarchical manner, includes the:

- Appointment of all relevant consultants early in the design phase
- Identification of responsible parties within the team to implement relevant sustainability goals and targets
- Detailing of sustainable design methodology action plans and progress
- Addressing of opportunities and challenges with integrative team strategies to achieve the targets
- Organising of design charrettes at key stages within the project design

Definitions

Design charrette: A collaborative meeting for design and planning. The aim of design charrettes is for the team to jointly set and review sustainability targets, progress and outcomes They serve as platforms for the various disciplines within the project team to voice opportunities to optimise design, and for the team to work together to evaluate the opportunities against other constraints.

Documentation Requirements

Design Stage
• Reports, documents, correspondences and notes of discussions at the various project stages demonstrating the integrative design process • Evidences of the implementation of design optimisation arising from the charrettes discussion

(ii) Design for operation

1 point can be scored by involving Facility Manager (FM) in the design stage and incorporating his inputs into design.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
Reports, documents, correspondences and notes of discussions that FM's inputs are taken into design considerations. This can include incorporations to BMS.	Evidences of the implementation of the design or features that cater to the maintenance or operational need raised by FM.

(iii) Use of BIM.

1 point each can be scored for the following:

- **Collaborative BIM**: The use of a coordinated BIM modeling framework that harmonises the various disciplines' designs in a 3D environment, to co-ordinate spatial design and reduce clashes during construction.
- **Green BIM**: The use of integrative BIM models to form the base models for at least one environmental analysis and building performance simulations, the results of which can be used to further optimise the building design.

Documentation Requirements

Design Stage
• Collaborative BIM: BIM Execution Plan showing evidence of BIM Collaboration requirements, and coordinated BIM models of the Architectural, Structural and MEP (Mechanical, Electrical and Plumbing) disciplines • Green BIM: BIM Execution Plan showing evidence of Green BIM requirements, details of the analysis software/ performance plugins used, processes and how this has been employed to evaluate and optimise the building design in areas such as (but not limited to) building energy use, façade heat gains and ETTV, lighting and daylighting analysis, as well as natural ventilation performance etc

4D, 5D & 6D BIM (Advanced Green Efforts)

1 point each can be scored for the 3 levels of SMART BIM under *Advanced Green Efforts*:

4D (Time) BIM – This links time information to the BIM model for project scheduling and coordination. With real time construction activity on site linked to it, the 4D model can be used to review progress against the construction programme and identify methods to assess delays, make up time and evaluate extensions of time claims.
5D (Cost) BIM – This consists of elemental details, finishes, fixtures and equipment within the model linked to data on performance, manufacturers and specifications. The use of integrated scheduling tools can be incorporated to assist in the preparation of cost and quantity schedules and tracking of the project budget.
6D (Facilities Management) BIM – This involves the updated as built model of the building complete with the procured fixtures, finishes and equipment data.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• 4D BIM : Report showing virtual planning (including virtual mock-ups and sequencing) of 3 critical areas in the project, and 4D BIM model with information suitable for sequencing, to demonstrate how 4D BIM facilitates actual construction. • 5D BIM: Evidence of the use of integrated scheduling tools with BIM model and/ or BIM model with information suitable for quantity take-off and cost estimating, to demonstrate how 5D BIM facilitates cost planning and monitoring. • 6D BIM: Report showing the 6D BIM handover requirements and 6D BIM model with information suitable for facility management.	Coordinated 4D, 5D and/ or 6D model.

1.1c Environmental Credentials of Project Team

Intent

A building project team with specialist green credentials can more competently and effectively coordinate the environmental design approach throughout the building design, construction and operation stages.

Scope

Applicable to all building developments.

Assessment

A maximum of 2 points can be scored for the project teams with the following credentials:

Green Individuals (Up to 0.5 point)

- Green Mark Accredited Professional [GMAP] or Green Mark Accredited Professional (Facilities Management) [GMAP(FM)] – 0.25 point
- Green Mark Advanced Accredited Professional (GMAAP) or Green Mark Advanced Accredited Professional (Facilities Management) [GMAAP(FM)] – 0.5 point

Green and Gracious Builder (Up to 0.5 point)

- Main builder is a BCA certified Green and Gracious Builder – 0.25 point for *Certified* and *Merit* or 0.5 point for *Excellent* and *Star* rating

Green Companies (Up to 1.5 points)

- ISO 14001 certified: Architect, M&E engineer, C&S engineer, developer and main contractor - 0.25 point for each consultant type
- SGBC Green Services Certified firms – 0.25 point each

Documentation Requirements

Design Stage
• Certified true copy of the following: ○ Certified GMAP / GMFM / GMAAP / GMFP   ○ main builder's Green and Gracious Builder award   ○ ISO 14000 certificate of developer, main contractor, M&E consultant, C&S engineer and architect where applicable • Extracts of SGBC certified companies from SGBC website

Worked Example

A project has the following members in its project team.

- A certified GMAP who is actively involved in leading the sustainable design process during throughout the various project stages. The Professional Engineer (Mechanical) is a certified GMAAP (0.5 point)
- BCA certified Green and Gracious Builder (Star level) (0.5 point)
- The Architect, Developer and M&E Engineer are ISO 14001 certified (0.75 point)
- The Architect and M&E Engineer are SGBC Certified companies (0.5 point)

Therefore, points scored for 1.1c = 2.25 points

1.1d User Engagement

Intent

This refers to the provision of relevant information and guidance to building occupants/visitors to raise awareness on the building's green features, and on how they can contribute positively to reduce the building's environmental impact further.

Scope

Applicable to all building developments with occupants/visitors.

Assessment

A maximum of 3 points can be scored for the following:

- **Building user guide** – 0.5 point: To be disseminated to all eventual occupants in the building, the user guide should provide a detailed overview of the sustainable design strategies and green features employed in the building, on how they are operated and benefit the user.
- **Sustainability Education Corner** – 0.5 point: The Sustainability Education Corner should be dedicated to education and promotion of green building elements and environmental sustainability as well as the green features specific to the development. It should be located at a prominent area, easily accessible and noticeable to all tenants, building occupants and/or visitors.
- **Sustainability Awareness & Education Programme** – 0.5 point: Awareness & educational programme could include regular scheduled events or tour to generate sustainability awareness
- **Green fit out guidelines** – 1 point: To be disseminated to the relevant tenant management/ personnel, the guidelines should detail recommended minimum environmental standards to assist them in making sustainable fit-out decisions. Required for all ratings.
- **Green lease** – up to 3 points: To be incorporated into the tenancy agreement, the green lease should establish agreed levels of environmental performance between the landlord and the tenant for ≥ 60% of the net lettable area.
  - 3 points for ≥ 60% of the net lettable area.
  - 1 point for ≥ 25% of the net lettable area.

- **Displaying Green Mark credential** – 1 point: Can be awarded upfront when building owner commits to display the Green Mark Decal or Green Mark Plaque at prominent location (visible to public) when the project is completed. Photos evidence of installed GM credential to be submitted to BCA. Required for Platinum projects.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Building user guide & Green Fit-out guideline: Draft of guide prepared and endorsed by the client representative, complete with commitment that it will be circulated. • Sustainability Education Corner: Location of corner and draft details of the information that will be provided at the corner • Sustainability Awareness & Education Programme: Commitment from building owner on the operation of programme and draft details of the programme. • Green lease: Draft green lease for specified NLA prepared and endorsed by the client representative, complete with commitment that it will be incorporated into the tenancy agreement with details of procedures to ensure compliance	• Sustainability Awareness & Education Programme: Details of the programme and schedule done/planned. • Green lease: Official tenancy agreement with green lease and compliance procedures incorporated, complete with evidence of its application to the specific tenants Building user guide & Green Fit-out guideline — As-Built Sustainability Education Corner & Displaying Green Mark Credential — (photo)

Guidance Notes – Recommendation information to be included in the Building User Guide

An outline of the Building User Guide is as follows:

- Introduction – An overview of the design, the passive and environmental strategies employed and how they benefit the user.
- Façade and Roof Design - Details on how the façade are designed to reduce solar heat gain and facilitate natural ventilation where applicable
- Energy
  - Details of the energy efficient equipment and their operational controls
  - Details of energy labelling for any supplementary equipment and advice on selection
  - Details on how to track energy consumption
- Water
  - Details information on the WELS rated products, water efficient system adopted and water conservation strategies
- Waste & Recycling
  - Information on the waste collection strategies and waste recycling practices
- Green Transportation and Access
  - Details of bicycle parking provisions and local transportation options to and from the building
- Local Amenities
  - Details of the amenities and facilities within and around the building
- Responsible and Healthy Fit Out
  - Details of the green products used within the building
  - Importance of using green fit-out and low VOC materials
  - Embodied energy of building materials selection
- Responsible Purchasing
  - Advice on green procurement strategies relevant to the type of building occupant
- Others
  - The environmental impact of user behaviour
  - Information on good practices for sustainable building operations relevant to the building users including links to websites, publications and organisations providing information or guidance on environmentally sound operations, environmental tips and initiatives

For green lease, guiding templates (*Office Green Schedule* and *Retail Green Schedule*) may be found in the BCA website.

1.2 Urban Harmony (10 pts)

With buildings forming part of a larger urban environment, it is important to identify the impact of the physical form of a building, which prefixes its sustainable performance, with respect to its immediate locale and larger context. Designing for a building's human-centricity looks at how its presence can co-exist in harmony with its surrounding context and positively impact the movement and comfort of the people in its neighbourhood.

- 1.2a Sustainable Urbanism (5 pts)
- 1.2b Integrated Landscape and Waterscape (5 pts)

Photo courtesy of UOL Group Limited

1.2a Sustainable Urbanism

Intent

Through site analysis and mitigation measures, a sustainable accessible and contextual response can be developed to ensure that the development enhances the urban realm as well as minimises its environmental impact and dis-amenity to the surrounding buildings.

Scope

Applicable to all building developments.

Assessment

A maximum of 5 points can be scored under the following sub-criteria:

(i) Environmental Analysis

Up to 2 points can be scored for either the following conducted prior to the commencement of activities on site to identify the anticipated effects on climate change, flora and fauna, soil, air and water that the development may have. It should identify and implement measures to mitigate any adverse impacts, protect valuable site ecology and/ or to improve the site to its original condition.

- Environmental study – 1 point
- Comprehensive Environmental Impact Assessment (EIA) by 3rd party – 2 points

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
Submission of an environmental study report, or an EIA by 3rd party, acknowledged by the client or client representative. The EIA shall be conducted by a competent specialist. The environmental study report shall not necessarily be used to fulfil authority requirements. The report/ EIA should detail: • The proposed development its need and existing environment • The impacts of the proposed development and its alternatives on the environment, minimally covering the aspects of climate change, flora and fauna, soil, air and water where applicable • Recommendations and measures to mitigate any adverse impacts and / or opportunities to improve the site beyond its original condition before the development. (Note: Replacement is not able to be considered as mitigating measures for features of identified value removed in the construction process or site clearance.) • A non-technical summary	As-Built (committed environmental mitigation measures implemented during the construction and initial operation of the building)

(ii) Response to Site Context

Creation of possible new ecology and natural ecosystems (Advanced Green Efforts)

1 point can be scored if the project can detail strategies in the EIA on how the completed project 'heals the land'. Beyond mitigation measures, it should have a net positive impact by enhancing the site ecology beyond its current state. The regenerative features should be quantified in terms of an overall net improvement versus the building not being constructed and the site remaining in the current context.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Detailing of strategies to achieve the criteria intent and how the regenerative features are quantified • Detailing of metrics to be used and tracked during project completion	A study utilising the agreed metrics at the design stage conducted at suitable intervals during the building's operational life that demonstrates the projects regenerative performance

A site analysis identifies the relationships between the human and physical geography of the site. It should consider how the urban context, site topography and hydrology, site micro climate, site access and connectivity can inform the design of the urban form and site layout to respond accordingly. Up to 3 points can be scored for either:

- Level 1 site analysis and design that demonstrates sensitivity to the site condition – 1 point
- Level 2 site analysis optimised design with at least 2 types of iterative simulations – 3 points

Documentation Requirements

Design Stage
Level 1/ Level 2 site analysis report

Guidance Notes

An outline of the site analysis report is as follows:

- Executive Summary – A non-technical summary that summarises the site analysis
- Urban context – The urban form, land use and its impact on the site. This shall include key vistas, view corridors, the urban grain as well nearby amenities
- Site Topography & Hydrology – Land and topographical survey of the site facilitating design decisions based on the site's topographical features, storm water runoff and other key features. Can link to the EIA under *1.2a (i)* if conducted
- Site Micro Climate - Sun/ Wind/ Acoustics/ Views/ Air Quality:
  - Level 1: Identification on plan and photographic evidences of the key micro climatic conditions of the site and how this will be considered in the design
  - Level 2: Macro level simulations, with at least 2 iterations, that analyse the site context on top of level 1.
- Site Access and Connectivity – Details of pedestrian and vehicular traffic, site accessibility and public transport options. The analysis shall investigate the connectivity potential to connect the site to existing green infrastructure such as parks, gardens or cycle routes, as well as sheltered connectivity to public transport. The analysis should also look at physical connectivity feasibility to adjacent buildings (existing or planned)
  - Level 1: Concept design studies demonstrating how the functional requirements of the project responds positively to the site context including enhancing site access
  - Level 2: Iterative massing studies through macro simulations, with at least 2 iterations, that identify how the urban form of the building has been optimised, the location of outdoor amenities have been located to take advantage of the site conditions, including outdoor thermal comfort analysis. The simulations should identify that the building minimises its impact on its neighbours

(iii) Urban Heat Island (UHI) Mitigation

Demonstrate measures to mitigate the urban heat island effect and through the material selection of the hardscape (eg. materials with high Solar Reflectance Index), softscape (eg. greenery) and building surfaces (eg. coatings such as cool paints). Areas for renewable energy generation such as photovoltaic panels are deemed to comply. Up to 1 point can be scored for:

- ≥ 50% site coverage (at plan view) with mitigation measures – 0.5 point
- ≥ 80% site coverage (at plan view) with mitigation measures – 1 point

Guidance Notes

The site plan (2D plan area in m^2) can be used to calculate the site coverage of UHI mitigation measures such as:

- Green and blue spaces for landscaping and roof
- Roofing materials or coatings or cool paints with high Solar Reflectance Index (SRI) > 40
- Unshaded hardscape areas with SRI > 39, inclusive of unshaded carparks, internal roads, plazas and pedestrian walkways
- Permeable paving strategies such as gravel or open paving systems
- Other performance based strategies that demonstrate UHI effect mitigation

Areas for renewable energy generation, e.g. where photovoltaic panels are placed, can be deemed to comply.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Site plan highlighting vegetation, waterbodies, hardscape and roof areas • Calculation of hardscape areas shaded by vegetation based on a midday sun i.e. the shadow shall correspond to the area directly under the tree canopies. The tree canopy size shall be based on the mature crown size as per NParks guidelines (also referenced under *1.2c (i) Greenery Provision*) • Material schedules or specifications of the roof and hardscape finishes with corresponding SRI values. Where such values are not provided, calculations in accordance to *ASTM E1980 – 11* may be used supported by solar reflectance and thermal emittance specifications	As-Built Purchase Summary

(iv) Green Transport

0.5 point each can be scored for the provision of the following:

- Electrical vehicle charging and parking infrastructure for vehicles or to facilitate electric car-sharing service: There shall be at least 1 lot per 100 lots (Up to 5 lots)
- Meet the prevailing lower bound requirement by of 'Range Based Car Parking Standard (RCPS)' based on development type and parking zone published by LTA.
- Provision of bicycle lots over and above requirements stated in URA circular *URA/PB/2018/03-DCG (or prevailing circular)* and *LTA's Code of Practice - Street Work Proposal Relating to Development Works (or prevailing COP)* with at least 1 bicycle parking lot per 1,500m^2 of GFA (Up to 30 lots).
- Additional features to promote bicycle usage. Examples of features (at least 2 of the features should be implemented in order to score) include:

➢ Adequate shower and toilet provision above NEA requirements ➢ Adequate provision of lockers ➢ Bicycle maintenance facility ➢ Comprehensive wayfinding signage	➢ Dedicated circulation routes within development for cyclists to access bicycle parking and end-of-trip facilities safely ➢ Ground level sheltered parking ➢ Innovative bicycle parking designs ➢ Security surveillance for bicycle parking

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Electrical vehicle charging and parking infrastructure - Extracts of the tender specifications and plan showing the provision of electric vehicle charging (location & numbers) and parking infrastructure - Plans indicating the location, number and provision of electric vehicle charging and parking infrastructure • Reduced car park provision below the prevailing car park standard, such as application approved by LTA • Extracts of the tender specifications and plans showing the location of features promoting bicycle usage.	As-Built

1.2b Integrated Landscape and Waterscape

Intent

Projects are encouraged to integrate a verdant landscape and waterscape into their building design, to enhance the biodiversity around the development and provide visual relief to building occupants and neighbours.

Scope

Applicable to all building developments.

Assessment

A maximum of 5 points can be scored under the following sub-criteria:

(i) Greenery Provision

The provision of greenery for the development can be quantified via the Green Plot Ratio (GnPR). Points can be scored as follows:

GnPR	Points Allocation
0.5 to <1.0	0.5
1.0 to <2.0	1.0
2.0 to <3.0	2.0
3.0 to <4.0	2.5
≥ 4.0	3.0

Note: Please take note of landscape replacement requirements based on Gross Plot Ratio (GPR) and development type stated in URA circular *URA/PB/2017/06-DCG (or prevailing circular).*

Definitions

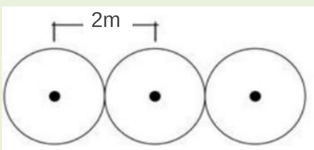
Green Plot Ratio (GnPR): GnPR calculates the 3D volume covered by plants using the prescribed Leaf Area Index (LAI) by NParks.

Guidance Notes

The LAI of the individual plant species and its canopy area are predetermined design parameters as listed below:

Plant Group	Trees	Palms	Shrubs & Groundcover	Turf
Leaf Area Index (LAI)	Open Canopy = 2.5 Intermediate Canopy = 3.0 Dense Canopy = 4.0	Solitary = 2.5 Cluster = 4.0	Monocot = 3.5 Dicot = 4.5	2.0
Fixed Area*:	Columnar = 12 m^2 Non Columnar = 60 m^2	Solitary = 20 m^2 Cluster = 17 m^2	Planted Area	Planted Area
Note: Exceptions apply to trees or palms planted at ≤ 2.0m centres trunk to trunk/ columnar trees as elaborated further below.				

The plant species sub-categories and LAI values can be obtained from the online website: *http://florafaunaweb.nparks.gov.sg* by searching the common/ scientific names of the plants.



Trees and palms spacing (centre-to-centre): If the selected trees and palms are to be planted at ≤ 2m from trunk-to-trunk as illustrated below, the leaf area shall be calculated as the product of LAI value and planted area

Columnar trees: For trees that have tight, columnar crowns, the canopy area of 12 m^2 is to be adopted for calculation of leaf area. These species include (but not limited to) the following:

- *Garcinia Cymosa Forma Pendula*
- *Garcinia Subelliptica*
- *Polyalthia Longifolia*
- *Carallia Brachiate*
- *Gnetum Gnemon*

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Plan - showing the site area as well as the greenery that is provided within the development, including a listing of the number of trees, palms, shrubs, turf and the respective sub category and LAI values • GnPR Calculation	As-Built

Worked Example

Category	Sub category	(A) LAI value	(B) Canopy Area	(C) Qty/ Planted Area	(A) x (B) x (C) Leaf Area
Trees (no.)	Intermediate Canopy	3.0	60 m^2	8 no.	1,440 m^2
	Dense Canopy	4.0	60 m^2	12 no.	2,880 m^2
Palms (no. or m^2)	Solitary (trunk-to trunk ≤ 2m at 1.5m radius)	2.5	NA	$\pi \times 1.5^2 = 7$ m^2	17.5 m^2
	Cluster	4.0	17 m^2	10 no.	680 m^2
Shrubs (m^2)	Dicot	4.5	NA	20 m^2	90 m^2
Turf (m^2)	Turf	2.0	NA	90 m^2	180 m^2
Vertical Greenery (m^2)	-	2.0	NA	10 m^2	20 m^2
				Total Leaf Area :	5307.5 m^2

Assuming the site area is 4000m^2,
Green Plot Ratio (GnPR) = Total leaf area / site area = 5307.5 / 4000 = 1.327

Therefore, points scored for *1.2b (i)* = 1 points.

GnPR ≥ 5 (Advanced Green Efforts)

1 more point can be scored under *Advanced Green Efforts* if the project has a GnPR ≥ 5.

(ii) Tree Conservation

0.5 point each can be scored for the following:

- Preservation of existing trees on-site to prevent disturbance to established habitats.
- Replanting of an equivalent number of similar or native species of equivalent LAI for felled trees.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Site layouts showing the existing and final locations (where applicable) and number of the trees to be restored or conserved or relocated. • Existing site plans showing the location and numbers of trees that are to be felled with the identification of the tree species and LAI values. The proposed landscape plans shall show the proposed equivalent number and tree species with LAI values of the replacement tree	

(iii) Sustainable Landscape Management

1.5 points can be scored for projects certified under NParks Landscape Excellence Assessment Framework (LEAF) certification. For projects not certified under LEAF, 0.5 point each can be scored for the following:

- The adoption of native species of greenery > 50% of the flora selected wherever possible to maintain the local ecosystem
- Projects that scored full points under 1.2a (i) for EIA
- A landscape management plan established that covers, a) The use of organic composts from horticultural wastes, b) the potential for onsite composting, c) general landscape maintenance and management plan during building occupation

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender, or a signed commitment from the developer / building owner that NParks LEAF certification will be applied • Adoption of native species: Landscape plan outlining the native species with a calculation of the % of site coverage • Draft landscape management plan with supporting tender specifications	• LEAF certificate Adoption of native species Landscape management plan — **As-Built**

(iv) Sustainable Stormwater Management

Points can be scored for either of the following:

- Projects that have obtained PUB Active, Beautiful and Clean Waters (ABC Waters) certification – 1 point
- Treatment of stormwater run-off from total area through the provision of infiltration or design features before discharge to the public drains, to reduce storm surges and to treat the water
  - ≥ 10% of run-off: 0.5 point
  - ≥ 35% of run-off: 1 point

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• PUB ABC Waters Certificate • Provision of infiltration or design features: ➢ Design calculation that shows the percentage of site area that is drained to the infiltration or design features for treatment, with endorsement of an ABC Waters Professional ➢ Location plan of the relevant infiltration or design features	• Declaration of an ABC Waters Professional on the % of site area that is drained to the completed infiltration or design features for treatment Infiltration or design features

Photo courtesy of CapitaLand Limited

1.3 Tropicality (10 pts)

Shaping building passive design in consideration of the climatic context, including its orientation, facades as well as interior layout can reduce the building's heat load and energy usage and enhance effective thermal comfort for its occupants. From a performance point of view, buildings should be highly permeable in areas of natural ventilation and at the same time be shielded against heat ingress.

- 1.3a Tropical Façade Performance (3 pts)
- 1.3b Internal Spatial Organisation (3 pts)
- 1.3c Ventilation Performance (4 pts)

1.3a Tropical Façade Performance

Intent

The holistic consideration of façade performance can reduce direct sunlight into the building and minimise thermal heat gain, enhancing indoor comfort and lowering the energy for conditioning the indoor environment.

Scope

Applicable to facades and roofs bounding conditioned or non-conditioned spaces.

Assessment

A maximum of 3 points can be scored for the façade performance, based on weighted average area, assessed through either:

Simulation method: Through building physics software simulation, 1 point can be scored for meeting the notional façade detailed as follows, and for every 5% heat load reduction of the envelope and solar insolation reduction of the fenestrations against the notional façade.

Overall Weighted Values	Industrial Buildings	Other building types
Window U-Value	5.4 W/m²K	2.8 W/m²K
Wall U-Value	1.5 W/m²K	0.7 W/m²K
Overall Envelope U-value	2.4 W/m²K	1.6 W/m²K
Window-to-Wall Ratio (Each façade)	0.2	0.4
Total Effective Glass Shading Coefficient (SC_1 x SC_2)	0.6	0.4
Roof U-Value	1.1 W/m²K	0.8 W/m²K
Sky light/ Roof window U-Value	4.3 W/m²K	2.2 W/m²K
RTTV (where there are sky lights for AC areas)	50 W/m²K	50 W/m²K

Checklist method: Eligible for industrial buildings with a WWR ≤ 0.25, and other building types with a WWR ≤ 0.5. Points can be scored as follows:

Non Simulation Checklist for Industrial Buildings:

Overall Weighted Values	Baseline	Points for Improvement	Point cap
Envelope U-Value	2.4 W/m²K	0.5 points for every 0.4 W/m²K reduction from baseline	2 pts
WWR (Excludes Façade openings/ voids)	0.2	0.5 pt for meeting baseline 0.5 pt for every 0.05 reduction from baseline	2 pts
Glass Shading Coefficient (SC_1)	0.5	1 pt for meeting baseline 0.5 pt for every 0.05 reduction from baseline	2 pts
Effective Sun Shading	-	≥ 10% effectiveness (North and South) - 1pt ≥ 30% effectiveness (East and West) - 1 pt	2 pts
Roof U-Value	1.0 W/m²K	0.5 pt for every 0.1 W/m²K reduction from baseline	2 pts
Sky light/ Roof window U-Value	4.0 W/m²K	0.5 pt for meeting baseline 1 pt for U-Value of 2 W/m²K	1 pt

Non Simulation Checklist for Other Building Types:

Overall Weighted Values	Baseline	Points for Improvement	Point cap
Envelope U-Value	1.6 W/m^2K	0.5 pt for meeting baseline 0.5 pt for every 0.2 W/m^2K reduction from baseline	2 pts
WWR (Excludes façade openings/ voids)	0.4 (East, West facades not to exceed 0.3)	1 pt for meeting WWR of 0.4 0.5 pt for every 0.05 reduction from baseline	2 pts
Glass Shading Coefficient (SC_1)	0.4	0.5 pt for meeting baseline 0.5 pt for every 0.05 reduction from baseline	2 pts
Effective Sun Shading	-	≥ 10% effectiveness (North and South) - 1pt ≥ 30% effectiveness (East and West) - 1 pt	2 pts
Roof U-Value	0.8 W/m^2K	1 pt for meeting 0.8 W/m^2K	1 pt
Sky light/ Roof window U-Value	2.2 W/m^2K	0.5 pt for meeting U-Value	0.5 pt

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Checklist method: - Excel calculations on how the weighted values were derived and point scored in the prescribed template format as in the worked example. • Simulation method: ➢ Details of software used, process and extract of simulation results to demonstrate heat load reduction against the notional façade. The model shall accurately reflect the spatial parameters of the building and be created using a DOE 2.0 or equivalent software. The façade shall be modelled as per the notional façade and as per design. The comparison excludes any internal heat gains and internal zoning. The percentage heat load reduction is determined through comparing the result against the notional façade model. The heat gain shall be computed based on relevant climate data (including solar heat gains) based on an annual simulation.	• Qualified Person (QP) endorsed as-built drawings of the façade including construction details 

Worked Example

An office building has a WWR of North = 0.27, South = 0.40, East = 0.25, West = 0.28. Each façade is 500m^2. The overall WWR is 0.3. The office has 2 types of wall: basic RC wall for the south façade W_1 (area: 300m^2; U value: 2.00 W/m^2K), and the remaining facades of aluminium cladding composite wall material W_2 (total area: 1100m^2; U value: 0.39 W/m^2K). Windows are all basic double glazed of type F_1 (total area = 600m^2; U-value: 2.6 W/m^2K; SC: 0.65).

Overall Weighted Envelope U-value $= \frac{(U_{W1} \times A_{W1}) + (U_{W2} \times A_{W2}) + (U_{F1} \times A_{F1})}{Overall\ facade\ area} = \frac{(2.0 \times 300) + (0.39 \times 1100) + (2.6 \times 600)}{500 \times 4}$

$= 1.29\ W/m^2K$

Based on this the total points for the façade design is:

Overall Weighted Values	Baseline	Points for Improvement	Points
Envelope U-Value	1.6 W/m^2K	0.5 pt for meeting baseline 0.5 pt for every 0.2 W/m^2K reduction from baseline	$\frac{1.6 - 1.29}{0.2} \times 0.5 + 0.5$ =1.275 pts
WWR (Excludes façade openings/ voids)	0.4 (East, West facades not to exceed 0.3)	1 pt for meeting WWR of 0.4 0.5 pt for every 0.05 reduction from baseline	$\frac{(0.4 - 0.3)}{0.05} \times 0.5 + 1$ =2 pts E, W facades WWR < 0.3
Glass Shading Coefficient (SC_1)	0.4	0.5 pt for meeting baseline 0.5 pt for every 0.05 reduction from baseline	0.65 > 0.4 so no points (If there is a mix of glass types with different SC, to weight them accordingly by area)

Therefore, points scored for 1.3a = 3.275 points (capped at 3 pts).

Low heat gain façade (Advanced Green Efforts)

1 point can be scored for achieving ETTV < 35W/m^2.

Documentation Requirements

As per P.1 Envelope & Roof Thermal Transfer

Vertical Greenery on the East and West Façade (Advanced Green Efforts)

- 1 point for more than 30% of east and west façade areas
- 0.5 point for more than 15% of east and west façade areas

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
Façade drawings and calculation showing the vertical greenery provision on East and West Façade	As-Built

Thermal Bridging (Advanced Green Efforts)

1 point can be scored for the use of thermal break /insulating profiles certified by approved local certification bodies, namely the Singapore Green Building Council and the Singapore Environment Council, and with a frame U-values, U_{fr}, of < 6.0 W/m2K for ≥ 80% of external facades adjoining air-conditioned interiors.

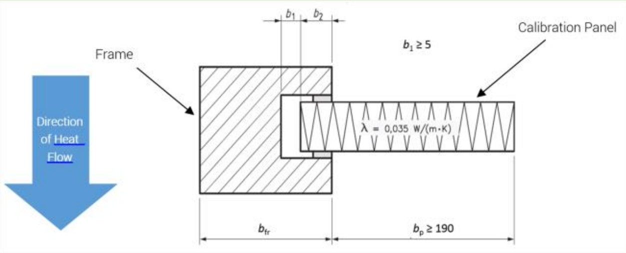
Definitions

Thermal barrier profile: A profile composed of two or more metal sections connected by at least one thermally insulating (non-metallic) part. The thermal barrier can be continuous or in parts.

Thermal transmittance value of frame (U_{fr}): The thermal transmittance of the frame design in W/m^{2}K (incorporating any thermal barrier profile if any). This excludes the thermal transmittance of the glazing.

Guidance Notes

The U_{fr} value of frames may be improved through thermally breaking the frame. According to ISO 10077-2, U_{fr} may be computed through the use of a calibration panel. The following shows a schematic of a generic profile section with calibration panel installed.



$$L_{fr}^{2D} = U'_{fr} b_{fr} + U'_p b_p$$

$$U_{fr} = \frac{(L_{fr}^{2D} - U_p b_p)}{b_{fr}}$$

Where:
b_{fr} (mm): Projected frame length
b_p (mm): Calibration panel length for 2-D heat transfer effects
L_{fr}^{2D} (W/mK): 2-D heat flow through entire cross section incorporating calibration panel
U_{fr} (W/m^{2}K): Pure frame U-value as defined in ISO 10077, without the influence of the calibration panel
U'_{fr} (W/m^{2}K): Frame U-value with calibration panel installed. It is inclusive of the influence from the calibration panel
U_p (W/m^{2}K): 1-D Calibration panel pure U-value, without the influence of the frame
U'_p (W/m^{2}K): Calibration panel U-value 190 mm from sightline (or length corresponding to b_p). It is inclusive of the influence from the frame

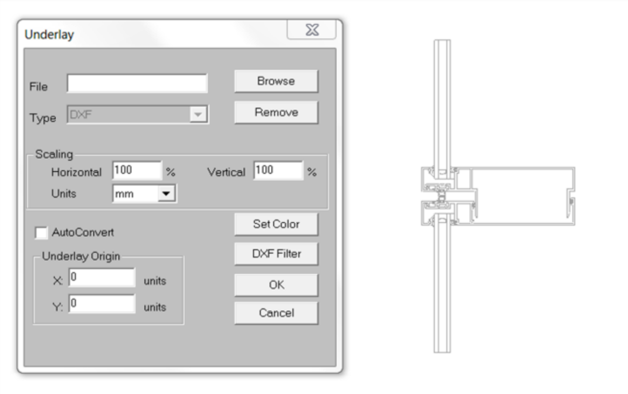
The use of the calibration panel may be simulated virtually in order to obtain the U_{fr}. When the frame design and material properties have been confirmed, such a thermal simulation report can be easily obtained from the relevant manufacturer or facade consultant. Acceptable simulation software must generate results In accordance with *ISO 15099:2003 - Thermal Performance of Windows, Doors and Shading Devices* and *ISO 10077 -Thermal Performance of Windows, Doors and Shutters*. Simulation must be carried for all different windows/ curtain wall profile sections used in the building project.

Documentation Requirements

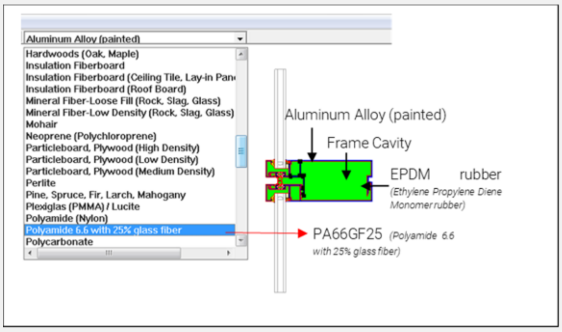
Design Stage	Operation Document (for handover to FM)
• Extracts from the tender specifications showing the requirement to incorporate SGBC certified thermal break/ insulating profile and to achieve U_{fr} value < 6.0W/m^{2}K for each frame for ≥ 80% of the applicable facades • Initial design drawings labelling clearly the use of thermal break/ insulation profile	• Thermal simulation report (from windows/ curtain wall manufacturer or facade consultant) showing that Ufr of the relevant facades used in the project complies with the criteria requirements As-Built

Worked Example

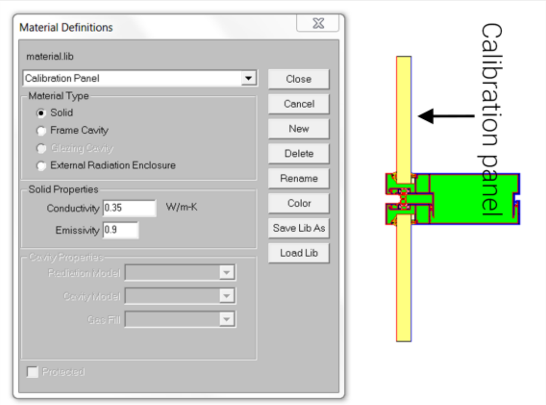
The following worked example shows the steps to simulate and determine Ufr via a thermal simulation report. In this example, a single mullion profile cross-section of a single generic unitized curtain wall system with thermal break/ insulating profiles is used.



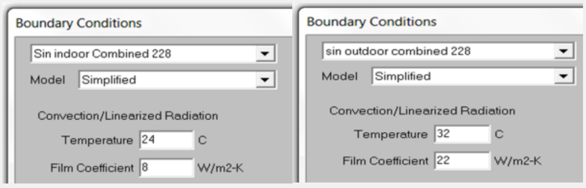
1. Import exploded DXF file of the curtain wall profile cross-section into the thermal simulation software as an overlay.



2. Trace the imported curtain wall profile cross-section & assign every element in the profile with appropriate materials from the software's material library.
3. Draw a 191mm (from sightline without protruding gasket) calibration panel in place of infills (e.g. glazing, spandrel panels, etc).

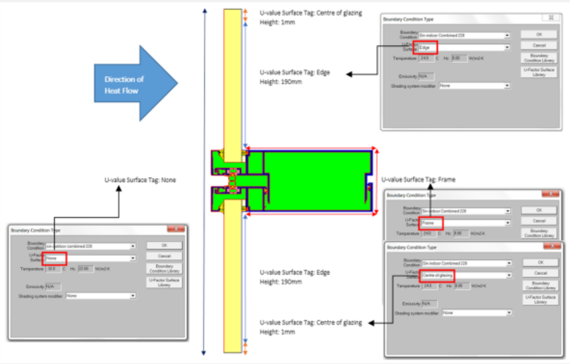


4. Input the properties for the calibration panel.



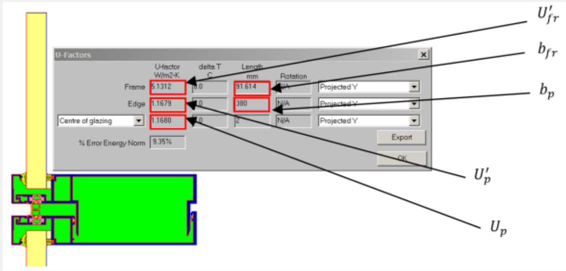
5. Input the relevant boundary conditions for Singapore context.

6. Assign the U-value surfaces accordingly (None, Centre of Glazing, Frame & Edge) to boundary condition type (inside or outside) as shown.



7. Save and run the simulation.

$$L_{fr}^{2D} = U'_{fr} b_{fr} + U'_p b_p$$
$$= 5.1312 \times \frac{91.614}{1000} + 1.1679 \times \frac{380}{1000}$$
$$= 0.914 \text{ W/mK}$$



8. Extract these 5 values from the thermal simulation report and input them into the following equations in order to obtain the frame U value.

$$U_{fr} = \frac{(L_{fr}^{2D} - U_p b_p)}{b_{fr}}$$
$$= \frac{\left(0.914 - 1.1680 \times \frac{380}{1000}\right)}{\frac{91.614}{1000}}$$
$$= 5.131 \text{ W/m}^2\text{K} < 6 \text{ W/m}^2\text{K}$$

1.3b Internal Spatial Organisation

Intent

Adopting passive design strategies in the internal spatial organisation of a building provides opportunities to enhance building performance.

Scope

Applicable to all building developments.

Assessment

Up to 3 points can be scored for the following:

- 1 point can be scored for locating non-air-conditioned spaces, e.g. lift cores, staircases, toilets, electrical plantrooms etc that covers 2/3 of the east and west facing walls to reduce thermal heat gain into occupied spaces. 0.5 point can be scored for 1/3 of the east and west façades covered by these non-air-conditioned spaces.
- Prorating the number of transient common spaces, e.g. toilets, staircases, corridors, lift lobbies and atriums by the mode of ventilation against the total number of applicable spaces – Up to 2 points

$$Points\ scored = \frac{\text{Number of NV spaces x 2} + \text{Number of MV spaces x 0.5} + \text{Number of AC spaces x 0}}{\text{Total number of spaces}}$$

Note: Handicap toilets are excluded from count. Each toilet is counted as 0.5 each

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Plans and elevations showing % of non-A/C façade areas over total East & west façade area • Mode of ventilation: - Plans & details of the common spaces including façade openings & mode of ventilation ➢ Calculations showing % of spaces that are served by the different modes of ventilation	As-Built

Worked Example

A proposed development has the following details:

Facing	Façade areas	Façade areas of non-A/C Area
East	3000	1600
West	3000	2000
Total	6000	3600

% of non-A/C façade areas for East and West facing facades = 3800/6000 = 60% < 2/3. Hence, point scored = 0.5 point

A proposed development has the following details:

Number of Common Areas	AC	NV	MV
Toilets	0	10	10
Staircase	0	1	5
Corridors	0	8	5
Lift Lobbies	10	1	0
Total Number	10	20	20
Weightage	0	2	0.5
Sum (No. x Weightage)	0	40	10

Total number of common spaces = 10 + 20 + 20 = 50

Total points scored

$$= \frac{0+40+10}{(10+20+20)} = 1 \text{ point}$$

Therefore, points scored under *1.3b* for mode of ventilation = 1 point

1.3c Ventilation Performance

Intent

Naturally ventilated functional areas should be effectively designed to be thermally comfortable and healthy for the building occupants.

Scope

Applicable for naturally ventilated occupied spaces and gathering spaces such as building atria.

Assessment

A maximum 4 points can be scored for this sub-indicator based on the following options:

Ventilation Performance Checklist

<table>
<tr><th>Parameter</th><th>Description</th><th>Points</th></tr>
<tr><td>Openings towards prevailing wind directions</td><td>0.1 point for every 10% of units or rooms with openings facing towards the prevailing winds (North & South)</td><td>1</td></tr>
<tr><td>Depth of room vs opening
W: Limiting depth for effective ventilation
H: Floor-to-ceiling height</td><td><table>
<tr><th>Ventilation</th><th>Non-Atria</th><th>Atria*</th></tr>
<tr><td>Single sided ventilation</td><td>W ≤ 2H</td><td>W ≤ 3H</td></tr>
<tr><td>Cross ventilation</td><td>W ≤ 5H</td><td>W ≤ 7.5H</td></tr>
</table>*A factor of 1.5 can be applied to the W-H ratio for atria. Atria are typically higher than surrounding floors (double volume or greater)</td><td>≥50% of applicable spaces meet - 1 pt or
≥70% of applicable spaces meet - 2 pts</td></tr>
</table>

Full Ventilation Simulation

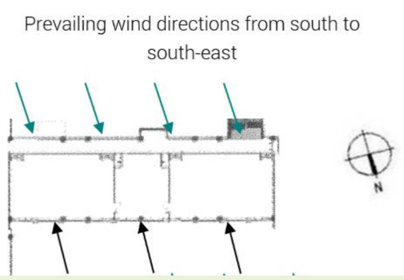
Up to 4 points can be scored for ventilation simulations or wind tunnel testing conducted based on *Green Mark NRB: 2015 Technical Guide and Requirements Annex A: Computational Fluid Dynamics Simulation Methodology and Requirements*. The simulation results and recommendations derived are to be implemented to ensure optimised natural ventilation. More than 70% of applicable naturally ventilated spaces to meet the minimum weighted average wind velocity to score. Where the wind speed result cannot be met, thermal comfort or air quality modeling should be performed and the relevant criteria stated in *Annex A* met for all naturally ventilated spaces:

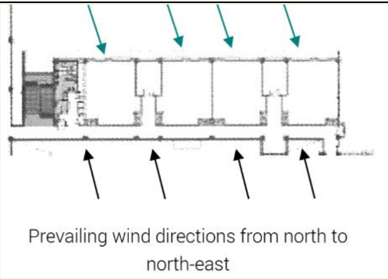
Points	Minimum weighted Average Wind Velocity	Thermal Comfort	Air Quality
3	Moderate (0.2m/s)	-	-
4	Good (0.4m/s)	-1.0 < PMV < +1.0	Air Change Rate ≥4 Air Exchange Efficiency ≥ 1
	Very Good (0.6m/s)	-0.8 < PMV < +0.8	Air Change Rate ≥10 Air Exchange Efficiency ≥ 1.2

Guidance Notes

Checklist Method

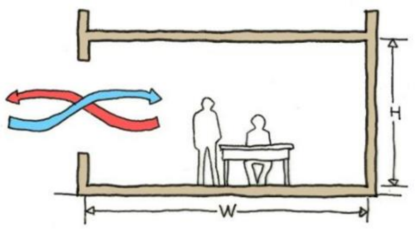
Openings toward prevailing wind directions: This applies to naturally ventilated occupied spaces with window openings facing the north and south directions. The prevailing wind comes from two predominant directions; that is the north to north-east during the Northeast monsoon season and south to south-east during the South-west monsoon season. Hence, spaces with window openings facing the north and south directions have the advantage of the prevailing wind conditions that would enhance indoor thermal comfort. Meteorological data on the more precise wind direction and velocity of the site location can also be used as the basis for the design.





It is not necessary for the window openings to be located perpendicularly to the prevailing wind direction. An oblique angle is considered acceptable. The following is an example of a building layout with all spaces having window openings facing the north and south directions.

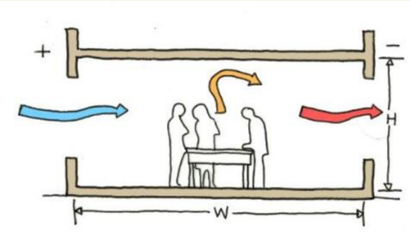
Depth of Room vs Opening - Single sided ventilation: This applies to naturally ventilated occupied spaces with window openings on one side. They shall meet W ≤ 2H to score points.



For gathering spaces such as atria which are single-sided, they may apply a factor of 1.5 to the W-H ratio for occupied spaces. This means they can meet W ≤ 3H instead to score.

Exceptions: In cases where non-ducted circulation fans are provided (e.g. HVLS fans), they may apply a factor of 2 to the W-H ratio for typical spaces. They mean they can meet up to W ≤ 4H instead to score.

Depth of Room vs Opening - Cross ventilation: This applies to naturally ventilated occupied spaces with window openings on opposing sides of the space. They shall meet W ≤ 5H to score points.



For gathering spaces such as atria which have cross ventilation, they may apply a factor of 1.5 to the W-H ratio for occupied spaces. This means they can meet W ≤ 7.5H instead to score.

Exceptions: In cases where non-ducted circulation fans are provided, they may apply a factor of 2 to the W-H ratio for typical spaces. They means they can meet up to W ≤ 10H instead to score.

Full Ventilation Simulation

As per *Annex A: Computational Fluid Dynamic Simulation Methodology and Requirement*

Worked Example

Checklist Method

A school comprises the following:

- Block A: 4 out of 10 classrooms have opposite window openings facing the N-S direction. The rest of the classrooms have single-sided window openings. The classrooms are naturally ventilated with dimensions H = 3.5 m, W = 8 m
- Block B: All the 8 classrooms have opposite window openings facing the E-W direction. The classrooms are naturally ventilated with dimensions H = 3.5 m, W = 8 m
- Block C: All the 5 rooms in this block are air-conditioned, e.g. administrative office, meeting rooms, lecture rooms, auditorium and computer rooms
- A naturally ventilated atrium (H: 5 m, W: 14 m) with openings on opposite sides facing the N-S direction

Space type	Fulfilled Requirement for Depth of Room vs Opening?	Openings facing N-S?
4 cross-ventilated classrooms with opposite window openings facing the N-S direction	W/H = 8/3.5 = 2.3 Fulfils requirement of W ≤ 5H	Yes
6 classrooms with single-sided openings	W/H = 8/3.5 = 2.3 Does not fulfil requirement of W ≤ 2H	No
8 cross-ventilated classrooms with opposite window openings facing the E-W direction	W/H = 8/3.5 = 2.3 Fulfils requirement of W ≤ 5H	No
A naturally ventilated atrium with openings on both sides	W/H = 14/5 = 2.8 Fulfils requirement of W ≤ 7.5H	Yes
Total percentage	% of spaces which fulfilled requirement of depth of room vs opening $= \frac{4+8+1}{4+6+8+1}$x100% = 68.4%	% of spaces with openings towards prevailing wind directions $= \frac{4+1}{4+6+8+1}$x100% = 26.3%

Total points for openings towards prevailing wind directions = $\frac{26.3}{10} \times 0.1$ = 0.26 points

Total points for depth of room vs opening = 1 point (≥ 50% of applicable spaces meet)

Total points for effective ventilation based on checklist method = 1.26 points

Ventilation Simulation

A project has at least 7,350m^2 of naturally ventilated occupied spaces and is targeting Gold^{PLUS} certification. It would first need to perform a natural ventilation simulation with results and recommendations implemented. However, after doing so, less than 70% of its naturally ventilated spaces are able meet a minimum area-weighted velocity of at least 0.4 m/s due to certain constraints. The spaces thus can achieve at least Moderate ventilation performance but is unable to meet Good natural ventilation performance required of Gold^{PLUS} projects. It would then need to carry out either thermal comfort or air quality simulation (it is eligible to do so as the spaces can achieve at least Moderate ventilation performance). It must prove all its naturally ventilated spaces can either achieve PMV within the stipulated range via thermal comfort modeling, or achieve an air change rate and air exchange effectiveness meeting the stipulated requirements via air quality modeling. Thereafter, it would be deemed to comply with the prerequisite requirement for Gold^{PLUS} and achieve 4 points in the criteria.

Wind Driven Rain Simulation (Advanced Green Efforts)

Up to 1 point can be scored for wind driven rain simulation in compliance with *Annex A* to identify the most effective building design and layout that minimises the impact of wind-driven rain into naturally-ventilated occupied spaces.

2. Building Energy Performance

The built environment is an important contributor towards reducing global carbon emissions and fossil fuel consumption. This section builds on *Section 1 – Climatic Responsive Design*, and focuses on how building projects can demonstrate the optimisation of building energy systems through energy efficiency, effectiveness and replacement strategies to reduce their environmental impact.

The energy performance of a building is measured through the efficiency of its active mechanical and electrical systems. In the urban tropics, this is mainly attributed to air conditioning systems, artificial lighting and hot water production in some building types. In addition, to consider the energy effectiveness of a building holistically, the extent of use of energy systems in terms of their absolute energy consumption should also be taken into account. Further tapping unto opportunities to utilise renewables in place of fossil energy sources, the energy performance of building projects can be improved significantly.

An Energy Performance Points Calculator in Excel format has been formulated to aid the design team to understand the buildings' total energy performance, while providing options to reduce energy consumption. This calculator can be used to compute this section's points.

P.4 - P.6 + POINTSPREREQUISITES 30 POINTS

2.1 Energy Efficiency (22 pts)
Option 1: Energy Performance Points Calculator
Option 2: Performance-Based Computation

2.2 Renewable Energy (8 pts)

Advanced Green Efforts (7 to 9 pts)

P.4 Air Conditioning Total System and Component Efficiency

Intent

Energy efficient air-conditioning systems with better optimised total system performance require less energy to produce and distribute conditioned air into building spaces.

Scope

Applicable to air-conditioning systems serving the building comfort cooling needs.

Assessment

Where the cooling capacity of any air-conditioning system exceeds 30 kW, the equipment (excluding air distribution) shall comply with the relevant provisions of *SS 530: 2014 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment*.

Where the building's aggregate air-conditioned areas exceed 500 m^2, the Design Total System Efficiency (DSE) and the efficiency of the cooling and air distribution components shall not exceed the limits in the tables below. For buildings with different systems, the tables will apply for the system with a larger aggregate capacity. The DSE 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.

a) Air Cooled Chilled-Water System/ Unitary Air-Conditioning System

Relevant equipment: *Air-cooled chillers, chilled-water pumps, variable refrigerant flow (VRF) systems, single-split units, multi-split units, air distribution system (e.g. AHUs, PAHUs, FCUs)*

Green Mark Rating	Peak Building Cooling Load (RT)		Remarks
	<500 RT	≥500RT	(η_c, η_a) shall meet their respective thresholds. η_c: System kW/ton excluding the air distribution equipment η_a: Air distribution equipment kW/ton $\eta_t = \eta_c + \eta_a$
	Minimum DSE η_t (kW/RT)		
Gold	NA *(0.9, N.A.)*	NA *(to be assessed on case by case basis)*	
Gold^PLUS	1.10 *(0.85, 0.25)*		
Platinum	1.03 *(0.78, 0.25)*		

b) Water Cooled Chilled Water System

Relevant equipment: *Water-cooled chillers, chilled-water pumps, condenser water pumps, cooling towers, air distribution system*

Green Mark Rating	Peak Building Cooling Load (RT)		Remarks
	<500 RT	≥500RT	(η_c, η_a) shall meet their respective thresholds. η_c: System kW/ton excluding the air distribution equipment η_a: Air distribution equipment kW/ton $\eta_t = \eta_c + \eta_a$
	Minimum DSE η_t (kW/RT)		
Gold	NA *(0.75, N.A.)*	NA *(0.67*, NA)*	
Gold^PLUS	0.95 *(0.7, 0.25)*	0.9 *(0.65, 0.25)*	
Platinum	0.93 *(0.67, 0.25)*		

*to comply with NEA's Minimum Energy Efficiency Standards (MEES) as well

c) District Cooling System (DCS) – Within or outside gazetted zones, operated by supplier of district cooling services registered under the Energy Conservation Act

Relevant equipment: *DCS plant (e.g. chillers, chilled-water pumps, condenser water pumps, cooling towers, network pumps, thermal storage, heat exchangers, renewable energy or energy recovery systems within the plant vicinity), building air-distribution system*

Green Mark Rating	Minimum DSE ηt^{*} (kW/RT)	Remarks
Gold	0.9 *(0.65, N.A.)*	*(ηc, ηa)* shall meet their respective thresholds. *ηc*: DCS system kW/ton *ηa*: Building's air distribution equipment and chilled-water pumps. *ηt= ηc+ηa*
Gold^PLUS	0.9 *(0.65, 0.25)*	
Platinum		

*For DCS plants serving the building that were commissioned before October 2016, the supplier can meet the requirements under alternative Path B stipulated in the *GM NRB: 2015 Technical Guide and Requirements* instead.

Definitions

Peak building cooling load: Determined based on design day conditions, namely where solar gains and outdoor temperatures are at their highest and there is full occupancy.

Design Total System Efficiency (DSE): The efficiency of the air-conditioning system including the air distribution equipment (e.g. PAHUs, AHUs, FCUs) in kW/RT.

Guidance Notes

Unitary Air-Conditioning System [DSE = Unitary Cooling Equipment Efficiency + Air Distribution Efficiency]

The unitary cooling efficiency component of the DSE (excluding the air distribution components) is computed based on the total weighted system efficiency. The formula used is 3.517/ $COP_{weighted}$. 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 that served by a singular unitary system which is determined by the condenser unit and the connected fan coil units/ air handling units.

Weighted Coefficient of Performance: $COP_{weighted}$ refers to the weighted Coefficient of Performance. It is calculated via the following formula from NEA: $COP_{weighted} = 0.4 \times COP_{100\%} + 0.6 \times COP_{50\%}$

$COP_{100\%}$ and $COP_{50\%}$ are defined as the ratio of the cooling capacity to effective power input at full load and at 50% cooling capacity respectively.

Weighted Operational Cooling Load: $RT_{weighted}$ refers to the weighted operational cooling load of the unitary system in RTH. It is calculated based on the operational schedule of the systems as follows: $RT_{weighted} = 0.4 \times RT_{100\%} + 0.6 \times RT_{50\%}$

$RT_{100\%}$ and $RT_{50\%}$ are the 100% and 50% of installed capacity of the zone (excluding standby units) respectively.

Water-Cooled/ Air-Cooled Chilled Water Plants [DSE = Chiller Plant Efficiency + Air Distribution Efficiency]

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

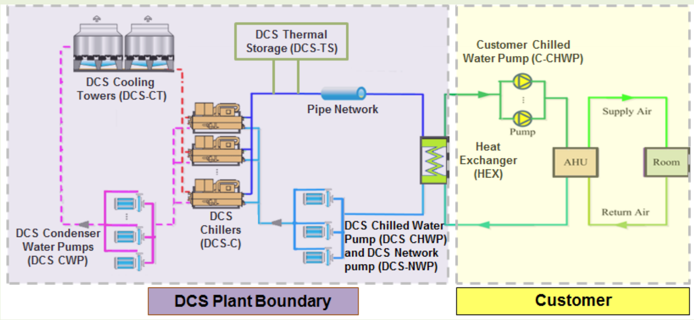
Operational design cooling load: The operational building cooling load profile shall be simulated for one whole year to generate the average cooling load over the building's operational hours for one day in RTh. The annual cooling consumption shall be computed based on the following operational hours:

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

District Cooling System (DCS) (only for DCS that are suppliers and comply to DCS Act)

DSE = DCS Plant Efficiency + Air Distribution Efficiency

The DCS plant efficiency refers to the annual electricity consumption of a DCS plant (kWh) over the annual cooling consumption (RTh) of the DCS plant. The operation hours are assumed to be 24 hrs operation per day x 365 days. The relevant equipment for the computation of the DCS plant efficiency includes those within the DCS Plant boundary.
Other auxiliary services for the DCS plant room (electricity consumption from lighting, mechanical ventilation, air-conditioning systems, receptacle loads etc.) can be excluded from the plant efficiency computation. The energy generated by the photovoltaic system at the plant can also be used to offset the total energy consumed by the DCS plant. The energy efficiency of the DCS plant shall be measured over 8,760 hours in a year.
The air distribution efficiency applies to the customer building's air distribution system. It excludes the customer chilled water pumps.



DCS Plant Boundary (includes but not limited to the following equipment)

- *DCS Chilled Water Pumps (DCS-CHWP)*
- *DCS Chillers (DCS-C)*
- *DCS Condenser Water Pumps (DCS-CWP)*
- *DCS Cooling Towers (DCS-CT)*
- *DCS Network pump (DCS-NWP)*
- *DCS Thermal Storage (DCS-TS)*
- *DCS Heat Exchanger (HEX)*

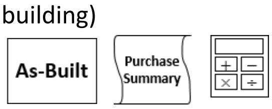
Customer Boundary

- *Customer Chilled Water Pump (C-CHWP)*
- *Customer Air Distribution System (e.g. AHUs, PAHUs, FCUs)*

Note for buildings served by DCS: The load profile of the specific customer building is to be determined by the project team over the operational hours prescribed by BCA. The energy efficiency of the DCS plant shall be computed by the DCS company based on the total cooling demand of the customer buildings connected and/ or confirmed to be connected to the plant. Evidences of the connection and supply of cooling provision between the customer building and the DCS company shall also be shown. For existing DCS plants commissioned before Oct 2016, the energy efficiency of the DCS plant can be excluded from P.4 and energy modeling savings computation if valid clearance from BCA is given to adopt Path B, but information shall still be provided by the DCS company for the computation of EEI/ EUI. For new building projects aiming for higher Green Mark ratings and tapping onto new DCS plants commissioned after Oct 2016, the baseline will be similar to standalone chiller plant system, stipulated in Annex C Energy Modelling Methodology and Requirements. The computation of energy saving for intended rating will be computed based on energy consumption comparison of the proposed air-conditioning system with the baseline model.*

For buildings with different air-conditioning systems, the system and component efficiencies required to fulfil the prerequisite shall only be that of the system with the larger aggregated capacity. On the other hand, the efficiency values used to score points under *2.1a* and/ or *2.1e* shall be weighted based on the efficiencies of all the different air-conditioning systems used within the building.

Documentation Requirements

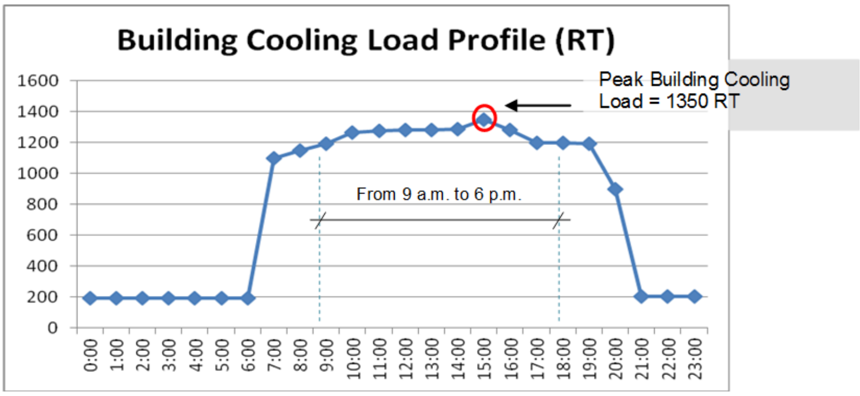
Design Stage	• Drawings/layout showing - ➢ proposed building cooling system (for new cooling systems) ➢ mode of ventilation of spaces ➢ location of the plant room and cooling towers • Technical specifications and product information of the various components of the cooling system (for new cooling systems) and air distribution system designed and installed • Part load performance curves, pump head (for pumps of new cooling systems) and fan static pressure calculations • For Gold^{PLUS} and Platinum projects: Detailed calculations of fan input power for each PAU, AHU and FCU in the building based on operational design load • Detailed calculations of the DSE that include the cooling load profile in the prescribed format as shown in the worked examples *The DCS company shall submit the following documentation to BCA for BCA to issue clearance to adopt Path B. If the submission is satisfactory, BCA shall issue clearance, valid for 3 years from the date of issue. The developer/ owner of the building targeting Green Mark rating should check with the DCS company early in the project stage on the plant's eligibility to adopt Path B: ➢ Completed Energy Audit Report of the DCS plant and proof of installation of M&V instrumentation (compliance with Verification requirements under section *P.14 Permanent Instrumentation for the Measurement and Verification of Air Conditioning Systems*). The report shall be endorsed by PE(Mechanical) or Energy Auditor of the plant ➢ Operating conditions, energy efficiency and schematics of the equipment and measurement instrumentation of the DCS plant Energy efficiency roadmap of the DCS plant and commitment by the DCS company that the efficiency of the equipment within the defined DCS Plant Boundary shall be 0.65 kW/RT or better by 2025. The roadmap shall include the retrofitting plans and plant efficiency target at years 2016, 2019, 2022 and 2025
Operation Document (for handover to FM)	• 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 (Green Mark NRB: 2015) 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: Power consumption of the unitary systems • DCS: For Path A, as per in-house chilled water plants but both the PE/ EA of the plant and of the customer building shall endorse the Report For Path B, as per-in house chilled water plants but only for the air distribution system, endorsed by PE/ EA of the customer building. Valid clearance from BCA to adopt Path B shall be shown • (Note: As-built drawings showing the connection and supply of cooling provision between the building owner and the DCS company shall be submitted. At least one month's bill paid by the customer building to the DCS company when the customer building is reasonably occupied shall be provided to calculate the annual cooling demand of the customer building) • 

Worked Example

An office building is served by an in-building chilled water plant, and has an air-conditioned floor area of 67,500 m^2. Variable-speed drives are designed to control the speed of the chilled-water pumps and cooling tower fans. The building is also served by a VRF system during the night-time for certain areas. However, as the tonnage of the chiller plant is larger, *P.4* is only applicable to the chiller plant. The project is targeting Green Mark Gold, hence the minimum chiller plant efficiency for water cooled chilled water plant building to achieve Gold level of certification is 0.68 kW/RT. There are no prerequisite requirements for the air distribution equipment for Gold projects.

Step 1 – Determine the peak building cooling load and relevant baseline

Simulation of annual building cooling load profile shall be carried out to determine the daily average cooling load profile, peak building cooling load and the relevant baseline standard.



Time	Hourly Average Cooling Load (RT)
8:00	1,150
9:00	1,190
10:00 to 18:00	1,260
19:00	980

From the simulated building cooling load profile, the peak building cooling load is found to be 1,350 RT (≥ 500 RT).

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

The proposed air-conditioning 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: 3 nos. x 45 kW (2 duty and 1 stand by)
- Condenser Water Pumps: 3 nos. x 37 kW (2 duty and 1 stand by)
- Cooling Towers: 3 nos. x 900 RT (2 duty and 1 stand by). Each cooling tower has 3 no. of 7.5 kW fans

It is important to design the air-conditioning plant configuration for other load conditions that are not within the building operating hours specified, although this is not required for DSE calculation purposes.

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

Based on the performance data of the selected chillers from 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 simulated total building load profile, we have:

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

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

- 2 nos. x 45 kW primary chilled-water pump to be installed with Variable Speed Drive (VSD)
- Water flow rate per pump at full load (Q) = 106 L/s
- Operating static head (h)= 28 m
- Pump(η_p) & Motor efficiency (η_m)= 86.8 % & 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/m³
g: Gravitational acceleration in m/s²
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) is used in this example 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.*

While the project team can propose other equivalent methodologies, the affinity law is not recommended as it does not take into account losses during actual operating conditions.

Total pump power @ 85% part-load (kW) = 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)
= 71.22 x 0.77002 = 54.84 kW (*When x=0.9, 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

2(c) Condenser water pumps:

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

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

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

Although VSD is installed, the flow is fixed at 45Hz (90%). Hence, power consumption is fixed at 90%.
Using the pump part-load power curve equation,
Total pump power @ 90% part-load (kW)
= 62.04 x 0.77002 = 47.77 kW (*When x=0.9, 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

2(d) Cooling towers:

- 2 nos. of cooling towers to be installed with VSD,
- 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 used in this example to estimate the pump power at the part load conditions:

Cooling tower fan power ratio

$= 0.331629 - 0.885676x + 0.605565x^2 + 0.948482x^3$ *where x is the part load ratio.*

While the project team can propose other equivalent methodologies, the affinity law is not recommended as it does not take into account losses during actual operating conditions.

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*)
Pump power @ 80% part-load (kW) = 48.92 x 0.4963 = 24.28 kW (*When x=0.8, the corresponding power ratio is 0.4963*)

Step 4 – Derive the Chiller Plant Efficiency (DSE)

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 (RT)	B (kW)	C = A + (B/3.517) (RT)	D (RT)	C / D x 100% (%)	(kW)
1,190 RT	620	1,366.28	1,800	76%	20.78
1,260 RT	658	1,447.08	1,800	80%	24.28

Since this example is an office building, the hours of operation for the calculation of the DSE are to be 9 AM to 6 PM

Hours	Daily Average Cooling Load (RT)	Chillers Power Input (kW)	CHW Pumps Power (kW)	CW Pumps Power (kW)	CT Power (kW)	Total Power Input (kW)	Chiller Configuration
9:00:00 AM	1,190	620	47.50	47.77	20.78	736.05	2 x700
10:00:00 AM to 3:00:00 PM (each hr)	1,260	658	54.84	47.77	24.28	784.89	2 x700
4:00:00 PM to 6:00:00 PM (each hr)	1,190	620	47.50	47.77	20.78	736.05	2 x700
Daily Consumption (9:00:00 AM to 6:00:00 PM)	12,320 RTh	6,428 kWh	519.04 kWh	477.70 kWh	226.80 kWh	7,653.54 kWh	
Chiller Plant Efficiency kW/RT		0.522	0.042	0.038	0.019	0.62	

Chiller Plant Efficiency of the proposed building cooling system = Total Energy Consumption/Total Cooling = 7,665.44/12,320 = 0.62 kW/RT.

The project achieves design system efficiency of 0.62 kW/RT, thus meeting the pre-requisite requirement for Gold level of certification of ≤ 0.68 kW/RT.

For higher awards projects, the power consumption of the air distribution equipment should be computed as well to derive the total DSE

P.5 Lighting Efficiency and Controls

Intent

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

Scope

Applicable to artificial lighting provisions for the type of usage specified in Clause 7 of *SS 530 : 2014 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment*.

Assessment

The maximum lighting power budget for artificial lighting and lighting controls shall comply with Clause 7 of *SS 530: 2014*. In hotel buildings, a control device shall be installed in every guestroom to automatically switch off the lighting when unoccupied.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Lighting layout plans, control circuitry plans technical product/data sheet and schedules showing the numbers, locations - types of lighting luminaries used and compliance to the stated requirements. • Lighting level simulation showing the resultant lux level and uniformity of the lighting design that meets or surpasses prevailing code requirements.	• Documentation of onsite verification of the as-built lighting lux level achieved As-Built Purchase Summary

P.6 Vertical Transportation Efficiency

Intent

Energy efficient vertical transportation systems require less energy to transport passengers in buildings.

Scope

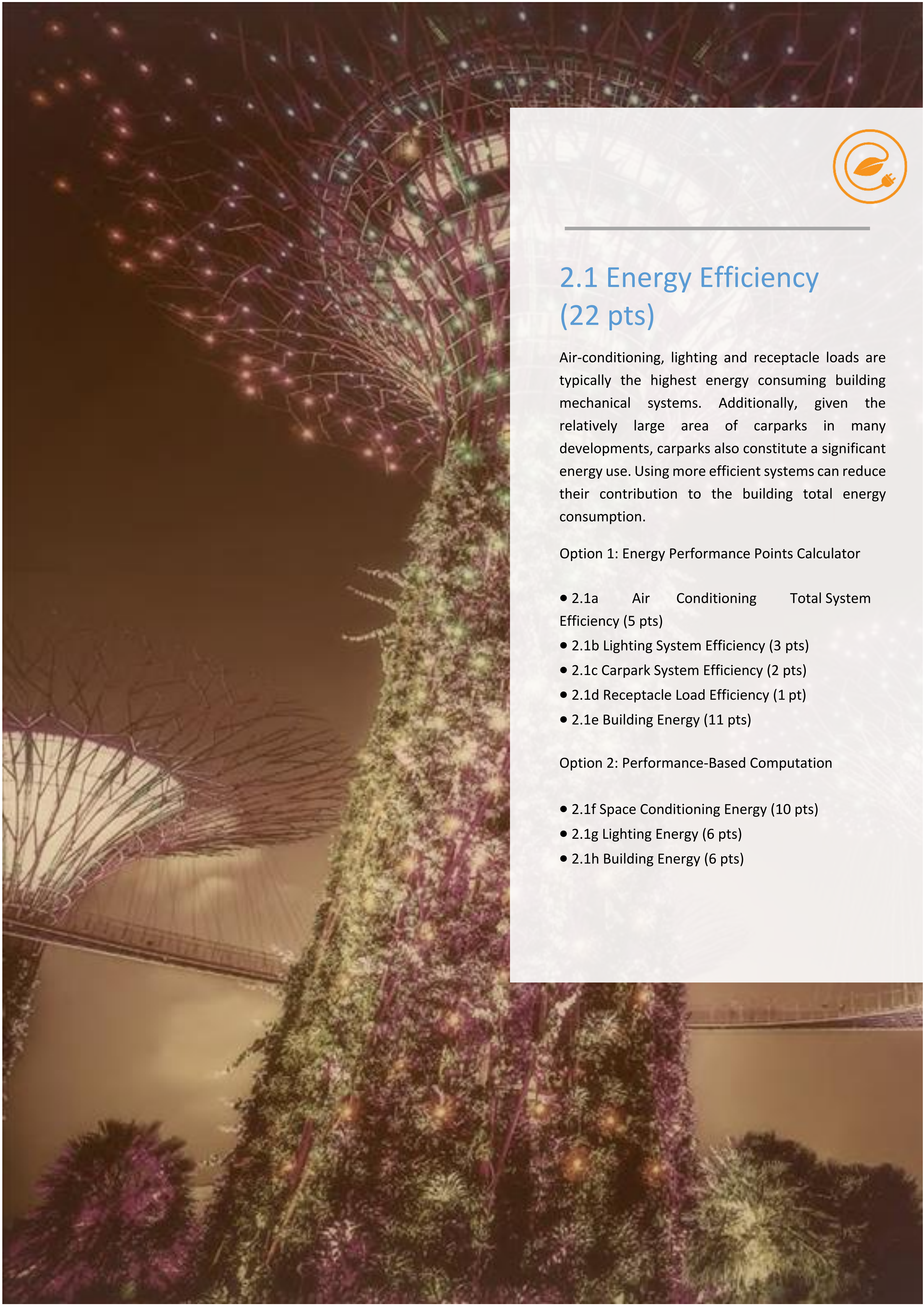
Applicable to all lifts and escalators, except typologies where such technology is not available.

Assessment

Lifts and escalators shall be equipped with AC variable voltage and variable frequency (VVVF) motor drive and sleep mode features.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of specifications that indicate the types of lifts, escalators and related features used.	• Product catalogue, Purchase Summary



2.1 Energy Efficiency (22 pts)

Air-conditioning, lighting and receptacle loads are typically the highest energy consuming building mechanical systems. Additionally, given the relatively large area of carparks in many developments, carparks also constitute a significant energy use. Using more efficient systems can reduce their contribution to the building total energy consumption.

Option 1: Energy Performance Points Calculator

- 2.1a Air Conditioning Total System Efficiency (5 pts)
- 2.1b Lighting System Efficiency (3 pts)
- 2.1c Carpark System Efficiency (2 pts)
- 2.1d Receptacle Load Efficiency (1 pt)
- 2.1e Building Energy (11 pts)

Option 2: Performance-Based Computation

- 2.1f Space Conditioning Energy (10 pts)
- 2.1g Lighting Energy (6 pts)
- 2.1h Building Energy (6 pts)

Option 1: Energy Performance Points Calculator (22 points)

2.1a Air Conditioning Total System Efficiency

Intent

The use of energy efficient air-conditioning systems can optimise their total system performance, and reduce the energy needed to produce and distribute conditioned air into building spaces.

Scope

Applicable to all the air-conditioning systems serving the building comfort cooling needs, including the air distribution equipment.

100% non – air-conditioned building projects will score full points under this indicator.

Assessment

The Energy Performance Points Calculator shall be used to calculate the percentage improvement of the weighted total design system efficiency of all the various air conditioning systems used in the project, against the code baseline. The figure should be based on the operational design load determined by the simulated average annual total cooling load profile. A maximum of 5 points can be scored as follows:

	Peak Building Cooling Load (RT)	
	<500 RT	≥500RT
	Total Design System Efficiency (kW/RT)	
Baseline	1.08	0.98
Points scored = 0.2 x (% improvement from baseline)		

For district cooling plants under Path B scenario, where the plant is excluded from the computation, the baseline reference for the building air distribution equipment can be taken as 0.28 kW/ton for the purposes of points computation here.

Guidance Notes

The Energy Performance Points Calculator shall be used to compute the points for this option.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• As per *P.4 Air Conditioning Total System and Component Efficiency*. • Energy Performance Points Calculator excel file • For computation of fan power, 5% driver loss needs to be accounted for the use of VSD. Project team can use lower value if they can substantiate VSD loss with documentation.	• As per *P.4 Air Conditioning Total System and Component Efficiency*.

Worked Example

Example 1: Computation of the various efficiencies and final points under *2.1a* for a theoretical office building which has an air cooled chilled water system, unitary/ split system as well as a water cooled chilled water system is shown. The operating hours for office buildings as specified: Monday to Friday: 9 a.m. to 6 p.m.

(a) Air Cooled Chilled Water System

Using the Energy Performance Points Calculator, the following inputs are given to determine the DSE of the air-cooled system:

- Average Cooling Load; Chiller Power input (P_{CH}); Chilled water Pump Power (P_{CHWP})
- Total Airside 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 Fan flow, the part load fan power may be referenced from ASRHAE 90.1, Table G3.1.3.15 Part-Load Performance for VAV Fan Systems or Part-Load Fan Power Equation)*

Hrs	Air Cooled Chiller Plant System					
	Daily Avg. Cooling Load (RT)	P_{CH} (kW)	P_{CHWP} (kW)	Chiller Plant Total Power (kW)	Chiller Plant (kW/RT)	Chiller configuration
9:00:00 AM	361	285	12	297	0.82	500RT X 1 nos
10:00:00 AM	349	275	11	286	0.82	500RT X 1 nos
11:00:00 AM	450	353	19	371	0.82	500RT X 1 nos
12:00:00 PM	447	351	18	369	0.82	500RT X 1 nos
1:00:00 PM	437	340	18	358	0.82	500RT X 1 nos
2:00:00 PM	459	360	19	379	0.83	500RT X 1 nos
3:00:00 PM	454	356	19	375	0.83	500RT X 1 nos
4:00:00 PM	413	322	16	337	0.82	500RT X 1 nos
5:00:00 PM	373	295	13	307	0.82	500RT X 1 nos
6:00:00 PM	309	253	9	262	0.85	500RT X 1 nos
Daily Consumption (9:00AM - 6.00PM)	4,054 RTh	3,188 kWh	154 kWh	3,341 kWh	kWH/RTh = 0.82	

Hrs	Air-Distribution System					Total System	
	CF Power (kW)	Air-Side VF Power (kW)	Total Air Distribution Power (kW)	Air Distribution Efficiency (kW/RT)	Air Distribution Configuration	Total Airside + Chilled-Water Systems Power (kW)	Total Air + Chilled-Water System Efficiency (kW/RT)
9:00:00 AM	0.00	88	88	0.24	VAV	385	1.07
10:00:00 AM	0.00	85	85	0.24	VAV	372	1.07
11:00:00 AM	0.00	100	100	0.22	VAV	472	1.05
12:00:00 PM	0.00	101	101	0.23	VAV	470	1.05
1:00:00 PM	0.00	99	99	0.23	VAV	457	1.04
2:00:00 PM	0.00	100	100	0.22	VAV	479	1.04
3:00:00 PM	0.00	99	99	0.22	VAV	474	1.04
4:00:00 PM	0.00	97	97	0.24	VAV	435	1.05
5:00:00 PM	0.00	91	91	0.24	VAV	399	1.07
6:00:00 PM	0.00	75	75	0.24	VAV	337	1.09
Daily Consumption (9AM - 6PM)	0 kWh	937 kWh	$\Sigma PL_{i,\ airside}$ = 937 kWh			4278 kWh	

Air-cooled Chiller Plant Efficiency (kW/RT)		0.82
Air-Distribution	Total Energy Consumption (kWh)	
Total	937,117	

TOTAL AIR DISTRIBUTION ENERGY CONSUMPTION (kWh)	**937**
TOTAL AIR DISTRIBUTION EFFICIENCY (kW/RT)	0.23

(b) Unitary/ Split Conditioners System

- Average Hourly Cooling Load (RT*weighted*); Hourly Weighted COP (COP*weighted*)
- Total airside power input: Assume maximum load conditions without diversity (unless simulated through modeling)

Hours	Unitary/ Split Conditioners System				
	Average Hourly Simulated Cooling Load (RT)	Hourly weighted COP	Total Condensing Units & Indoor Units Power Input	Unitary/ Split System Efficiency (kW/RT)	Unitary/ Split System Configuration
9:00AM	200	4.9	144	0.72	200RT x1
10AM to 6PM (hourly)	350	4.82	255	0.73	200RT x2
7PM to 10PM (hourly)	150	4.71	112	0.75	200RT x1
Daily Consumption (9:00AM - 6.00PM)	3950 RTH		2890 kWh	kWh/RTh = 0.73 kW/RT	

Hours	Air-Distribution System			Total System	
	Total Air Distribution Motor Input Power (kW)	Air Distribution System Efficiency (kW/RT)	Air Distribution Configuration (FCU, Others)	Total Power Input of AC System, (kW)	Total Efficiency (kW/RT)
9:00AM	32	0.16	FCU	176	0.88
10AM to 6PM (hourly)	60	0.17	FCU	315	0.90
7PM to 10PM (hourly)	24	0.16	FCU	136	0.91
Daily Consumption (9:00AM - 6.00PM)	664 kWh			3,554 kWh	

Unitary/ Split System Efficiency (kW/RT)		0.73
Air-Distribution	Total Energy Consumption (Wh)	
Total	663,500	

TOTAL AIR DISTRIBUTION ENERGY CONSUMPTION (kWh)	**663.5**
TOTAL AIR DISTRIBUTION EFFICIENCY (kW/RT)	0.17

(c) Water Cooled Chilled Water System

Using the Energy Performance Points Calculator, the following inputs are given to determine the DSE – kW/RT of the water cooled system:

- Average Cooling Load; Chiller Power input (P_{CH});
- Chilled & Condenser Water Pump Power (P_{CHWP} & 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 Fan flow, Part load fan power may be referenced from ASHRAE 90.1, Table G3.1.3.15 - Part-Load Performance for VAV Fan Systems or Part-Load Fan Power Equation)*

The data within the following 2 tables were extracted from the Calculator:

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
9:00:00 AM	1,444	760	46	95	43	943	0.65	700 RT x 3 nos.
10:00:00 AM	1,395	734	43	95	42	913	0.65	700 RT x 3 nos.
11:00:00 AM	1,801	941	71	95	54	1160	0.64	700 RT x 3 nos.
12:00:00 PM	1,790	935	70	95	54	1153	0.64	700 RT x 3 nos.
1:00:00 PM	1,749	907	67	95	52	1120	0.64	700 RT x 3 nos.
2:00:00 PM	1,836	959	74	95	55	1182	0.64	700 RT x 3 nos.
3:00:00 PM	1,816	949	72	95	54	1170	0.64	700 RT x 3 nos.
4:00:00 PM	1,654	857	60	95	50	1061	0.64	700 RT x 3 nos.
5:00:00 PM	1,493	786	49	95	45	974	0.65	700 RT x 3 nos.
6:00:00 PM	1,237	674	3	95	3	840	0.68	700 RT x 2 nos.
Daily Consumption (9:00AM - 6.00PM)	ΣCL_i =16,215 RTh	8,501 kWh	585 kWh	948 kWh	486 kWh	10,517 kWh	kWh/RTh = 0.65 kW/RT	

Hrs	Air-Distribution System					Total System	
	Air-Side CF (kW)	Air-Side VF (kW)	Total Air-side (kW)	Air Distribution (kW/RT)	Air Distribution Configuration	Total Air +Water (kW)	Total air +water (kW/RT)
9:00:00 AM	0	353	353	0.24	AHU-VAV	1,296	0.90
10:00:00 AM	0	341	341	0.24	AHU-VAV	1,254	0.90
11:00:00 AM	0	401	401	0.22	AHU-VAV	1,561	0.87
12:00:00 PM	0	406	406	0.23	AHU-VAV	1,559	0.87
1:00:00 PM	0	397	397	0.23	AHU-VAV	1,517	0.87
2:00:00 PM	0	400	400	0.22	AHU-VAV	1,582	0.86
3:00:00 PM	0	396	396	0.22	AHU-VAV	1,566	0.86
4:00:00 PM	0	389	389	0.24	AHU-VAV	1,450	0.88
5:00:00 PM	0	365	365	0.24	AHU-VAV	1,339	0.90
6:00:00 PM	0	302	302	0.24	AHU-VAV	1,142	0.92
Daily Consumption (9AM - 6PM)	0 kWh	3,748 kWh	3,748 kWh			14,226 kWh	

Water-cooled Chiller Plant efficiency (kW/RT)	0.65
Air-Distribution	Total Energy Consumption (Wh)
Total	3,748,470

TOTAL AIR DISTRIBUTION ENERGY CONSUMPTION (kWh)	**3,748**
TOTAL AIR DISTRIBUTION EFFICIENCY (kW/RT)	0.23

Summary

Based on the above information, the Calculator will generate the Total System Efficiency and point score.

System	Total RTh	Chiller Plant System/ Unitary System Efficiency (kW/RT)	Air Distribution System Efficiency (kW/RT)	Total Air Conditioning System Efficiency (kW/RT)
Water Cooled Chilled Water Plant	16215	0.65	0.23	0.88
Air Cooled Chilled Water Plant	4054	0.82	0.23	1.06
Unitary System	3950	0.73	0.17	0.90
TOTAL	24,218	0.69	0.22	0.91

Total Daily Cooling Consumption (RTH)	AC System Type	Reference Total System Efficiency (Including Air Distribution (kW/RT)
24218	Combination of System	0.98
% Improvement In AC Efficiency		6.89
POINTS SCORED FOR 2.1a		1.38

Example 2: A building is served by a DCS plant commissioned after Oct 2016 ⇒ DCS under Path A.
Use the Energy Performance Points Calculator to select the correct mode of DCS supply.

Is this project using chilled water supplied from a DCS (regardless gazetted or non-gazetted)? [Please choose from drop-down list.]	Yes, Path A	Please insert DCS efficiency information in Cell G8.Cell G7 is optional, if available for information. Ignore cells input for Chiller plant system from cell D40 to J63. Hourly RT inputs are still required for cell C31 to C54.

Obtain District Cooling system (DCS) plant efficiency (kW/RT) provided by DCS suppliers. In this example the DCS plant efficiency is 0.65kW/RT.

Please key in info for DCS below (To be obtained from the DCS provider)		
Average daily cooling load demand from DCS	17,538.24	RTh for one day
Average total power input from DCS (including secondary/distribution pumps, input only if available)	0	kWh/day
Average DCS plant efficiency (To obtain report from DCS Supplier)	0.65	kW/RT

Key in the air-side information for the Customer building (same as the steps for air-side computation for other types of air-conditioning systems). The total efficiency of the air distribution system combined with the DCS plant can thus be obtained, and the points derived.

If the plant were commissioned before Oct 2016, it would be under Path B. In this case, the airside efficiency is used for points scoring against a baseline of 0.28 kW/RT.

2.1b Lighting System Efficiency

Intent

The use of energy efficient lighting can reduce the energy needed to illuminate a space.

Scope

Applicable to building interior lighting and landscape lighting, including tenant lighting provision. Carpark and emergency lighting shall be excluded from the calculation.

Assessment

The Energy Performance Points Calculator shall be used to calculate the percentage improvement of the building's weighted lighting power budget against the code baseline in *SS 530: 2014 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment*. A maximum of 3 points can be scored as follows:

- Points scored = 0.1 x (% improvement from baseline)

The lighting should be designed to the recommended lux levels in *SS 531 – 1: 2006 (2013)– Code of Practice for Lighting of Workplaces*.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Completed Energy Performance Points Calculator • As per *P.5 Lighting Efficiency and Controls*	• As per *P.5 Lighting Efficiency and Controls*

Worked Example

Step 1: Using the Energy Performance Points Calculator, the following inputs for a particular building are given to determine the percentage improvement in the lighting performance from code:

- Area of the various spaces within the project
- Total power consumption based on the lighting layout design for each area and lighting fitting type used

Description	Areas (m^2)	Design Data		SS 530 : 2014 Requirements	
		Total Power Consumption (by area) (W)	Design Lighting Power Budget (W/m^2)	Reference Lighting Power Budget (W/m^2)	Reference Total Power Consumption (by area) (W)
Office, Work and Study					
Open Office 1	1,500	11,205	7.47	12.00	18,000.00
Meeting Rooms	100	728	7.92	12.00	1,200.00
Transport and Goods					
Corridors	500	3,048	6.10	7.00	3,500.00
Stairs, Escalators, Travellators	300	1,600	5.33	6.00	1,800.00
Lift Lobbies	500	3,548	7.10	7.00	3,500.00
Rest, Clean, Exercise and Play					
Toilets	150	1,500	10.00	10.00	1,500.00
Manufacturing & Maintenance					
Mechanical & Electrical Rooms	150	1,500	10.00	10.00	1,500.00
Other					
Open Office 2	1,500	11,205	7.47	12	18,000.00
TOTAL	4,700	34,334	7.32	10.43	49,000
Annual Consumption (kWh/yr)		98,195.24			140,140

% IMPROVEMENT OVER REFERENCE	*29.9%*
POINTS SCORED FOR 2.1(b)	*2.99*

Step 2: If the project is using any lighting control strategy then input the relevant details in the lighting control strategy table under lighting Power Budget Tab in the Energy Performance Calculator.

In this example, assume the perimeters of the open offices 1 and 2 are installed with automatic daylight responsive controls while the 5 meeting rooms' lights are installed with partial-on occupant sensing controls. Each occupancy sensor controls an area of 10m^2.

Control strategy and Area [Select from drop-down list]	No. Fittings	Total Power per Fitting (W)	Power Adjustment Factor	Savings (W)	Annual Savings kWh/yr
Automatic daylight responsive control	65	28	0.03	54.6	156.16
Partial-on occupant sensing control	26	28	0.15	109.2	312.31
			Total	163.80	468.47

Step 3: The additional savings achieved from lighting controls is not considered for points computation for 2.1b. However, it will be reflected in the building energy tab and can contribute to the points under 2.1e.

Energy Use	Notional Building Electricity (kWh/Yr)	Proposed Building Electricity (kWh/yr)	% Savings	% of Proposed Consumption
Air Conditioning System	-	-	-	*0.0%*
Lighting	*140,140.00*	*97,726.77*	*30.3%*	*100.0%*
Mechanical Ventilation	-	-	-	*0.0%*
Vertical Transportation	-	-	-	*0.0%*
Hot Water Generation	-	-	-	*0.0%*
Energy efficient Features	-	-	-	*0.0%*
Others [please specify]			-	*0.0%*
Service Equipment	-	-	-	*0.0%*
Common area cooling	-	-	-	*0.0%*
Common area cooling (Applicable only for Retail Int Corridors and Retail Atrium)	-	-	-	*0.0%*
BASE BUILDING	*140,140.00*	*97,726.77*		

2.1c Carpark System Efficiency

Intent

The use of energy efficient carpark ventilation and lighting systems can reduce the energy needed for carpark operations.

Scope

Applicable to buildings with carparks. For building projects with no and open carpark, full points can be scored here.

Assessment

The Energy Performance Points Calculator shall be used to generate the savings of the carpark lighting and ventilation systems against code. A maximum of 2 points can be scored as follows:

- Points scored = 0.05 x (% improvement from baseline)

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Completed Energy Performance Points Calculator. • Carpark drawings, schedules, layouts, data sheets and lux level simulations. • Mechanical ventilation schematics, data sheets, airflow simulations, control strategies and calculations.	• On-site lux level measurements As-Built / Purchase Summary

Worked Example

Step 1: Determine Ventilation System Energy

Based on the contractor/ supplier's specification, input the MV Fan Schedule into the Energy Performance Points Calculator. The Energy Performance Points Calculator will generate the Design and Reference case fan efficiency.

MV Fan Schedule

Location	Area Served	Label	Floor Area (m^2)	Space Height (m)	ACH	Air Flow Rate (CMH)	*Designed Flow Rate of the Selected Motor Fan (CMH)	External Static (Pa)	#Motor Nameplate Power (W)	#Motor Input Power (W)
e.g. B1	e.g. Carpark for office	MVB1-1	13,612	2.5	5	170,150	170,150		40,000	39,000

Continued for MVB1-1

Option 1 - Nameplate Power			Option 2 - Input Power			
Design Fan Efficiency (W/CMH)	Reference Fan Efficiency (W/CMH)	Reference Nameplate power (W)	Design Fan Efficiency (W/CMH)	Reference Fan Efficiency (W/CMH)	Reference Input power (W)	PD (Pa)
0.235	*0.350*	*59,552.500*	*0.229*	*0.300*	*51,045.000*	

Total Airflow Rate (CMH)	170,150.00
Total Reference Nameplate Power (kW)	59.55
Total Design Nameplate Power (kW)	40.00
Savings (kW)	19.55

Step 2: Determine the lighting system energy performance

Based on contractor/ supplier's specification kindly input the lighting schedule into the Energy Performance Points Calculator:

Description	Areas (m^2)	Design Data		SS 530 : 2014 Requirements	
		Total Power Consumption (by area) (W)	Design LPB (W/m^2)	Reference LPB (W/m^2)	Reference Total Power Consumption (by area) (W)
Carpark	13,612	25,000	1.84	3	40,836
Loading Docks	0	0	0.00	0	0
TOTAL		25,000			40,836
% IMPROVEMENT OVER REFERENCE		38.8%			

Step 3: Determine % improvement and points scored

Based on the information provided at Steps 1 and 2. The Energy Performance Points Calculator will be able to generate the total energy of the building's carpark systems and points score.

Energy Use	Notional Car Park Electricity (kWh/yr)	Proposed Car Park Electricity (kWh/yr)	% Savings
Lighting	116,791	71,500	38.8%
Mechanical Ventilation	170,320	114,400	32.8%
Air Conditioning	-	-	-
Receptacle Load	-		-
TOTAL	287,111	185,900	
PROPOSED IMPROVEMENT (kWh/yr)		101,211	
% IMPROVEMENT		35.3%	
POINTS SCORED FOR 2.1c		1.76 points	

2.1d Receptacle Load Efficiency

Intent

The use of energy efficient receptacle equipment can reduce their energy consumption.

Scope

Applicable to non-speculative buildings.

Assessment

Where the procurement of energy efficient receptacle plug loads and process equipment can be committed and quantified at the design stage, their aggregate savings against BCA's reference receptacle power budget can be generated using the Energy Performance Points Calculator. A maximum of 1 point can be scored as follows:

- Points scored = 0.025 x (% improvement from baseline) x (% of functional areas)

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Completed Energy Performance Points Calculator • Technical Specification & Commitment to procure/ evidence of procurement of energy efficient receptacle equipment • Provision of separate sub-metering/electrical circuit for receptacle load to facilitate measurement during operation. The sub-meters provided are to be linked with BMS. • The energy associated with each equipment shall be calculated and a W/m² value derived. Guideline figures are listed in the Energy Performance Points Calculator and can be used • Baselines: For refrigerators or other NEA tick-labelled systems the baseline shall be a 1 tick system. For process loads, they shall be compared to the industry norm and savings shall be justified through empirical evidence	• Onsite logged measurements or sub metered readings of receptacle load As-Built Purchase Summary

2.1e Building Energy

Intent

Encourage effective design of building systems to reduce building's overall energy consumption.

Scope

Applicable to all buildings.

Assessment

The Energy Performance Points Calculator* shall be used to generate the percentage improvement of the design energy consumption of the base building against the notional reference. The consumption should exclude carpark and receptacle loads. A maximum of 11 points can be scored as follows:

- $Points\ scored = \frac{\%\ improvement\ from\ baseline}{3}$

**Note: In addition to the Energy Performance Points Calculator, energy modeling (for buildings with air-conditioned areas ≥ 5000m²) or detailed calculations (for buildings with air-conditioned area < 5000m²) shall be performed to demonstrate that minimum energy savings for Gold^{PLUS} and Platinum ratings are met, as per 0. Pre-requisite Requirements.*

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Completed Energy Performance Points Calculator • Technical specifications and product information of all energy related systems	As-Built Purchase Summary

Further Improvement in Design Energy Consumption (Advanced Green Efforts)

Beyond the points cap, further points can be scored for improvement of the design energy consumption against the notional reference based on the above formula, up to a maximum of 2 points.

Option 2: Performance-Based Computation (22 points)

2.1f Space Conditioning Performance

Intent

Efficient use of energy to maintain a thermally acceptable indoor environment, by effective design of natural ventilation, energy efficient mechanical ventilation and air-conditioning systems.

Scope

Applicable to all air-conditioning and ventilation systems design to maintain thermal comfort, including the air distribution equipment and mechanical ventilation systems.

Assessment

Up to 10 points can be scored based on the systems to achieve the intended thermal comfort of the spaces, prorated by functional areas (excluding circulation, plant rooms and transit areas). Improvement is calculated based on system efficiency of conditioning systems used in the project, against the code baseline. Project can use single mode of ventilation for scoring if more than 90% of the functional space uses one mode of ventilation.

Up to 10 points based on proration of functional spaces

<table>
<tr><th>Mode of ventilation</th><th>Scoring methodology</th></tr>
<tr><td>Natural Ventilation</td><td>6 points for design for natural ventilation

Up to 4 points based on scoring in section 1.3c will be added on.</td></tr>
<tr><td>Mechanical Ventilation</td><td>Efficient mechanical ventilation design

Point scored = 0.15 x % improvement from baseline stated in SS553.
<table>
<tr><th rowspan="2">Systems</th><th colspan="2">Constant Volume & Variable Volume</th></tr>
<tr><td>Fan systems with nameplate motor power</td><td>≥ 4kW</td><td>< 4kW</td></tr>
<tr><td>Option 1: Fan system motor nameplate</td><td>0.35</td><td>No baseline</td></tr>
<tr><td>Option 2: Fan system input

*Applicable pressure drop adjustments can be considered based on SS553 in accordance to GM NRB: 2015 Technical Guide and Requirements, subjected to BCA’s evaluation</td><td>0.3</td><td>0.17</td></tr>
</table>
</td></tr>
<tr><td>Air-Conditioning</td><td>Up to 9 points for efficient air-conditioning system
<table>
<tr><th rowspan="4">Baseline</th><th colspan="2">Peak Building Cooling Load (RT)</th></tr>
<tr><td><500 RT</td><td>≥500RT</td></tr>
<tr><td colspan="2">Total Design System Efficiency (kW/RT)</td></tr>
<tr><td>1.08</td><td>0.98</td></tr>
</table>
Points scored = 0.4 x (% improvement from baseline)

*TDSE refers to combined efficiency of the cooling and air distribution components

*For district cooling plants under Path B scenario, where the plant is excluded from the computation, the baseline reference for the building air distribution equipment can be taken as 0.28 kW/ton for the purposes of points computation here.</td></tr>
</table>

Guidance Notes

The option will be computed based on performance of respective systems and would not require Energy Performance Points Calculator for computation

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• A plan to show the declared mode of ventilation for each space and compute the % for each mode of ventilation based on occupant areas. • For mechanically ventilated areas, project team shall submit catalogues and details of intended mechanical fan systems. • For A/C areas, documents required as per *P.4 Air Conditioning Total System and Component Efficiency*. All projects shall submit air distribution information. • For computation of fan power, 5% driver loss needs to be accounted for the use of VSD. Project team can use lower value if they can substantiate VSD loss with documentation	• A/C items as per *P.4 Air Conditioning Total System and Component Efficiency*. As-Built Purchase Summary

Worked Example

Please see example 2.1a. Peak load occurs at 2pm.

Hrs	Air-Cooled Chiller Plant System			Air-Distribution System		Total System	
	Daily Avg. Cooling Load (RT)	Chiller Plant Total Power (kW) [P_{CH} + P_{CHWP}]	Chiller Plant (kW/RT)	Total Air Distribution Power (kW)	Air Distribution Efficiency (kW/RT)	Total Airside + Chilled-Water Systems Power (kW)	Total Air + Chilled-Water System Efficiency (kW/RT)
2:00 PM	459	379 [360+19]	0.83	100	0.22	479	1.044

Hrs	Water-cooled Chiller Plant System			Air-Distribution System		Total System	
	Daily Avg. Cooling Load (RT)	Chiller Plant Total Power (kW) [P_{CH} + P_{CHWP} + P_{CWP} + P_{CT}]	Chiller Plant (kW/RT)	Total Air Distribution Power (kW)	Air Distribution Efficiency (kW/RT)	Total Airside + Chilled-Water Systems Power (kW)	Total Air + Chilled-Water System Efficiency (kW/RT)
2:00 PM	1,836	1182 [959 + 74 + 95 + 55]	0.64	400	0.22	1,582	0.862

Hours	Unitary/ Split Conditioners System				
	Average Hourly Simulated Cooling Load (RT)	Hourly weighted COP	Total Condensing Units and Indoor Units Power Input (kW)	Unitary/ Split System Efficiency (kW/RT)	Unitary/ Split System Configuration
2:00PM	350	4.82	255	0.728	200RT x2

Peak Cooling Load	AC System Type	Total Power (kW)	Combined Total System Efficiency (Including Air Distribution) kW/RT	Reference Total System Efficiency (Including Air Distribution) kW/RT	% Improvement In AC Efficiency	Points Scored For 2.1a
459	Air-Cooled Chiller Plant System	479	1.044	Breakdown		
1,836	Water-cooled Chiller Plant System	1,582	0.862			
350	Unitary/ Split Conditioners System	255	0.728			
2645	Combination of System	2316	0.875	0.98	10.7%	4.26

Efficient Space Conditioning Energy Design (Advanced Green Efforts)

- Up to 1 point for achieving highly efficient air-conditioning design
  - 1 point for achieving 0.65kW/ton TDSE
  - 0.5 point for achieving 0.70kW/ton TDSE

* For buildings tapping on district cooling plants under Path A scenario, it will include district cooling system efficiency as well as air and water distribution efficiency of the building.
* Not applicable to buildings tapping on district cooling plants under Path B scenario.

2.1g Lighting Performance

Intent

The use of energy efficient lighting can reduce the energy needed to illuminate a space.

Scope

Applicable to building interior lighting and landscape lighting, including tenant lighting provision and carpark lighting. Emergency lighting shall be excluded from the calculation.

Assessment

Up to 6 points can be scored for energy efficient lighting design (including carpark lighting) based on percentage improvement of the building's weighted lighting power budget against the code baseline in *SS 530 : 2014 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment*.

- Points scored = 0.17 x (% improvement from baseline)

The lighting should be designed to the recommended lux levels in *SS 531 – 1: 2006 (2013) – Code of Practice for Lighting of Workplaces*.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• As per *P.5 Lighting Efficiency and Controls*	

Worked Example

Please see example 2.2a (pls include carpark lighting if applicable).

% IMPROVEMENT OVER REFERENCE	*29.9%*
POINTS SCORED FOR 2.1(b)	*5.08*

Efficient Lighting Design (Advanced Green Efforts)

- Up to 1 point for achieving highly efficient lighting design
  - 1 point for 50% improvement
  - 0.5 point for 40% improvement

2.1h Building Systems Performance

Intent

Encourage effective design of building systems other than space conditioning systems and lighting systems to reduce building's overall energy consumption.

Scope

Applicable to all buildings.

Assessment

Up to 6 points can be scored for achieving lower building energy through lower receptacle load, more efficient carpark ventilation and energy efficient practices and features.

(i) Receptacle Load Efficiency

Where the procurement of energy efficient receptacle plug loads and process equipment can be committed and quantified at the design stage, their aggregate savings against BCA's reference receptacle power budget, as specified under can be computed against baseline receptacle load value. A maximum of 2 point can be scored as follows:

Receptacle loads	Nominal Values	Receptacle loads	Nominal Values
Computer Intensive Office	$22W/m^2$	Schools (Tertiary/IHLs)	$8W/m^2$
General office areas	$16W/m^2$	Schools (Primary/Secondary)	$5W/m^2$
Large conference areas	$11W/m^2$	Server/Computer rooms	$540W/m^2$

- Points scored = 0.05 x (% improvement from baseline) x (% of functional areas)

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• As per 2.1d with computation update with/without the use of Energy Performance Points Calculator	

Worked Example

A mixed office and retail development was designed to meet $13W/m^2$ for receptacle in office areas. 70% of the floor area belongs to the office. The proposed receptacle load has 18.75% improvement from baseline of $16W/m^2$ for office areas. Point scored = 0.05 x 18.75 x 70% = 0.66 points

(ii) Car Park Ventilation Energy

Up to 1.5 point can be scored by prorating mode of ventilation for carpark and achieving least energy consumption for carpark's ventilation systems against code.

Ventilation Mode	Mechanical Ventilation (Up to 1.25 points)		Natural Ventilation (1.5 points)
	Without CO sensor/without Fume Extract	With CO sensor / Fume Extract	
Points	Point scored = 0.015 x % improvement from baseline (Up to 1 point)	+ 0.25 points	1.5 points

Note: For building with no carpark, full point can be scored if building occupants is more than 10 pax.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Carpark drawings showing the parking layout and any loading bays • Mechanical ventilation schematics, data sheets, airflow simulations and calculations.	As-Built, Purchase Summary

Worked Example

• A carpark of 10,000m2 has 95% of areas in basement carparks and 5% of areas in open areas. • For mechanical ventilated basement carpark with CO sensor, please see example 2.1c Step 1	Total Airflow Rate (CMH)	170,150.00
	Total Reference Nameplate Power (kW)	59.55
	Total Design Nameplate Power (kW)	40.00
	Savings (kW)	19.55
	% Improvement	32.83%

Point scored = 5% of score for naturally ventilated carpark + 95% of score for mechanical ventilated carpark
= 0.05 x 1.5 + 0.95 x (0.015 x 32.83 + 0.25) = 0.78 points

(iii) Energy Use Intensity

0.5 point can be scored for meeting 25th percentile EUI as per prevailing BCA Building Energy Benchmarking Report (BEBR). Note that all projects will need to compute Energy Efficiency Index (EEI) and Energy Use Intensity (EUI) in kWh/m^2/yr as prerequisite requirement.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Computation of Total Building Energy's Consumption to compute EUI and compare with top 25th percentile EUI with prevailing BCA BEBR.	• Building's utilities bills and electrical meter readings for computation of EUI with BEBR's benchmark value adopted during design stage.

(iv) Energy Efficient Practices and Features

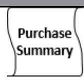
Up to 2 points can be scored for achieving lower energy consumption with more energy efficient practices and features.

Points scored = 0.5 x (% improvement from baseline total building consumption)

*Note: Hot water saving is computed based on Hot Water System Ratio (with or without heat recovery), which will consider heating energy, pumping energy and thermal losses of system.

Such items could include energy efficient hot water systems, heat recovery devices, solar thermal devices, sunpipes/ light shelves to replace artificial lightings with photosensors, motion sensors/ photosensors to control artificial lighting, regenerative/gearless drive lifts etc.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Technical specifications and product information of all energy related systems	

Worked Example

A hotel building uses the following energy efficient features have a combined energy saving of 7%

- Energy efficient heat pump system to generate hot water
- Heat recovering system
- Regenerative lift
- Motion sensors for staircases and toilets

Total Building Energy Consumption = 4.4 million kWh/yr

Computation for heat pump
Heat Source Output, Q_1 = 1,000,000kWh/yr
Hot water recirculating Thermal Energy Loss, Q_2 = 300,000kWh/yr
Effective Hot Water Thermal Energy Consumption, $Q_3 = Q_1 - Q_2$
= 700,000kWh/yr
System electrical input energy = 250,000kWh/yr

Hot Water System Ratio = $\frac{Effective\ Hot\ Water\ Thermal\ Energy\ Consumption}{System\ Electrical\ Input\ Energy - Energy\ Recovery} = \frac{700,000}{250,000-0}$
= 2.8

Baseline energy consumption = $\frac{Effective\ Hot\ Water\ Thermal\ Energy\ Consumption}{1.6} = \frac{700,000}{1.6}$
= 437,500kWh/yr

Energy saving due to hot water system = 437,500kWh/yr – 250,000kWh/yr = 187,500 kWh/yr

Suppose energy saving due to other items are as follows:
Heat recovering system = 50,000kWh/yr
Regenerative lift = 50,000kWh/yr
Motion sensors = 22,000kWh/yr

Total energy saving = 309,500kWh/yr

% energy saving = $\frac{309{,}500\ kWh/yr}{4{,}400{,}000 kWh/yr} = 7.03\%$

Point scored = 2 points (7% > 4% for max credit)

1 point for Additional Energy Efficient Practices and Features (Advanced Green Efforts)

Additional Energy Efficient Practices and Features (Advanced Green Efforts)

- Up to 2 points can be scored for further improvements.
  - 1 point for every 3% improvement above 4% improvement from baseline total building consumption

2.2 Renewable Energy (8 pts)

After considering energy efficiency and effectiveness, replacement of fossil energy use with renewables should also be looked into. This indicator focuses on driving the creation of opportunities for generation and utilisation of renewable energy. It aims to spur and acknowledge efforts by buildings to work towards the vision of zero energy or net positive energy low-rise buildings and low energy high-rise buildings.

Note: Renewable energy and solar energy are used synonymously here as the context of Singapore's tropical climate, coupled with limited natural resources, warrants solar energy as the most viable renewable energy option.

- 2.2a Solar Energy Feasibility Study (0.5 pt)
- 2.2b Solar Ready Roof (1.5 pt)
- 2.2c Adoption of Renewable Energy (6 pts)

2.2a Solar Energy Feasibility Study

Intent

The evaluation of a building footprint's potential in harnessing solar energy can raise awareness on viable solar opportunities in the development and assist building developers in their decision making to adopt photovoltaics.

Scope

Applicable to all building developments.

Assessment

0.5 point can be scored for a solar feasibility report detailing the following aspects:

- Roof characteristics and shading considerations
- Technical solar energy generation potential
- Economics of solar installation
- Roof access and safety requirements
- Roof spatial optimisation recommendations

Documentation Requirements

Design Stage
Submission of a solar feasibility report, as outlined below, acknowledged by (i) the QP/PE(Electrical) or PV specialist or Certified GM Specialists (Certified GMAP, GMAAP) and (ii) the Developer's Project Manager. • Executive Summary – A non-technical summary of the potential for solar adoption for the building, including the developer's decision on whether solar PV would be installed for the building, accompanied with appropriate justification. • Roof Characteristics and Shading Considerations – description of the roof characteristics (i.e. number of roofs, roof area, and height variation of various roofs) to be provided with drawings. Any potential shading from external sources (e.g. adjacent buildings, trees, etc.) as well as internal sources from within project (e.g. M&E services, lamp posts, etc.) are to be considered and quantified. Any considerations for shading due to external factors beyond the project site area are to be supplemented with site drawings (or future development plans) that depict the estimated height of shading source. • Technical Solar Energy Generation Potential – Based on the shading consideration and any site specific constraints, the following information is to be provided using the prescribed list of assumptions provided below. Any unique assumptions are to be clearly stated.   - Expected solar capacity (in kWp) potential of the roof and annual electricity generation (in kWh) based on solar capacity potential • Economics of Solar Installation – Using the electricity generation potential, the economics of the solar installations are to be quantified with the following considerations: - Upfront costs of installation   - Expected maintenance costs, annual electricity bills based on energy consumption calculation, costs saving for generation of electricity to be consumed on site, revenue from solar electricity sold to grid (if applicable) and Payback period/Discount rate • Guiding Assumptions   - Solar PV technologies (unshaded) with area efficiency of 0.1 kWp/m^2 and annual generation yield of 1,100 – 1,300 kWh/kWp can be assumed if project has not decided on the specific PV technology to be used   - Tariff at $0.20 per kWh for low tension rate and $0.15 per kWh for high tension rate can be assumed if project has not have information on potential electricity tariff (Further information may be found at http://www.solar-repository.sg/future-electricity-price-scenarios) • Roof Access and Safety requirements – Identify the access and safety measures that would have to be installed. • Roof Optimisation Recommendations – Recommendations for the spatial optimisation of the roof design to facilitate including M&E equipment locations to maximise the usable roof space.

2.2b Solar Ready Roof

Intent

Designing roofs to be ready for photovoltaic installation facilitates ease of their deployment should building developers decide to do so at later stages of a project/ during building operation.

Scope

Applicable to projects that scored under *2.2a Solar Energy Feasibility Study*. Where solar panels are installed under *2.2c Adoption of Renewable Energy*, the area coverage of the feasible roof area by the panels can be counted towards compliance under this indicator.

Assessment

The project shall demonstrate its roof design for solar readiness for at least 50% of feasible roof area determined through *2.2a*. 0.5 points each can be scored for the following:

- Structural readiness: Roof designed to accommodate optimised easy structural installation of solar panels on rooftop spaces, and included proof that the building and roof can support any additional static and wind load imposed by future PV systems
- Electrical readiness: Provisions to accommodate optimised easy electrical installation of solar panels on rooftop spaces
- Spatial readiness: Roof designed to optimise the available non-shaded rooftop area for solar panels - adoption of roof spatial optimisation recommendations outlined in *2.2a Solar Energy Feasibility Study*

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Detailed drawings showing the relevant design features for roof readiness. For example: To score for structural readiness, the structural QP shall certify that the building and roof can support any additional static and wind load imposed by future PV system	As-Built

Worked Examples

Structural readiness

The building and roof shall be able to support any additional static and wind load imposed by the PV system. Depending on the type of roof and components of the PV installation, the static load differs. For wind load, it depends on the installation angle. In terms of roof designed to accommodate easy structural installation of solar panels, examples (non-exhaustive) are as follows:

- Trellis: The use of trellis with 10-15° slope instead of horizontal top surface, to facilitate optimal module tilt angle
- RC roof: The provision for a solution that does not require heavy ballast to prevent modules from lifting off in strong wind. (e.g. provision of anchor points for solar support systems prior to waterproofing)

Electrical readiness

- Provision of room or sheltered space at roof level or max one level below, to accommodate inverters, circuit breakers and PV feed-in switch boards

Spatial readiness

- Shifting of shade-casting structures such as staircase doghouses, lift motor rooms, water tanks and M&E equipment away from the east-west sun path, where possible

2.2c Adoption of Renewable Energy

Intent

On-site generation of renewable energy can reduce the building development's power consumption from the grid and carbon emissions.

Scope

Applicable to building developments with on-site generation of renewable energy.

Assessment

The Energy Performance Points Calculator or manual calculation can be used to calculate savings from replacement of the building electricity consumption through the use of renewable energy.

Points can be scored up to a maximum of 6 points based on the following:

This will also include the use of solar hot water systems and renewable energy sources such as solar panels.

Expected Energy Use Intensity (EUI) [kWh/m²/yr]	% Replacement of Building Electricity Consumption by Renewable Energy
≥ 220	1 point for every 0.5%
50 ≤ EUI < 220	1 point for every 1.25%
< 50	1 point for every 2.5%

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Drawings & Technical -specification showing location and the salient features of the renewable energy system and the expected renewable energy generated • Calculation of the percentage replacement of electricity and the total annual electricity consumption of the development	• Testing and commissioning report • Logging of the energy production and calculated energy replacement rate As-Built, Purchase Summary

Worked Example 1

Based on contractor/ supplier's specifications, compute the % replacement:

Description (Example)	Area Of PV Array (m²)	kWp Installed (kWp)	Annual Yield (kWh)	Notes
Upper roof Block A	2,000	200	240,000	
Roof Block B	2,000	200	240,000	
Total		400	480,000	

Annual Replacement Rate	**10.02%**
Total Building Consumption (kWh)	4,788,030
EUI	158.63
Points Scored	8.02 (cap at 6 points)

Therefore, points scored under 2.2c (based on EUI > 50) = 6 points
Points scored under *Further Electricity Replacement by Renewables (Advanced Green Efforts)* = 2.02 points

Further Electricity Replacement by Renewables (Advanced Green Efforts)

Up to 5 more points can be scored for further percentage electricity replacement by renewable energy.

3. Resource Stewardship

With global use of resources increasing in the backdrop of the limited carrying capacity of the Earth, it is imperative that we work towards conserving the Earth's resources for future generations. "Resource Stewardship" in the built environment refers to the responsible use and protection of the environment through conservation and sustainable practices. This section rewards projects for the responsible use and conservation of resources from the stages of construction through to building operations and occupancy. Resources covered include water, construction materials, construction and operational waste.

P.7 + POINTSPREREQUISITES 30 POINTS

3.1 Water (8 pts)
3.2 Materials (18 pts)
3.3 Waste (4 pts)

Advanced Green Efforts (8 pts)

P.7 Water Efficient Fittings

Intent

The use of water efficient fittings can reduce the building's potable water consumption.

Scope

Applicable to all building developments with water fittings installed.

Assessment

The project shall demonstrate the use of water efficient fittings that meet minimum requirements as detailed in the following table:

Type of Water Fittings	Prescribed Minimum WELS rating	Applicable Areas
Basin Taps & Mixers	3 Ticks WELs rating	Public/ staff/ school toilets
	2 Ticks WELs rating	Other areas
Sink Taps & Mixers	2 Ticks WELs rating	All areas
Shower Taps, Mixers or Showerheads	2 Ticks WELs rating	Public/ staff/ school shower facilities
Dual Flush Flushing Cisterns	2 Ticks WELs rating	All areas

Exemptions can be granted on a case-by-case basis, where there are special functional needs. As for all other water fittings such as flush valves, bib taps that are not listed in the above table shall comply with the mandatory standards stipulated in the *Singapore Standard CP 48 : 2005 – Code of Practice for Water Services*.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender design specification showing all the water fitting provisions for the development: • Water fitting schedules showing the numbers, types and the WELS ratings of the proposed fittings in the prescribed tabulated format shown below along with the WELS certificate.	As-Built, Purchase Summary

Worked Example

Example of a hotel development where the pre-requisite has been met:

Water Fitting/ Product Type	Quantity			Applicable Areas	Delivery Order Ref No / Brand	Total No
	3 Ticks	2 Ticks	Mandatory WELS			
Basin taps & mixers	50			Public toilets	T1234/ Xbrand	480
	30			Staff toilets	T3456/ Ybrand	
		400		Hotel guestrooms, other areas	T2222/ Zbrand	
Sink taps		50		All areas	T4321/ Abrand	50
Shower taps & Mixers	20			Shower facilities at common areas (Public use)	T2343/ ZXbrand	420
			400	Hotel guestrooms	T6524/ ABbrand	
Showerheads		20		Public use	T7648/ YZbrand	420
			400	Hotel guestrooms	T2676/ XZbrand	
Dual flush Flushing Cisterns		420		All areas	T2454/ FVbrand	420
Total No. of fittings	100	890	800			1790

3.1 Water (8 pts)

With increasing occurrences of droughts and dry spells attributed to varying weather phenomenon and global warming, bouts of water shortage globally are an ever imminent threat. As Singapore has limited water catchment resources, it is crucial to implement good water management in order to ensure the long term sustainability of Singapore's water system. Considering water efficient, monitoring and potable water replacement strategies in the building design can reduce potable water consumption and raise awareness on responsible use of water during building operation.

- 3.1a Water Efficient Systems (3 pts)
- 3.1b Water Monitoring and Leak Detection (2 pts)
- 3.1c Alternative Water Sources (3 pts)

3.1a Water Efficient Systems

Intent

The design of water efficient mechanical systems and strategies can minimise potable water consumption in building operations.

Scope

Applicable to all buildings with landscape irrigation, cooling towers or water fittings.

Assessment

(i) Landscape Irrigation

0.5 point each can be scored for the following, maximum of 1 point:

- Every 25% of the landscape areas that are served by water efficient irrigation systems with features such as automatic sub-soil drip irrigation system with moisture or rain sensor control.
- Every 20% of the landscape areas that comprises drought tolerant plants.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Water efficient irrigation system: - Extracts of the tender and design specification showing the provision and details of the water efficient irrigation system. - Relevant layout plans showing the overall landscape areas and the areas that would be served using the system. Calculation showing the percentage of the landscape areas that would be served using the system. • Drought tolerant plants: - Relevant layout plans & calculation showing the overall landscaping and areas that use drought tolerant plants	• Water efficient irrigation system: As-Built  • Drought tolerant plants Purchase Summary

Worked Example

A project has 45% of the landscape areas served by automatic sub-soil drip irrigation system with rain sensor control. Thus, points scored = 0.5 point (Every 25% of landscape areas served by water efficient irrigation systems attains 0.5 point)

The other 55% of the landscape areas comprises drought tolerant plants. Thus, points scored = 1 point (Every 20% of the landscape areas with drought tolerant plants attains 0.5 point) = 1.5 points (capped at 1 point)

Total points scored under *3.1a(i)* = 0.5 +1 = 1.5 point

(ii) Water Consumption of Cooling Towers

1 point each can be scored for the following:

- Provision of cooling tower water treatment system along with effective filtration system that can help increase solubility of water and facilitate 7 or more cycles of concentration (CoC) at acceptable water quality.
- Provision of devices that recovers waste heat from the condensers and helps reduce the water requirement needed to remove heat through the cooling towers.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Cooling tower water treatment: - Technical specifications of the proposed cooling tower water treatment system, filtration system and the methodology that would enable 7 or more CoC without compromising on the water quality and operational performance. - Relevant drawings and details showing how the cooling towers have been designed, the location of the cooling towers and other supporting systems that are required to achieve the proposed CoC where relevant • Reduction of water requirement for cooling towers: - Technical and design specification of devices such as heat pumps • Calculation of the expected heat recovered and potential water savings.	• Cooling tower water treatment - Onsite testing reports - Maintenance regime • Reduction of water requirement for cooling towers - Commissioning report **As-Built**

Worked Example

Reduction of water requirement: A mixed development uses heat pump to recover waste heat from condenser loop and reduce water requirement needed for cooling tower operation. The heat pump has a heating capacity of 430.6 kW at the condenser water loop as the heat source. The manufacturer's technical data sheet is as follows:

DESIGN PERFORMANCE												
Capacity (kW)	Input Power (kW)	Performance (COP)	Heating (kW)	Cooling (kW)	Evaporator				Condenser			
					P.D. (kPa)	T in (°C)	T out (°C)	Flow (l/s)	P.D. (kPa)	T in (°C)	T out (°C)	Flow (l/s)
430.6	86.1	5.0	430.6	344.2	28.6	35.0	29.0	13.7	37.4	55.0	65.0	10.3

The water savings shall thus have to be calculated to score the point.

Based on the fundamental principle Q = m x h

Where

Q: Evaporation heat (kJ/kg)
H: Evaporation heat (kJ/kg) 2257 @atmospheric pressure
m: Mass of water (kg)
Water saving in Volume V = Mass/ Density

Assuming the estimated total heat load requirement of this particular development for one whole day to be 2,580 kWh, we can then derive it to be equivalent to about 6 hours of operation of the heat pump by dividing it over the heat capacity of 430.6 kW.Based on the technical data sheet, the heat pump has a cooling capacity of 344.2 kW which is the heat source that can be harvested from the condenser water loop. In other words, this will be the reduction in heat required to be removed through the cooling towers or the amount of heat that is diverted from cooling towers.

Total heat source harvested per day = 344 kW x 6 hours = 2,064 kWh = 7,430,400 kJ

Mass of water m = Q/h = 7,430,400 / 2,257 = 3,293 kg

Volume of water = Mass / Density = 3,292 kg / 995.7 kg/m^3 = 3.3 m^3 which is 3,300 L of water per day.

(Note: The heat source of heat pumps can typically be harvested from the chilled water loop or condenser water loop. Please also note that the density of water is different for different temperatures. For example, for chilled water loop, water temperature is approximately 10 – 15°C, thus the water density value between 998.2 – 999.7 kg/m^3 should be used in the computation. Similarly, for condenser water loop where water temperature is approximately 30-35°C, the water density value between 992.2 – 995.7 kg/m^3 should be used.)

From the calculation, the project can save 3,300 L/day of water if a heat pump is used to harvest the heat source from condenser water loop.

Better Water Efficient Fittings (Advanced Green Effort)

- Up to 1 point can be scored should the project demonstrate the use of better WELS rated water efficient fittings
  - 0.5 points for use of better WELS rated water efficient fittings for 100% of basin taps & mixer and dual flush flushing cisterns
  - 1 point for the use of better WELS rated water efficient fittings for 100% of applicable water fittings as prescribed in P.7 whilst ensuring user requirements are not compromised.

Documentation Requirements

- As per the documentation requirements of P.7 Water Efficient Fittings.

3.1b Water Monitoring

Intent

Better control and monitoring can facilitate setting of consumption reduction targets. Making the monitored information accessible to end users can facilitate user engagement programmes and promote behavioural changes with regard to water management and use.

Scope

Applicable to all buildings with potable water usage.

Assessment

2 points can be scored under this section.

(i) Water monitoring and leak detection

0.5 point each can be scored for the following:

- Provision of private meters for all major water uses in the development
- Provision of smart remote metering system with alert features for leak detection

Guidance Notes

Common major water uses for building type where private meters should be installed to monitor the amount of water used area are as listed:

Building Type	Major Water Uses	
Hotels	• Guestrooms • Cooling towers* • Food and beverage outlets • Production kitchen • Laundry	• Cold water supply inlet to hot water supply or boiler • Swimming pool • Spa & gym
Institutional Buildings (IHL, prison, military or defence installations)	• Cooling towers* • Toilets for each block • Washing areas	• Swimming pool • Food and beverage outlets / kitchens)
Hospitals	• Cooling towers* • Toilets, wards and operating theatres for each block	• Kitchen • Cold water supply inlet to hot water supply or boiler
Sports and Recreational Facilities and Tourist Attractions	• Cooling towers* • Exhibits or enclosures • Washing areas • Toilets	• Food and beverage outlets • Irrigation • Swimming pools
Office or Retail Buildings (or any other building types that are not specifically stated)	• Cooling towers* • Toilets • Pantries	• Food and beverage outlets • Production and processes

Note: For cooling towers, make-up water meters are to be provided to monitor water loss due to evaporation, drift and blow down during cooling tower operation.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Private meters: - Extracts of tender specification stating the provision of water metering for all major water uses as outlined in the *Guidance Notes* - Schematic drawings of cold water distribution system showing the location of the private water metering provided • Remote metering system: - Schematic drawings and extracts of tender specification stating the provision of remote metering system and how it connects to the building management system and highlights of the specific alert features to detect water leakages.	• Screenshots of the BMS system integration and the water leak detection alert settings. **As-Built**

(ii) Water Usage Portal and Dashboard

Up to 1 point can be scored. This requires the provision of water management portal, dashboard or other equivalent forms in the form of digital displays or web-based/ mobile application. 0.5 point each can be scored for the provision of following functions in the water usage portal and dashboard:

- Display metered data, trending of water consumption (historical data) and relevant parameters which facilitate better management of water consumption during building operation.
- Enable individual tenants/space to monitor their own water usages and consumption. Information will include monthly consumption of 50th percentile line of the tenants/space, based on operating hours, within the buildings. The information could also include 25th and 75th percentile line to facilitate understanding of consumption range.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Specifications of the water usage portal, dashboard or other equivalent forms and relevant parameters such as areas, occupancy areas or use type that are to be included for monitoring and setting of water consumption targets. • The data acquisition system, typically a building management system (BMS), must be able to store the measured data for at least 36 months, and to create reports showing minimally monthly, and annual water consumption associated with each meter with option to export data. • For the display of 50th percentile line based on operating hours, data can be displayed based on weekly or monthly information of individual tenant/space. As a good practice, the inclusion of 25th and 75th percentile line will help occupants to understand their consumption performance better. • Plans and schematics to illustrate: - Location and means of access of the portal • Single line diagram of the water sub-metering scheme and links to a BMS or equivalent system	

3.1c Alternative Water Sources

Intent

The use of alternative water sources can reduce potable water consumption for general application and use.

Scope

Applicable to all buildings with potable water usage.

Assessment

Where alternative water sources are used for general application, for example landscape irrigation, toilet flushing, cooling tower make-up water or washing of external areas/ carpark areas, up to a maximum of 3 points can be scored based on the types of water recycling systems used as well as the extent of reduction in potable water usage:

- AHU condensate collection where > 50% of total condensate is collected – 1 point
- NEWater supply – 1 point
- On-site recycled water – 1 point
- Rainwater harvesting – 1 point

Guidance Notes

Rainwater harvesting: The minimum rainwater harvesting capacity required is to be based on (i) the demands for rainwater use using relevant parameters such as no. of occupants, water usage frequency or irrigation needs or (ii) the collection area and precipitation using the following formula:

Volume = Roof Area x Precipitation x Efficiency

where

Volume (litres)	*Amount of rain that can potentially be harvested in that time period.*
Roof Area (m²)	*Collection area. For slope, curved, pitch roof or similar form, projected areas can be used.*
Precipitation (mm)	*Amount of rainfall in that time period. Average mean daily rainfall derived from the latest annual total rainfall and annual mean raindays published by Meteorological Services Singapore is to be used in computation.*
Efficiency (%)	*Percentage of water that could be captured, as opposed to splashing out of the system somewhere and it is assumed to be 90% for simplicity.*

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Schematic drawings and calculation of the following: - AHU condensate collection - NEWater supply - On-site recycled water such as greywater recycling - Rainwater harvesting (indicate volume of the tank, the catchment area and area of usages).	As-Built

3.2 Materials (18 pts)

Buildings are resource intensive in their construction and fit-out, and incur a significant carbon footprint. Adopting sustainable construction design and practices, considering embodied energy from a life cycle approach as well as giving priority to sustainable fit-out systems can reduce the environmental impact of the building.

- 3.2a Sustainable Construction (8 pts)
- 3.2b Embodied Carbon (2 pts)
- 3.2c Sustainable Products (8 pts)

Photo courtesy of City Developments Limited

3.2a Sustainable Construction

Intent

To encourage the adoption of building designs, building structures and construction practices that are environmentally friendly and sustainable.

Scope

Applicable to all structural and non-structural components constituting the building superstructure.

Assessment

(i) Conservation and Resource Recovery

For projects built on sites with existing building structures, 1 point can be scored where either:

- The existing structures are conserved and not demolished.
- The existing structures are demolished with an enhanced demolition protocol, where a recovery rate of > 35% crushed concrete waste from the demolished building is sent to approved recyclers with proper facilities.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Conservation permit and supporting documents if applicable • Pre-demolition assessment records of demolition site showing clear recovery/ recycling targets and estimated quantities of salvageable materials • Method statement detailing how sequential demolition is to be carried out • Waste management plans such as plan layout showing locations of recycling bins for collection and storage of different recyclable waste, records of waste movement from site to recycling facilities, proposed usage of the various types of recovered waste • Details of best practice pollution prevention policies and procedures at construction and demolition sites.	• Detailed records of the volume of waste sent to the relevant approved recyclers. As-Built

(ii) Resource Efficient Building Design

Up to 4 points can be scored here:

Concrete Usage Index (CUI): Points scored are as follows:

Project's CUI (m^3/m^2)	Points
≤ 0.60	0.5
≤ 0.50	1
≤ 0.45	1.5
≤ 0.40	2
≤ 0.35	2.5

Adoption of sustainable building systems: Points can also be scored based upon the extent of use of sustainable building systems as a percentage of the constructed floor area (CFA) as follows:

Sustainable Building Systems	Points awarded		
	0.5 points	1.0 point	1.5 points
Pre-stressed Concrete Elements	Total coverage area <50%* of CFA	Total coverage area ≥ 50% of CFA	Total coverage area ≥ 75% of CFA
Hollow Core or Voided Concrete Elements			
Light Weight Concrete Elements			
High Strength Concrete Elements (Concrete grade >60MPa)			
Structural Steel Elements			
Composite Structural Elements			
Engineered Timber Elements			
Prefabricated Prefinished Volumetric Construction units			
Precast Concrete Elements			
Leave-in Formwork			
Others (to be accepted by BCA on case-by-case basis)			

* No computation required with adoption of sustainable building systems <50% of CFA

Definitions

Concrete Usage Index (CUI): CUI is defined as the volume of concrete in cubic meters needed to cast a square meter of constructed floor area (CFA):

Concrete Usage Index = Concrete Volume in m^3 / CFA in m^2

CUI serves as an indicator of the amount of concrete used to construct the superstructure that includes both the structural and non-structural elements. CUI does not include the concrete used for external works and sub-structure works such as basements and foundations.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• 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 • 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 • Technical product information (including drawings and supporting documents) of the building systems • Calculations of the use of alternative construction methods supported by detailed design drawings.	**As-Built**

Worked Example

Concrete Usage Index

Proposed development comprises a 30 storey block with a basement carpark and the following details:

Project Gross Floor Area (GFA) = 60,000m^2. Superstructure elements are all precast.

The concrete usage index for foundation and basement carpark works are excluded in CUI tabulation.

Computation Of Concrete Usage Index (CUI)				
Project Reference No.: AXXXX-00001-20XX	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 no. of columns		313	
	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 is of precast concrete, post-tensioned concrete, high strength concrete (>Grade 60) or reinforced concrete (RC) under the 'Remarks' column.*

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)
Therefore, total concrete usage = 28,395.5 m^3	Therefore, total constructed floor areas = 59,998m^2

Important 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 derivation of the concrete volume breakdown must be traceable on the drawings. The concrete usages for foundation and basement works are to be excluded in CUI computation. For project with raft foundation that is also the floor slab of 1st level, half of the volume will be accountable in the CUI calculation.

Based on the point allocation shown in Table 1 of *3.2a(ii)*, CUI of 0.47 $m^3/m^2 \leq 0.50$ m^3/m^2.

Therefore, points scored = 1 point

Sustainable Building Systems

Adoption rate of recognised building systems for the example is as determined below:

Building element	Coverage based on area on plan
Post-tensioned Slabs	40,000 m^2
High Strength Concrete Columns	57 x 0.3 x 0.3 = 5.13 m^2
Composite steel Beams	1,000 m^2
Lightweight concrete Walls	1,000 m^2
Precast green walls	2000 m^2
Total Area	43,005 m^2

**Note: Assumes no overlaps in the area of coverage on plan. Alternatively, area of coverage can be directly taken off from the plan drawing instead of a tabular calculation as above.*

From the CUI tabulation, CFA = 59,998 m^2

% coverage by area = 71.7% < 75%

Therefore, points awarded = 1 point.

Therefore, points scored for this sub-section = 1.0 + 1.0 = 2.0 points

Use of BIM to calculate CUI (Advanced Green Effort)

1 point can be scored where BIM is used to compute CUI.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Calculations from BIM software 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 • BIM model, 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 • Calculations from BIM software showing the use of alternative construction methods supported by BIM drawings.	As-Built

(iii) Low Carbon Concrete

A maximum of 3 points can be scored here.

Clinker content –Points can be scored for the use of concrete containing clinker ≤ 400 kg/m^3 for grades up to C50/60 for ≥ 80% of the applicable superstructural concrete by volume as follows.

Concrete Categories*	Points
Uncertified concrete	0.5
SGBC-certified 1-Tick concrete	1.0
SGBC-certified 2-Ticks concrete	1.5
SGBC-certified 3 and 4-Ticks concrete	2.0

**Note: SGBC-certified concrete is deemed to have fulfilled the requirement of clinker content ≤ 400kg/m^3*

Replacement of coarse and fine aggregates – 0.5 point can be scored for every 5% replacement by mass of coarse and fine aggregates with recycled concrete aggregates (RCA) and/ or washed copper slag (WCS) from approved sources for the superstructure concrete mix. The usage should not fall below 1.5% x GFA for RCA and/ or 0.75% x GFA for WCS for points scoring.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extract of tender specification or proposed concrete mix design showing the maximum clinker content and/or Calculation showing the quantity of recycled/ engineered aggregates (e.g. RCA/WCS) to be used for the project. • SGBC certification of the concrete products/mixes used for the project.	• SGBC certification of the concrete products/mixes used for the project As-Built Purchase Summary

Worked Example

Proposed development comprises a 30-sty block with a basement carpark as per example for *3.2aii CUI*

Clinker content

Two types of Grade 40 Concrete were used for the project:

Type 1 concrete:	Type 2 concrete:
The total cementitious mix specified is 370 kg/m³ of cement by mass. 20% of the cementitious mix was replaced by GGBS. Based on Table 1 of *SS EN 197-1*, the cement used for the project is classified as CEM2. Clinker content of this concrete = 0.8 x 370 kg/m³ = 296 kg/m³ <400 kg/m³. Extent of use of concrete (by volume) = 40% The concrete was not certified by SGBC.	The concrete was certified by SGBC with 2-ticks rating (deemed to meet requirement of clinker content < 400kg/m³). Extent of use of concrete (by volume) = 60%

Total concrete coverage (Type 1 and Type 2 by volume) that had clinker content ≤ 400 kg/m³ for the super-structure = 100%. Therefore, points scored = 0.5 points. Extra points cannot be scored for certified concrete as not all concrete used is certified.

Replacement of coarse and fine aggregates

The project uses 10% replacement of coarse aggregate with RCA and 5% replacement of fine aggregate with WCS for all slabs, and 30% replacement of coarse aggregate with RCA for all non-load bearing walls in the superstructure.

RCA	WCS
Minimum usage requirement for RCA = 0.015 x GFA = 0.015 x 60,000 = 900 tons Total concrete volume of all slabs = 400 m³ + 320 m³ x 30 = 10,000m³ Total concrete volume of all non-load bearing walls = 22 m³ + 10 m³ + (22 m³ x 30) = 1,652m³ [Approximate coarse aggregate content in concrete = 1 ton/m³] Total tonnage of RCA used for super structure = [*(10% x 1 ton/m³) x 10,000m³] + [*(30% x 1 ton/m³) x 1,652m³] = 1,495.6 tonnes > 900 tonnes, therefore meeting minimum requirement. Total tonnage of coarse aggregate used for super structure = 1 ton/m³ x concrete volume (m³) = 1 ton/m³ x 28,095.05m³ = 28,095.05 tonnes % of total RCA used for replacing superstructure concrete coarse aggregate content = 1,495.6 tonnes/ 28095.05 tonnes x 100% = 5.3% Therefore, points scored = 0.5 points	Minimum usage requirement for WCS = 0.015 x GFA/2 = 0.015 x 60,000/2 = 450 tons Total concrete volume of all slabs = 400m³ + 320m³ x 30 = 10,000m³ Total tonnage of fine aggregate used for super structure = 0.7 ton/m³ x concrete volume (m³), 0.7 ton/m³ x 28,095.05m³ = 19,666.5 tonnes [Approximate fine aggregate content in concrete = 0.7 ton/m³] Total tonnage of WCS used for super structure = [*(5% x 0.7 ton/m³) x 10000m³] = 350 tonnes < 450 tonnes, therefore not meeting minimum requirement. Therefore, points scored = 0 points

Therefore, points scored for this sub-section 3.2aiii = 0.5 + 0.5 = 1 point

Therefore, point scored under for 3.2a including 3.2aii = 2 + 1 = 3 points

Use of Advanced Green Materials (Advanced Green Effort)

- 0.5 point can be scored for use of SGBC-certified 4-Ticks concrete, as per above.
- 0.5 point can be scored for use of SGBC-certified reinforcement bars for structural reinforced concrete elements, for more than 80% of the applicable superstructure elements by volume.

Documentation Requirements

Design Stage	**Operation Document** **(for handover to FM)**
• As per *3.2aiii Low Carbon Concrete* for SGBC-certified 4-Tick concrete • Extract of tender specification or proposed use of SGBC-certified reinforcement bars for structural reinforced concrete elements for more than 80% of the applicable superstructural elements by volume • SGBC certification of the reinforcement bars used for the project.	• As per *3.2aiii Low Carbon Concrete* for SGBC-certified 4-Tick concrete • SGBC certification of the reinforcement bars. As-Built Purchase Summary

3.2b Embodied Carbon

Intent

BCA's Carbon Calculator or Carbon Submission Form (go.gov.sg/cc) allows developments identify their carbon debt and quantify their environmental impact and embodied energy, as well as allow benchmarking of projects over time.

Assessment

A maximum of 2 points can be scored for the use of BCA Carbon Calculator or Carbon Submission Form to submit the embodied carbon footprint of the development:

- Declaration of Concrete, Glass and Steel – 1 point
- Declaration of additional materials –Up to 1 point (0.25 pt per material)

go.gov.sg/cc

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Embodied carbon footprint computation saved and exported in PDF format via BCA Carbon Calculator and submitted with the relevant supporting documentation and calculations. Preliminary/ proposed concrete mix designs are acceptable at the design stage, but need to be updated if there are any amendments made to the designs during the verification stage. • For declaration of emission factors via BCA's online embodied carbon calculator, project team must provide the sources of the emission factors with the relevant detailed calculations. • Detailed report of the carbon footprint of the development including (but not limited to) the quantum and types of materials used within the development, the emission factors with supporting documentation. Examples of other contributing elements that can be considered include emissions from activities during the construction phase and transportation.	As-Built

Worked Example

Examples of additional materials that can be declared: Aluminium, paint, timber flooring, ceramic tiles etc.

Provide Own Emission Factors with Source Justification (Advanced Green Efforts)

Up to 1 point can be scored for the provision of own material emission factors (0.25 pt per material).

Compute the Carbon Footprint of the Entire Development (Advanced Green Efforts)

2 points can be scored for computation of the carbon footprint of the entire development and a detailed carbon footprint report based on all the materials used within the development.

3.2c Sustainable Products

Intent

The environmental performance of materials covered here includes their recycled content and environmental impact during production and resource extraction. The intent is to encourage the specification of resource efficient and environmentally friendly products for use in the fit-out of a building, taking a functional system approach to focus on greening major fit-out materials whilst allowing for flexibility in design as well as recognising designs with optimal/ minimal material use.

Scope

Applicable to non-structural building components. Structural components are excluded.

Assessment

A maximum of 8 points can be scored for (i) and (ii).

(i) Functional Systems

Points can be awarded for the specification and use of green products certified by approved local certification bodies, namely the Singapore Green Building Council and the Singapore Environment Council, within the 6 main functional system categories of the building as follows:

Non-Speculative Buildings/ Speculative Buildings with Tenanted Areas Included

Functional System Category	External Wall	Internal Wall	Flooring	Doors	Ceiling	Roofing
Base Group (Coverage: ≥ 80% for external wall and roofing and Coverage: ≥ 60% of total applicable area for the rest)	1 pt	1 pt	1 pt	1 pt	0.5 pt	0.5 pt
Finishes Group (Coverage: ≥ 60%)	2 pt	2 pt	2 pt	0.5 pt	0.5 pt	0.5 pt

Speculative Buildings with Tenanted Areas Excluded

Functional System Category	External Wall	Internal Wall	Flooring	Doors	Ceiling	Roofing
Base Group (Coverage: ≥ 80%)	1 pt	0.5 pt	0.5 pt	0.5 pt	0.25 pt	0.5 pt
Finishes Group (Coverage: ≥ 80%)	2 pt	1 pt	1 pt	0.25 pt	0.25 pt	0.5 pt

All products (only if used) within a Group for the stipulated coverage must be green certified to score for that Group. Additionally, in order to score for a Finishes Group, projects must score for the respective Base Group first. Detailed examples may be found in the *GM NRB: 2015 Technical Guide and Requirements*.

Definitions

Speculative building: A building where the specific tenants are unknown during the period of its construction.
Non-speculative buildings: A building where the specific tenants are known during the period of its construction.
Functional systems: The term is used to describe the holistic use of products within the respective functional (operational) systems. The interior architectural fit-out of buildings is made out of 6 major building components for specific functional uses, e.g. the external wall, internal wall, flooring, doors, ceiling and roof. The functional systems described in the Green Mark criteria awards Green Mark points when products are used holistically in the respective functional use. The products included in the functional system are dependent on the choice of products and the installation methodology to provide the functional system for what the space is designed to be used for. Products are thus classified into need-based groups/ systems. As such, the criteria recognises the use of less resources - where a functional system could meet the operational requirement by using less products, this is still considered as meeting the functional system objective. For example, if there is no need to plaster or skim coat to the slab soffit nor need for ceiling boards to cover the overhead, this can be considered to have met the functional system requirement for ceiling for that sectional area of the application.

Guidance Notes

There are two options for scoring. The project should decide on either one which is most appropriate for its context. The first table *Non-Speculative Buildings/ Speculative Buildings with Tenanted Areas Included* includes tenanted areas in the point computation. It applies for non-speculative buildings where the fit-out products, including tenant spaces, are known and to be included for the assessment. Speculative buildings where the building owners have the power to influence and control the tenants fit-out, such as through green leasing measures, could also apply the table.

The second table *Speculative Buildings with Tenanted Areas Excluded* applies for speculative buildings where the decision on the type of products are to be used in tenant spaces is not known and wants to exclude the area from assessment.

For the first table, the coverage of certified products in the functional systems shall be at least 60% of the area where the functional system is applied. For the second table, the percentage shall be at least 80%. However, please note that the roof and external wall for speculative and non-speculative buildings are independent of the tenants fit-out, and thus the points accorded for the greening of these functional systems are the same. The qualifying area coverage at 80% is applicable for both scenarios for these 2 specific functional systems.
Products are grouped within respective Groups - Base or Finishes Group - to form a holistic system. The Base Group will be a pre-requisite for its respective Finishes Group; i.e. the Base Group for the respective system shall achieve the score before the Finishes Group qualifies for scoring. The area coverage is determined as a system stacked; i.e. the spread of area where the base group qualifies, the same area will be evaluated whether the finishes installed qualifies.

All products under each Group (where used during building operation) shall all be green certified to score for the respective grouping. Where a product is not required to be used (by design requirement for operation) in the specific grouping, the non-use may be deemed to have met the requirement. The tables below list broad examples of the applicable products in respective group and functional systems. The list is non-exhaustive:

Typical Products

Group	External Wall Functional System	Internal Wall Functional System	Flooring Functional System	Pts
Base Group	Curtain wall, integrated wall system, wall panels, blocks, metal cladding, waterproofing, sealant, adhesives, jointing, grouting, pointing, (fixing brackets may be excluded)	Lightweight wall panels, drywalls, blocks, waterproofing, jointing, wall grouting, boarding insulation (fixing frame may be excluded)	Levelling base, floor screed, waterproofing	1
Finishes Group	• All external face finishes including skim coats, external paints (including primers), external coatings, corner beads, corner protectors • All internal face finishes including skim coat, internal paint, corner beads, corner protectors, fabrics, wall papers, wall tiles etc	All finishes including plastering, skim coat, corner beads, corner protectors, fabrics, wall papers, wall tiles, tiles grouting vinyl, laminates, veneers, adhesives, paint etc.	• Raised floor systems (Insulation, underlay, carpets/ carpet tiles) • Floor finishes including underlays, coatings, grouting, pointing, skirting, adhesives, carpets, vinyl's, tiles, laminate flooring, timber flooring, marble flooring etc.	2
Notes: *Where a product is not required for use within the grouping, it may be considered to have met the requirement. Excludes structural walls, structural floor slab external architectural aesthetic features and openings. Areas are taken on both sides of the walls.*				

Group	Ceiling Functional System	Roofing Functional System	Pts
Base Group	Plastering, skim coat (*Note where the ceiling is an off form soffit finish, it is deemed to comply)*	• For RC flat roofs: Levelling base, screed, waterproofing, insulation • For Framed Roof: Waterproofing, insulation (excluding structural frame)	0.5
Finishes Group	Ceiling boards (excluding framing, fixing and bracing), insulation adhesives, paint finish, coatings	All finishes including metal sheets, roof tiles, tile grouts, tiles, paints and coatings, adhesives, pointing, skirting	0.5
Note: Where a product is not required for use within the grouping, it may be considered to have met the requirement. Excludes structural slabs ceiling slabs, Excludes structural roof slabs/ framing. The Roofing Functional System only includes products above/ interspersed between the structural slab/ frame of the roof.			

Group	Door Functional System	Pts
Base Group	Glass door, door leaf, door finishes including laminates, paint and veneers/ vinyl sheets, varnish, coatings	1
Finishes Group	Door accessories, i.e. door frame, door frame finishes, ironmongery	0.5
Notes: *Where a product is not required for use within the grouping, it may be considered to have met the requirement.* *The Finishes Group here refer to the door accessories and not the door finishes.*		

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender design specification showing: ➢ The building functional system(s) which the project targets to score points for, and descriptions of each ➢ The requirements to use certified environmentally friendly products for components making up the functional system(s), where they are used *(Note: If within the functional system a component is not used, e.g. where off-form concrete finish is the final finish base in the design specifications as the final finish for use in operation, there is hence no need for additional tiling (or other) finishes. In this example, there is hence no need for additional tiling to be installed to qualify the finishes group. The off-form finish is deemed to have completed the finishes group).* • Tabulation of the functional system(s) which the project targets to score points for in the table format prescribed by BCA under the worked example • Design drawings marking the extent of use for each compliant functional system and the calculation of the extent of use. • Design details of the systems used within each functional system; i.e. construction method/ method statement details • Product catalogues and certificates (if the product selection is confirmed) • For speculative building projects which choose to include tenant future installations in their computation, to show evidence and document that building owner can assure that the requirement will be met by tenants; such as, tendency agreements etc: ➢ Tenanted fit-out components within the building functional system(s) which the project targets to score points for, and descriptions of each • The requirements to use certified environmentally friendly products for components making up the functional system(s), where they are used.	• For projects which include tenant future installations in their computation, to show evidence that the requirement will and / or is to be met. Where tenants have completed their fit-out, to show documentation that the tenant fit-out materials included in the scoring are green certified. 

Worked Example

Example 1: This is the ceiling of a single storey non-speculative building, Building A, inclusive of tenanted areas

Area A: Ceiling soffit (i.e. underside of slab above) with certified plastering and paint (100 m^2)
Area B: Ceiling soffit with certified skim coat and paint (200 m^2)
Area C: Pre-finished off-form ceiling soffit (150 m^2)
Area D: Ceiling soffit with non-certified ceiling board (150 m^2)

Tabulating the areas for Ceiling Functional System, bearing in mind structural items are excluded:

Area	Applicable items under Base Group	Applicable items under Finishes Group
A (100m^2)	Certified plastering and certified paint	No additional product required
B (200m^2)	Certified skim coat and certified paint	No additional product required
C (150m^2)	No additional product required	No additional product required
D (150m^2)	No additional product required	Non-certified ceiling board
Total area that considered meet requirement	All areas meet requirement (100%)	Areas A, B and C meet the requirement. Coverage = $\frac{100+200+150}{100+200+150+150}$ = 75.0%
Points	As Base Group coverage is > 60%, 0.5 point can be scored.	As Base Group coverage is >60% including tenants, project is eligible to score for Finishes Group. As area coverage for certified finishes under Finishes Group > 60%, points scored for Finishes Group = 0.5 point.
	Total points for Ceiling Functional System = 1 point.	

Example 2: This is the internal walls of a single storey speculative building, Building B. Area D belongs to tenanted area.

Area A: Block panel walls with waterproofing, jointing, grouting, plastering, skim coat, corner beads, finishing paint on both sides. Everything is certified except for the corner beads (150 m^2)

Area B: Lightweight panels party wall with waterproofing, joining, grouting, tiled finish on one side and plastering and paint on the other side. Everything is certified except for the tiled finish (80 m^2)

Area C: Drywalls with boarding and insulation (excluding fixing frame). Finishing paint on one side. The other side is not painted. Everything is certified (50 m^2)

Area D: Tenant area. Unknown what partitions tenants may install and landlord does not want to impose green lease (Tenant partition walls area unknown)

Tabulating the areas for Internal Wall Functional System, bearing in mind structural items are excluded:

Area	Applicable items under Base Group	Applicable items under Finishes Group
A (150 m^2)	Block panel walls with waterproofing, jointing, grouting. All are certified.	Plastering, skim coat, corner beads, finishing paint on both sides. Everything is certified, except for the corner beads.
B (80 m^2)	Lightweight panels party wall with waterproofing, joining, grouting. All are certified.	Non-certified tiled finish on one side and certified paint on the other side. All plastering used is certified.
C (50 m^2)	Drywalls with boarding and insulation (excluding fixing frame). Everything is certified.	Certified finishing paint on one side. The other side is not required to be painted hence is deemed to comply.
D (Unknown)	Unknown	Unknown
Total area that considered meet requirement	Areas A, B and C meet requirement. Coverage excluding tenanted area = 100%	One face of Area B and both faces of Area C meet requirement. Coverage excluding tenanted area= $\frac{80+(50\times2)}{(150\times2)+(80\times2)+(50\times2)}$ = 32%
Points	Project chooses to score using the table on excluding tenanted areas. As Base Group coverage is ≥ 80%, points can be scored =0.5 pt	As Base Group coverage is ≥ 80% excluding tenants, project is eligible to score for Finishes Group. However, as area coverage for certified finishes under Finishes Group <60%, points scored for Finishes Group = 0 point
	Total points for Internal Wall Functional System = 0.5 point.	

Example 3: Building C is a speculative type retail building which plans to score points for Internal Wall, Flooring and Door functional systems. Tenanted areas will be under green lease; i.e. the building owner has influence and control on the type of fit-out materials to be used by tenants. The points are computed as follows:

Description	All Certified Products?	Coverage	% of Functional System	GM Pts Achieved
Internal Wall Functional System Coverage: All internal wall of development including balconies with finishes (5,000 m^2)				
Base Group				
1. Block and panel walls (Includes waterproofing, jointing, wall grouting)	Yes	*100 m^2*	*2%*	1 point (100% of area is green certified)
2. Lightweight panel party walls (Includes waterproofing, jointing, wall grouting)	Yes	*800 m^2*	*16%*	
3. Lightweight panels for wet areas (Includes waterproofing, jointing, wall grouting)	Yes	*250 m^2*	*8%*	
4. Lightweight panel walls for back of house and services, plant rooms (Includes waterproofing, jointing, grouting)	Yes	*150 m^2*		
5. Drywalls for all tenanted spaces (Includes boarding, insulation. Excludes fixing frame)	Yes	*3,700 m^2*	*74%*	
Finishes Group				
1. Block and panel walls: C cement plastering, corner beads, and corner protectors where applicable; excludes fixing brackets) and finished with paint on both sides	Yes	*100 m^2*	*2%*	2 points (97.5% of area is

2. On lightweight panels party walls: Combination of cement plastering & skim coat, corner beads, and corner protectors where applicable, excludes fixing brackets) and finished with paint on both sides	Yes	*800 m²*	*16%*	green certified)
3. Lightweight panels in tenants' wet areas: Non-certified tiled finish on one side of the lightweight panels in tenants' wet areas, and with certified plastering and painted finish on another side	Yes (partial)	*125 m² out of 250 m²* *(only half face of wall qualifies)*	*2.5%*	
4. Lightweight panel walls for back of house and services, plant rooms; Cement plastering with paint finish on one side and bare finish (no finishing) on the other side	Yes	*150 m²* *(bare finish or no finish; 2nd level may be consider as meeting requirement)*	*3%*	
5. Finishing paint on both sides of the drywalls for all tenanted spaces	Yes	*3,700 m²*	*74%*	

Description	All Certified Products?	Coverage	% of Functional System	GM Pts Achieved
Flooring Functional System Coverage: All floors of development including balconies with finishes (2,500 m²)				
Base Group				
1. Floor of circulation spaces and tenanted spaces: Floor screed	Yes	*1,900 m²*	*76%*	1 point (100%)
2. Floor screed and waterproofing in wet areas	Yes	*500 m²*	*20%*	
3. Floor of service area: Floor screed	Yes	*100 m²*	*4%*	
Finishes Group				
1. Floor of circulation spaces: Certified floor tiles and grouting	Yes	*700 m²*	*28%*	2 points (88%)
2. Floor of tenants' spaces: Combination of certified timber flooring and adhesives and final coating, non-certified marble flooring	Yes	*Certified: 900 m² out of 1200 m²*	*36%*	
3. Floor of wet areas: Certified floor tiles and grouting	Yes	*500 m²*	*20%*	
4. Floor of service area: No finish (i.e. cement screed finish)	Yes	*100 m²*	*4%*	

Description	All Certified Products?	Coverage	% of Functional System	GM Pts Achieved
Door Functional System Coverage: All doors of development (100 nos)				
Base Group				
1. Doors to service spaces: Non-certified timber hollow core and certified low VOC paint system (include basecoat and final coats)	No	*9*	*91 nos.*	1 point (91%)
2. Doors to units: Certified timber fire rated doors with certified veneer and finishing coats	Yes	*85*		
3. Other doors: Certified glass door with no finish required	Yes	*6*		
Finishes Group (Door Accessories)				
1. Doors to service spaces: Certified door frame with certified low VOC paint finish for the frame	Yes	*9* *(not eligible because 1st level base is not a certified products)*	*81 nos.*	0.5 points (81%)
a) Door to tenanted spaces: Certified door frame with certified veneer and finishing coats	Yes	*75*		
b) Doors to units: Certified door frame with non-certified veneer for frame	No	*5*		
2. Other doors: No frame required	NA	*6*		

(ii) Singular Sustainable Products outside of Functional Systems

Where sustainable hardscape, building services and M&E products, including Electrical Energy Storage System (ESS), certified by an approved local certification body are used, 0.25 point can be scored per product for ≥ 80% of the applicable use, maximum of 2 points.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts from the tender specification and drawings showing the requirements to incorporate the environmentally friendly singular products that are certified by the approved local certification body for at least 80% of the respective applicable use • Product catalogues and certificates (if the product selection is confirmed).	As-Built Purchase Summary

Worked Example

Project X has drainage cells and chillers with green certification.
Therefore, points scored for 3.2c (ii) = 0.25 x 2 = 0.5 point

Sustainable Products with Higher Environmental Credentials (Advanced Green Effort)

Up to 2 points can be scored for the use of products certified to higher tiers of environmental performance (per product).

Singapore Green Building Product Certification Rating	Points per product (≥ 80% of the applicable use)
Very Good (2-ticks)	0.25
Excellent (3-ticks)	0.5
Leader (4-ticks)	1.0

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts from the tender specification and drawings showing the requirements to incorporate the higher ticks SGBP products for ≥80% of the respective applicable use • Product catalogues and certificates (if the product selection is confirmed)	As-Built Purchase Summary

Worked Example

Project X has internal partitions that are SGBP 2 ticks. As the partitions in tenants' spaces are unknown, the project is unable to quantify that the Internal Wall Functional System (including tenants) achieves the percentage coverage requirement of 60% for speculative buildings.

All its drainage cells are SGBP 3 ticks, and all chillers are SGBP 4 ticks.

Therefore, points can be scored only for drainage cells and chillers, as coverage ≥ 80% of applicable use. Points cannot be scored for the higher ticks rated internal partitions as the project was unable to show that the total wall area coverage is ≥ 60% of applicable use (including walls in tenants' spaces). Points scored = 0.5 + 1.0 = 1.5 points.

3.3 Waste (4 pts)

It is estimated that 2.2 billion tonnes of waste will be generated globally in 2025 (*Source: World Bank)*. Singapore's output of solid waste has increased significantly over the years, from 1,260 tonnes per day in 1970, to a high of 8,402 tonnes per day in 2015 *(Source: NEA)*. Waste is an indicator of excess as it means we are using more than we need and depleting precious raw materials which could be by our future generations. To minimise waste generation it is crucial to use resources (other than building materials) consumed during the construction process efficiently, as well as provide adequate facilities and systems to manage waste during building operation.

- 3.3a Environmental Construction Management Plan (1 pt)
- 3.3b Operational Waste Management (3 pts)

3.3a Environmental Construction Management Plan

Intent

An effective and holistic management plan can facilitate better environmental performance of the construction process and promote waste minimisation.

Scope

Applicable to all buildings.

Assessment

1 point can be scored for effective implementation of an environmental construction management plan on construction sites through specific target setting, monitoring of energy and water use and construction waste minimisation measures.

Guidance Notes

The environmental construction management plan should contain the following:

- Energy Targets: Total energy consumption target set for the construction which includes the quantity of diesel, electricity from the grid (kWh)
  - The benchmark should be normalised to the building GFA to facilitate future benchmarking for projects
  - Detailed recommendations for on-site energy management strategies
- Water Targets: Total water consumption target set for the construction in m^3
  - The benchmark should be normalised to building GFA to facilitate future benchmarking for projects
  - Detailed recommendations for on-site water management strategies
- Waste Targets: Dominant waste streams and means of collection and recycling
  - The benchmark to reduce construction waste shall be established as waste (kg)/GFA (m^2) of building
  - The waste recycling rate shall be established as percentage of waste diverted from landfill or incineration plant
- Monitoring and Reporting Method: Monitoring and measurement procedures for the usage of resources, waste and recycled streams on site, and how the targets are tracked, monitored and reported to ensure effective implementation of the environmental construction management plan.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Submission of the environmental construction management plan that would be implemented on site which should include definitive energy, water and waste target set for the construction.	• Environmental construction management plan with written narrative of the overall environmental performance and resource usages during construction as well as measures taken to rectify any abnormality in the usage of resources where applicable • Detailed charts showing the actual energy, water and waste monitoring and trending data against the benchmarks set at design stage as well as detailed records of the waste volume that were sent to the relevant approved recyclers are to be included.

3.3b Operational Waste Management

Intent

Appropriate collection and recycling provisions can facilitate the segregation of recyclable consumer waste at source. Provisions for the treatment of horticultural or wood waste for buildings with landscaping can promote their reuse and recycling as well.

Scope

Applicable to all buildings.

Assessment

A maximum of 3 points can be scored for 3.3b Operational Waste Management.

1 point each can be scored for the provision of the following:

- Facilities for the collection and storage of different recyclables such as paper, glass, metal and plastic in commingled or sorted form.
- Facilities or systems for food waste to be treated and recycled, for buildings generating large volumes of food waste.
- Facilities or systems for the placement of horticultural or wood waste for recycling.

0.5 point each can be scored for the provision of the following:

- Provision of separate chute for recyclables, beyond code compliance*.
- Provision of Pneumatic Waste Conveyance System (PWCS), beyond code compliance*.
  *NEA's Code of Practice on Environmental Health (or prevailing code)

The recycling facilities or systems provided should be applicable to the building type and occupancy base and located at the convenience of use for building users.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Waste management plan detailing the separation of waste expected within the building based on its use. • Plan layout showing the location of the recycling facilities for collection and storage of the relevant recyclables • For buildings with large volumes of organic food waste, the provision of facilities or systems for the segregation of food waste for separate collection, or the provision of an onsite food waste recycling system. • Specifications of separate chute for recyclables, Pneumatic Waste Conveyance Systems (PWCS). The separate chute for recyclables does not include storage and sorting.	• Contractual arrangement with waste collection vendors for offsite recycling where applicable. As-Built

4. Smart and Healthy Building

Most of us spend a substantial proportion of our time within buildings, where we are psychologically, physiologically and emotionally affected by our surrounding environment. Aspects of a healthy indoor environment include better air quality, effective daylighting, quality artificial lighting, pleasant acoustics, inclusivity as well as biophilic design features that evokes the experience of nature. Designing for healthy buildings can be a sound economic investment that reaps healthy economic returns, with measures to improve the indoor environment leading to manifold monetary savings from improved health and well-being. A healing, positive environment nurtures healthier and happier occupants. In spaces where people work and study, this can result in increased work quality and productivity output. For social, recreational and commercial spaces, this can translate to an enhanced consumer/ visitor experience and encourage more frequent patronage and human traffic.

At the same time, managing a building's indoor environmental quality well necessitates operating the building smartly. Smart controls, direct access to building data and early fault detection allow the facility management team to gain a good understanding of the building's health. This enables necessary intervention and optimisation measures to suit the occupants' health and well-being.

P.8 - P.15 + POINTSPREREQUISITES 30 POINTS

4.1 Indoor Air Quality (10 pts)

4.2 Spatial Quality (10 pts)

4.3 Smart Operations (10 pts)

Advanced Green Efforts (10 pts)

P.8 Thermal Comfort

Intent

The air-conditioning system should be designed to serve its intended purpose of providing a thermally comfortable space for occupants.

Scope

Generally applicable to all air conditioning systems serving occupied spaces of building developments.

Assessment

The normal design dry-bulb temperature for comfort air-conditioning shall be within 23ºC - 25ºC, and resultant relative humidity ≤ 65% in accordance with *SS 553 : 2016 - Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.*

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of tender specifications showing the requirement to design the system to meet the requirement of thermal comfort stipulated in *SS553 : 2016*	• On-site measurements verifying indoor air temperature and the relative humidity with measurement locations highlighted on a plan

P.9 Minimum Ventilation Rate

Intent

The provision of adequate ventilation in a building is of fundamental importance to ensure the health of the occupants. Insufficient ventilation can cause a build-up in the concentration of carbon dioxide and other contaminants emitted indoors.

Scope

Applicable to air-conditioning or mechanical ventilation systems in regularly occupied spaces of all building developments.

Assessment

The building's air-conditioning and mechanical ventilation systems shall be designed to provide appropriate minimum quantum of outdoor air rates as stated in Table 1 and Table 5 of *SS 553 : 2016*.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Minimum outdoor air interpretation and computation by zones according to *SS 553: 2016* Table 1 or Table 5 • The maximum exhaust airflow interpretation and computation by zones • Extracts of tender specification and drawings showing the requirement to design the system to meet the requirement of Table 1 or Table 5 in *SS 553 : 2016*	**As-Built**

Worked Example

Project calculates the required minimum outdoor air for every zones according to *SS 553: 2016* and tabulated as follows:

AHU schedule

AHU	Area type	Area served (m^2)	SS553 table 1 ($l/s/m^2$)	Required OA amount (l/s)	Designed OA amount (l/s)	PAHU
AHU 1-1	Lobby	300	0.3	90	120	PAHU 1
AHU 1-2	Office	500	0.6	300	350	PAHU 2
AHU 2-1	Office	400	0.6	240	300	PAHU 1
AHU 2-2	Office	400	0.6	240	300	PAHU 2
AHU 3-1	Office	400	0.6	240	300	PAHU 1
AHU 3-2	Office	400	0.6	240	300	PAHU 2
AHU 4-1	Office	400	0.6	240	300	PAHU 1
AHU 4-2	Office	400	0.6	240	300	PAHU 2

PAHU schedule

PAHU	Required OA amount (l/s)	Designed OA amount (l/s)
PAHU 1	1020	1100
PAHU 2	1250	1300

The project meets the pre-requisite requirements by providing appropriate minimum quantum of outdoor air rates as stated in Table 1 and Table 5 of *SS 553 : 2016.*

P.10 Filtration Media for Times of Pollution

Intent

The effective removal of harmful pollutants in outdoor air from the building ventilation system through high efficiency filters can enhance indoor air quality and the health and well-being of the occupants.

Scope

Applicable to air handling units (AHUs) or systems for dedicated treatment of outdoor air in air- conditioned building developments.

Assessment

AHUs or dedicated outdoor air units in the building shall be designed to accommodate fine dust filters of least a rating of Minimum Efficiency Reporting Value (MERV) 14 (ASHRAE 52.2: 2012) or F8 (EN779: 2012), when the outdoor pollution level is in the unhealthy range in accordance with MOH's guidelines, as stipulated in *SS 553 : 2016.*

Documentation Requirements

Design Stage	**Operation Document (for handover to FM)**
• Relevant design drawings and specifications depicting outdoor air filtration strategy and the design provision that MERV 14 filters can be installed during events of poor air quality. This would include fan sizing for the increased potential pressure drop, and the space for the filtration media to be placed	**As-Built**

P.11 Low Volatile Organic Compound (VOC) Paints

Intent

Limiting the use of high-emitting building and furnishing materials can improve the indoor environmental quality for the health and well-being of occupants.

Scope

Applicable to all indoor paints including primers, sealers, base coats and top coats.

Assessment

Low VOC paints certified by an approved local certification body shall be used for at least 90% of the total painted internal wall areas.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of tender specification & technical product showing the requirement to use low VOC paints that are certified by an approved local certification body • Certification details from approved local certification body	

P.12 Refrigerants

Intent

Controlling the use and release of ozone depleting substances and greenhouse gases can reduce their potential damage to the ozone layer and curb global warming.

Scope

Applicable to all air conditioning systems within building developments.

Assessment

Air conditioning systems shall use refrigerants with ozone depleting potential (ODP) of 0 or global warming potential (GWP) of less than 100.

A refrigerant leak detection system shall also be installed in critical areas of plant rooms containing chillers and/ or other equipment using refrigerants.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts from the tender specification stating the list of refrigerants that are permitted in the project based on their GWP and or ODP • Extracts from the specification indicating the leak detection system to be installed	• List of the refrigerants used in the air conditioning system(s) and the applicable cooling systems

P.13 Sound Level

Intent

Minimising noise and vibration from mechanical and electrical equipment can ensure a basic level of acoustic comfort for occupant health and wellbeing.

Scope

Applicable to mechanical and electrical equipment serving occupied spaces of building developments.

Assessment

The relevant equipment as aforementioned shall be designed to comply with the recommended ambient sound levels in Table 4 of *SS 553 : 2016*.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Calculations, measurements, equipment catalogues and/ or tender specifications to demonstrate that the equipment design will comply with the recommended ambient sound levels in the code	• Onsite measurement information of sound levels, complete with a method statement and plan drawings showing the relevant testing locations

P.14 Permanent Instrumentation for the Measurement and Verification of Chilled Water Air-Conditioning Systems

Intent

Better energy management and monitoring of chilled water air-conditioning systems can ensure their operational efficiency can be optimised and maintained throughout the equipment lifespan.

Scope

Applicable to chilled-water air-conditioning systems serving the building with aggregate cooling capacity exceeding 30 kW. This applies also to district cooling systems (DCS) operated by suppliers of district cooling services registered under the Energy Conservation Act.

Assessment

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. Each measurement system shall include the sensor(s), any signal conditioning, the data acquisition system and wiring connecting these components. The permanent instrumentation shall comply with the following:

- Location and installation of the measuring devices to meet the manufacturer's recommendation; location of temperature sensors should be within reach to facilitate site verification
- All data logging with capability to trend at 1-min sampling time interval, and recorded to the 3rd decimal digit
- Computation and display of air-side efficiency, water-side efficiency and total system efficiency.
- 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 where applicable: chillers, chilled water pumps, condenser water pumps, cooling towers, air distribution sub-system (i.e. AHUs, PAHUs, FCUs)
- A heat balance substantiating test for the water-cooled chilled-water system is to be computed in accordance to 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 generate automatically from BMS/BAS.

Documentation Requirements

Design Stage	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 errors contributed by flow meters, an additional 1% is to be included in the computation. 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 be computed in pump head calculation. For new installation, projects should design to use accurate flow meter with lesser pressure drop. • Projects are encouraged to use metering current transformers of Class 0.5 or better to achieve better accuracy. • Commitment to comply with the requirements.
Operation Document (for handover to FM)	The performance verification may include on-site testing by BCA officers. A heat balance-substantiating test for water cooled chilled-water plant to be computed in accordance with *BCA Code on Periodic Energy Audit of Building Cooling System* shall be submitted with the following information: • Energy Audit report (GM NRB: 2015). • Extracts of the instrumentation specifications and brochures. • Instrumentation calibration certificates. • As-built schematic drawings showing the location of each power meters, flow meters and temperature sensors. • BMS screenshots showing the relevant calibration inputs have been entered for the temperature measurement. • Site requirement: To determine the chilled-water plant efficiency, airside efficiency and total system efficiency using the following operation data/ installations to demonstrate compliance with the design specifications: - From Building Management System ➢ Chilled-water plant kW/RT, Air distribution system kW/RT, Total system kW/RT ➢ CHWS, CHWR, CWS & CWR temperatures of the header to be checked for consistency against the temperatures of individual chillers and/or individual branches ➢ CHW & CW - 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): ➢ CHWS, CHWR, CWS & CWR temperatures to be checked for consistency against the BMS data ➢ Approach of CHWS/CWS with refrigerant evaporating/condensing temperature ➢ Location of the chilled-water flow meter(s) installed to comply with manufacturer's recommendations **As-Built** **Purchase Summary**

P.15 Electrical Sub-Metering & Monitoring

Intent

Monitoring major energy uses in the building can enable audit and continuous improvement to optimise use and avoid energy wastage.

Scope

Applicable to all building developments with GFA of 5,000m^2 or more.

Assessment

Subsystem measurement devices with remote capability shall be provided, linked to a monitoring system and measure and trend energy consumption data of:

- Each of the following energy sub systems:

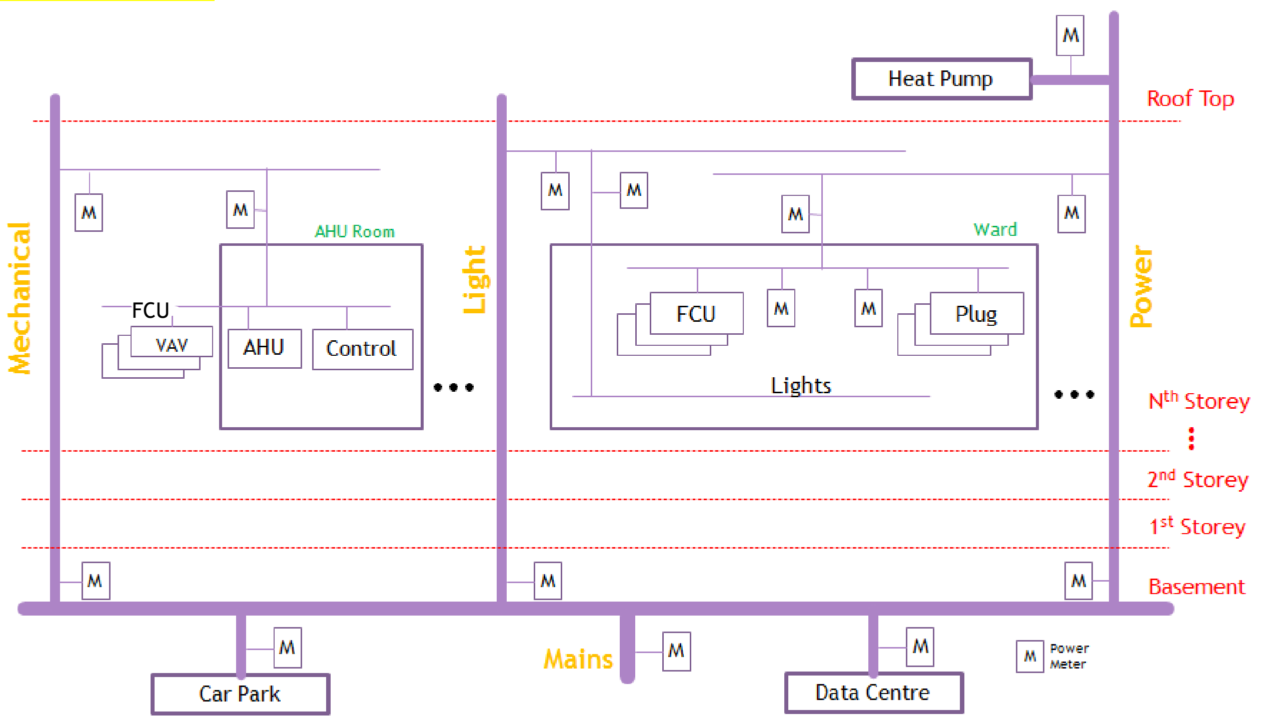
Use (Sum of all loads)	Sub-systems thresholds
Lift & escalator	Sum of all feeders > 50 kVA
Heater, including heat pump	> 50 kWth
Process loads	Connected loads > 50 kVA Connected gas or district services load > 75 kW
Mechanical ventilation	The subsystem's load > 15kW
VRF systems (CUs, FCUs)	No threshold

- Each tenancy or floor, as well as high energy load areas exceeding 50kVA such as car park, data centres, IT closets and process areas.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Sub-system equipment specifications • Power meter and current transducer specifications • The remote capability and link to a BMS/EMS system • Single line diagram showing the location of the power meters • Design of the main switchboards (MSBs) and power distribution boxes (DBs)	• BMS or supervisory control and data acquisition (SCADA) display of meter readings and trends • Commissioning report of the sub-metering system As-Built Purchase Summary

Worked Example



In the above metering scheme of a hospital, the energy consumption can be partitioned 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

There is also a private main meter to record the whole building energy consumption.

4.1 Indoor Air Quality (10 pts)

Contemporary research has shown that poor air quality is an attributing factor to sick building syndrome symptoms and respiratory illnesses, which can have detrimental effects on business productivity and performance as well as the wellbeing of the occupants. As people spend longer hours in buildings, research has also indicated that the cost of poor indoor environmental quality could well be even higher than most other costs. It is important to ensure good air quality to reduce the risk of illnesses within building occupied spaces where occupants are expected to work or remain in for an extended period of time.

- 4.1a Occupant Comfort (2 pts)
- 4.1b Outdoor Air (3 pts)
- 4.1c Indoor Contaminants (5 pts)

4.1a Occupant Comfort

Intent

The testing and evaluation of indoor air quality parameters is crucial to ensure occupant comfort. Engaging building occupants completes the feedback loop, and is essential for the management and improvement of operational practices in high-performing green buildings.

Scope

Applicable for normally occupied spaces air-conditioned for comfort purposes.

Assessment

(i) Indoor Air Quality (IAQ) Surveillance Audit

0.5 point can be scored for an IAQ surveillance audit conducted by an accredited laboratory under Singapore Accreditation Council with respect to the recommended IAQ parameters and acceptable limits stated in Table 1 of SS554: 2016 Code of Practice for Indoor Air Quality for Air-Conditioned Buildings, and committed to be conducted for the building within one year after occupancy or after reasonable occupancy has been reached.

1 point can be scored if the above IAQ surveillance audit is conducted based on the reference methods stated in Table 1 of SS554: 2016.

The spreadsheet of the standardised IAQ report template is available at:

- https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/IAQ-report-template.xlsx

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender specifications showing the requirements to conduct an IAQ surveillance audit within one year after occupancy by an accredited laboratory, with respect to the recommended IAQ parameters and acceptable limits stated in Table 1 of SS554: 2016.	• IAQ surveillance audit report by an accredited laboratory. For functional spaces outside of the above mentioned standards'/ guidelines' remit, the performance standards for the respective IAQ parameters shall be determined based on prevailing industry best practice standards

(ii) Post Occupancy Evaluation

0.5 point can be scored if a Post Occupancy Evaluation (POE) questionnaire is committed to be conducted within a year after building occupancy or after reasonable occupancy has been reached to assess occupant wellbeing and interactions with their indoor environment. Appropriate corrective actions should also be committed to be taken to improve the quality of the indoor environmental conditions if required.

The spreadsheets of the standardised POE survey questionnaire and results are available at:

- https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/poe_survey_template.xlsx
- https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/poe_results_template.xlsx

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender specifications showing the requirements to conduct a POE within one year after occupancy and to undertake corrective actions if required. Commitment to sample at least 10% of building occupants or at least 100 occupants should be made	• Demonstration that the response rate of the POE meets the sample size • Evaluation of the POE results and the list of the corrective actions based on the respondents' comments

(iii) Indoor Air Quality Display

0.5 point can be scored for the provision of display panels for temperature and relative humidity information at each floor/ tenancy, to raise awareness among building occupants on the internal conditions of the space.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender specifications showing the requirements to display temperature, and relative humidity at each floor and each tenanted area • Plan layouts showing the locations of the fixed display panels for each floor and each tenanted area	As-Built

Indoor Air Quality Trending (Advanced Green Effort)

Up to 2 points can be scored for the provision of monitoring and trend logging for the following:

- Provision for monitoring and trend logging of temperature and relative humidity through a centralised system – 0.5 point
- Provision for monitoring and trend logging of common indoor air pollutants, such as formaldehyde, at each floor – 1.5 point

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender specifications showing the requirements to monitor and trend-log temperature and relative humidity through a centralised system • Plan layouts showing the locations of the sensors that are monitored and trend-logged	• Technical specifications of the sensors • Two-week trend-logging data from the centralised monitoring system As-Built

4.1b Outdoor Air

Intent

Provision of adequate and proper ventilation in conditioned spaces to prevent build-up in the concentration of contaminants.

Scope

Applicable to all building developments with air conditioning systems supplying outdoor air to occupied spaces. Full points can be scored here for buildings with no air-conditioned spaces.

Assessment

(i) Ventilation Rates

A maximum of 1.5 points can be scored for the:

- Measurement and monitoring of outdoor airflow volume in accordance with desired ventilation rates at precool units (e.g. PAHUs and PFCUs) or all AHUs and FCUs - 0.5 point or 1 point respectively
- Use of demand control ventilation strategies such as carbon dioxide sensors or equivalent devices to regulate the quantity of fresh air and ventilation in accordance with the space requirements – 0.5 point

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Measurement and monitoring of outdoor airflow volume ➢ Detailed schematics, specifications and method statement for the provision of direct outdoor airflow measurement devices with capabilities to measure the outdoor air intake volume with an accuracy of ±10% of the minimum outdoor airflow ➢ Demonstrate location of sensors in accordance with the manufacturer's guidelines and linkage to BMS for monitoring the outdoor air volume (A standalone data logging system can be used if no BMS is available) ➢ Method statement for programming alerts, when the outdoor air volume drops below the minimum set points and varies by more than 15% above the airflow set point ➢ Plan layout indicating the provision of access panel for regular maintenance of airflow sensors • Use of demand control ventilation strategies ➢ Plan layouts and schematics showing the locations and the types of control devices utilised. ➢ Method statement on how the devices regulate the outdoor air volume to maintain indoor air quality. • When CO_2 sensors are used, demonstrate alerts have been programmed into the BMS where the CO_2 levels exceed the set point with reference to recommendations by *SS554 : 2016*.	• BMS or standalone system logged data (minimum of a 2 week period) of the outdoor air volume and airflow As-Built Purchase Summary

(ii) Enhanced Filtration Media

0.5 point or 1 point can be scored for the permanent provision of Minimum Efficiency Rating Value (MERV 14, ASHRAE 52.2 or F8/ EN779 class of filter or equivalent) to all PAHUs or to all PAHUs and AHUs respectively.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of tender specification and technical specification of - MERV 14 (ASHRAE 52.2) or F8 (EN779/EN1822) class or equivalent filters used for each air distribution system	• Technical specifications and filtration classification testing report of the filters used on site As-Built Purchase Summary

(iii) Dedicated Outdoor Air System

0.5 point can be scored for the provision of a dedicated outdoor air system, such as precool units, to encourage effective treatment of outdoor air for cooling and dehumidification.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Design intent and details of the air-conditioning and air distribution system • Schematics of the air distribution system that are connected to the dedicated outdoor air system (Precool AHU/FCU system)	As-Built

4.1c Indoor Contaminants

Intent

Indoor contaminant pollution control at source and air treatment strategies can safeguard the health of building occupants.

Scope

Applicable to buildings with relevant ventilations systems.

Assessment

(i) Local Exhaust and Air Purging System

1 point each can scored for the provision of:

- Local isolation and exhaust systems to remove the source of pollutants
- Air purging system to replace contaminated indoor air with outdoor fresh air

100% non – air-conditioned building projects will score full points under this indicator.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Local exhaust: ➢ Plans, schematics, mechanical drawing and tender specifications showing the requirements to provide local exhaust riser for local isolation and exhaust systems to remove the pollutants at source, i.e. from printing or photocopying equipment, to prevent the contamination of the functional areas. The ductwork shall be such that the exhausted air must not be recycled to other spaces. For speculative projects, the exhaust system fans must be installed as a part of the base building ➢ A written description on the attributes of the isolation strategies and exhaust system and how tenants shall connect to the exhaust risers for indoor pollutant removal • Air purging: Written descriptions and schematics on the air purging strategy including any requirements for dedicated fresh air intakes and indoor pollutant exhausts	• Air purging method statement, BMS schedules and screen shots of air purging programme for the project As-Built

(ii) Ultraviolet Germicidal Irradiation (UVGI) System

0.5 point can be scored for the provision of UVGI system in AHUs and FCUs to control airborne infective microorganisms.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender, technical specifications and schematics showing the provision of UVGI (UV wavelength to be 254 nm and safety interlock must be provided) system in AHUs and FCU • Highlight the location of the system is adjacent to and after the cooling coils • Manufacturer's guideline on the intensity, location, reflector design and number of lights according to the AHU design	As-Built

(iii) More Stringent VOC Limits for Interior Fittings and Finishes

A maximum of 2 points can be scored through the specification and use of products certified SGBP Very Good or above, which meet more stringent VOC emission limits. All products used in the respective Functional System with coverage of ≥ 80% of applicable areas must be SGBP Very Good or above to qualify for GM points for respective System.

- On interior fittings such as system furniture, cabinetry etc
- On wall or floor finishes as part of the functional system

Functional System					Other Systems
External Wall	Internal Wall	Internal Flooring	Ceiling	Doors	Fixed furniture/ system furniture
1 pt	1 pt	1 pt	1 pt	0.5 pt	0.5 pt

Note: For finishes, the combination of components that make out the finishes level of the functional system shall meet the criteria. Where bare finishes were to be used as part of the design for the operation of the building, this will apply to the final coat of treatment on the bare finish, be it protective coating or sealer or paint. If absolute no finishes are used, this criterion is not applicable unless the base finish is ascertained to meet the higher stringent standard on VOC contaminant.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender design specification showing: ➢ The building functional system(s) which the project targets to score points for, and descriptions of each element - On interior fittings such as system furniture, cabinetry etc - On wall or floor finishes as part of the functional system ➢ The requirement stating lower or no VOC contaminant, i.e. use of SGBC 2 ticks certified products for all components containing VOC that are used in the functional system(s) for the project. *Note: For projects which include tenant future installations in their computation, to show draft tenancy agreement specifying the above requirements* • Tabulation of the functional system(s) which the project targets to score points. • Design drawings marking the extent of use for each compliant functional system and the calculation of the extent of use. • Design details of the systems used within each functional system; i.e. construction method/ method statement details. • Product catalogues and certificates (if the product selection is confirmed).	• Product certificates, data sheets and delivery out of interior finishes and paints • Listing of interior finishes and finishes of tenanted spaces, where applicable. As-Built Purchase Summary

(iv) Use of Persistent Bio-cumulative and Toxic (PBT) free lighting

0.5 point can be scored for the use of PBT-reduced or free luminaries for ≥ 90% of light fittings in the project.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Specification of the luminaries used within the project and their requirement to be PBT free. • Show fittings - have mercury content of ≥50% lower than permissible limit, as per Environmental Protection and Management Act (Chapter 94A). • Calculations of the extent of PBT reduce or free luminaries usage.	• Data sheets of the luminaries that demonstrate that they are PBT-reduced or free luminaries As-Built Purchase Summary

Zero ODP Refrigerants with Low Global Warming Potential (Advanced Green Effort)

Points can be scored for the use of refrigerants with Ozone Depleting Potential (ODP) of 0 as well as low global warming potential (GWP) as follows:

- GWP < 750 - 0.5 point *or*
- GWP < 15 - 1 point

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extract from the tender specification showing the requirement for all zero ODP refrigerants to have low GWP as stated in the criteria	• List of the refrigerants used in the air conditioning system(s) and the applicable cooling systems

Photo courtesy of Keppel REIT

4.2 Spatial Quality (10 pts)

The spatial quality of a building is assessed through the experiential value of both the physical and social qualities of the spaces within the development. Although many spatial quality indicators are qualitative, there are a number of commonly agreed upon indicators that act as a reliable proxy to determine the projects spatial quality which can enhance the indoor environment and wellbeing of the occupants and visitors to the building. These include creating access to quality daylight and artificial lighting, ensuring spaces are acoustically comfortable and inclusive as well as incorporating design features that evoke a connection to nature.

- 4.2a Lighting (6 pts)
- 4.2b Acoustics (2 pts)
- 4.2c Wellbeing (2 pts)

4.2a Lighting

Intent

Natural lighting has been linked to the positive mental wellbeing of building occupants. It connects enclosed indoor environments with the external natural environment. In the tropics, special care must be taken to maximise effective daylight while minimising visual discomfort and maintaining the façade's thermal efficiency. This is made possible by incorporating effective daylight design strategies at the beginning of the design process. Where daylight is not possible, adherence to minimum quality standards for artificial lighting provisions ensures well-lit and comfortable spaces for occupants.

Scope

Applicable to common spaces and occupied spaces of building developments.

Assessment

Up to 6 points can be scored for the following:

(i) Effective daylighting for common areas

Effective daylighting for common areas – 2 points

Up to 2 points can be scored by prorating the number of daylit transient common spaces with effective automatic lighting controls against the total number of applicable spaces. Note: Each toilet is counted as 0.5.

1.5 points for % count with daylighting for toilets, staircases, corridors, lift lobbies and atriums.

0.5 point for % areas of carpark with daylighting or having no carpark.

(ii) Effective daylighting for occupied spaces

Effective daylighting for occupied spaces – 4 points

<table>
<tr><th>Method</th><th>Percentage of occupied spaces with access to effective daylighting (3 points)</th><th>Effective Mitigation of Overlit Areas (1 point)</th></tr>
<tr><td>Pre-Simulated Daylight Availability Tables: Simplified method for standard designs to guide concept stage design in identifying design strategies for optimised daylight design.</td><td rowspan="2">Points can be scored as follows based on the percentage of total occupied areas* that can achieve the specific Daylight Autonomy (DA) requirement of $DA_{N\ lx,50\%}$ (without overlighting), as outlined in the Green Mark NRB: 2015 Technical Guide and Requirements Annex B: Effective Daylighting Simulation and Pre-Simulated Daylight Availability Tables Methodology and Requirements. Effectively daylit areas shall be integrated with automated lighting controls.
* Note: exclude special rooms that cannot have daylighting due to operation needs.
<table><tr><th>Percentage</th><th>Points</th></tr><tr><td>15 to < 35 %</td><td>0.5</td></tr><tr><td>35 to < 55 %</td><td>1</td></tr><tr><td>55 to < 75 %</td><td>2</td></tr><tr><td>≥75%</td><td>3</td></tr></table></td><td>1 point can be scored for the adoption of suitable mitigation strategies for overlit spaces, such as blinds which are controlled with daylight sensors, variable opacity glazing (electrochromic glass, thermochromic glass), bi-level glazing (glazing with higher VLT for higher level glazing and glazing with lower VLT for lower level glazing) and fitted glazing.</td></tr>
<tr><td>Daylight Simulation: Performance-based method for non-standard/ complex designs.</td><td>1 point can be scored where mitigation measures to effectively address overlighting are included into the simulation model in accordance with Annex B.</td></tr>
</table>

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
With reference to *Annex B:* - • Tabulation of all applicable daylit area and computation of the distance of penetration from the façade, the height of the opening / fenestration and the percentage of daylit areas over total areas. • Drawings to show that openings fenestrations provide daylighting to the space.	With reference to *Annex B:* • Perform spot measurements of the effective daylighting through lux measurements **As-Built**

(iii) Quality of Artificial Lighting

Points can be scored for the following attributes of lighting used in occupied spaces, maximum of 1 point (90% of the applicable functional areas should be served by the relevant luminaires to score):

- Good light-output over life with a minimum lifespan rating of L70 ≥ 50,000 life hours - 0.5 point
- Lighting designed to avoid flicker and stroboscopic effects, by using high frequency ballasts for fluorescent luminaries and LED lighting with ≤ 30% flicker - 0.5 point
- Meeting the minimum colour rendering index (Ra or CRI) in Clause 5 of *SS 531 – 1 : 2006 (2013) – Code of Practice for Lighting of Workplaces* - 0.5 point
- LED Luminaires certified under SGBP scheme - 1 point

Definitions

LM80: The Illuminating Engineering Society of North America (IESNA) approved standard for measuring lumen maintenance of LED light sources. LM-80-08 applies to the LED package, array, or module alone, not a complete system; it is testing a component level. The standard does not provide guidance for extrapolation of testing results.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Light-output: ➢ LED lighting: Detailed specifications and the schedule of luminaries - to demonstrate the minimum R_a lifespan rating is in accordance with - IES TM-21 method, based on LM80 test report ➢ Other types of lighting: –Demonstrate lifespan rating requirement is in accordance with - relevant applicable internationally accepted test methods • Lighting designed with minimal flicker and stroboscopic effects: Submission of specifications showing use of LED lights of high frequency ballasts with frequency > 20 kHz and LED drivers with ≤30% flicker - • Meeting the minimum colour rendering index: Detailed specifications and the schedule of luminaries to demonstrate the minimum colouring rending index is in accordance with Clause 5 of *SS 531 – 1 : 2016 (2013) – Code of Practice for Lighting of Workplaces* in all areas. • Certified LED luminaires: Schedule of LED luminaires used and relevant SGBC certification.	• Lighting data sheets and relevant test reports As-Built Purchase Summary

Worked Example

The proposed development provides the following lighting quality for its occupants at various spaces:

Type of interior, task or activity	Design R_a	Reference R_a (SS531: 2006)
Office Space Type 1	80	80
Atrium	60	60
Corridor type 1	40	40
Toilet	80	80
Mechanical & Electrical Rooms	60	60
Carpark	40	40

The proposed lighting design meets the reference values as stated in SS 531: 2006 (2013) and the LED lightings installed are based on lifespan rating of L_{70} for ≥50,000 life hours and meet minimum colour rendering index, hence the project can score a maximum of 1 point under this credit.

4.2b Acoustics

Intent

An improved acoustical performance for normally occupied spaces can enhance the aural comfort of its occupants, facilitating communication, reducing unwanted sound and aiding in speech privacy.

Scope

Applicable to occupied spaces of building developments.

Assessment

(i) Sound Transmission Reduction

0.5 point can be scored for projects that demonstrate that the acoustic performance of the internal partitions between adjoining spaces will be constructed to achieve the following performance levels:

Description	Sound Transmission Class (STC)
Between general office spaces	40 - 50
Spaces where confidential speech are required/ Between mechanical and equipment spaces and occupied spaces:	50 – 60

Equivalent sound transmission metrics may also be used to qualify the range.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• STC details incorporated into the tender specifications	As-Built; Purchase Summary

(ii) Acoustic Report

1.5 points can be scored for an acoustic design and verification report based on requirements as follows.

Definitions

Reverberation time: The length of time required for sound to diminish 60 decibels from its initial level.

Guidance Notes

Acoustic Design Report format:

- Executive Summary – summary of the key design recommendations for the project
- Acoustic Considerations:
  - Impact of the project on the immediate noise environment, especially noise sensitive accommodation, including both the construction and operational stages of the building.
  - External noise sources and propagation affecting the development.
  - Internal noise sources, acoustical design and criteria used within the building.
  - Internal layout planning, finishes selection and acoustical performance of the building.
  - Site massing, landscaping and facades design to mitigate the adverse impacts of external noise.
- Façade Noise Ingress Control Criteria:
  - Noise survey methodology,results and standards.
  - Recommendations for façade treatment & spatial arrangement of interior spaces.
- Internal Acoustic Design Criteria:
  - Sound transmission reduction targets in compliance with 4.2b (i) Sound Transmission Reduction. STC shall be calculated using recognised design guidelines, field or laboratory test results by certified/accredited agency or design calculations.
  - Reverberation time targets.
  - This should be demonstrated via detailed design calculations or acoustic modeling.
  - Sound reinforcement systems and/or public address system (where applicable).
- Internal Acoustic Design Proposals:
  - Proposals for sound absorptive and sound insulation -with supporting calculations or field or laboratory test results by certified/accredited agency for typical areas.

Acoustic Verification Report Format:

- Environmental Noise & Survey (as-built)
  - Methodology and testing standards.
  - External impact of development on the surroundings.
- Façade Noise Ingress Control (as-built)
  - Façade ingress noise measurement for internal areas.
- Internal Acoustics (as-built)
  - Sound insulation & Reverberation times measurements.
  - Commissioning and handover of noise masking or sound reinforcement systems (where applicable).

Reverberation Requirements (adapted from *AS/ NZS 2107*):

Functional Space		Recommended Reverberation Time (*T60 seconds averaged between 500, 1,000 and 2,000Hz*)
Office	Open Plan Office	≤ 1
	Conference / Meeting Rooms	≤ 0.8 (0.4 for rooms with tele or video conference)
Institutional (Schools, Civic buildings)	Classrooms	0.6 - 1.0
	Seminar / tutorial rooms	0.6 - 0.8
	Libraries Reading rooms	< 1.0 0.6 - 0.8
	Music Rooms Music Studios	0.5 - 0.7 0.7 - 0.8
	Multi-Purpose Halls	< 1.5
	Gymnasiums	< 1.5
Hotel	Meeting Room Large Banquet Room/Hall	< 0.8 < 1.2
Atria/Commercial Lobby	Retail, office, institutional, or hotel atria or main lobby spaces	To reduce as far as practicable for noise control

Calculation of reverberation time

The reverberation time can be calculated by hand where:

$A = (\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \ldots + \alpha_n S_n)$

$RT = 0.163 \times V/A$

A - Total equivalent sound absorption area of a room (in Sabin or m^2)

$\alpha_{1,i}$ - the sound absorption coefficient for different materials 1→i as specified/used in a space/room.

$S_{1,i}$ - the total surface area of different materials, 1→i corresponding to the respective absorption coefficient (m^2).

RT – Reverberation Time in seconds.

V – Room Volume (m^3)

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Acoustic design and verification report for the project based on the format under Guidance Notes. The report should be prepared by a qualified acoustician.	• Acoustic verification report of onsite testing and measurements to demonstrate that the acoustic objectives have been met, with recommendations for continued operational performance. Where defects due to workmanship are found, these should be corrected • For sound insulation measurements, a representative sample of partitions shall be tested, i.e. 10% of the total (lower quantity if there is extensive repetition). For façade noise ingress measurements and reverberation time measurements, a selection of rooms shall be used for testing, i.e. 5% of the total (lower quantity if there is extensive repetition). Testing shall be conducted in accordance with *ISO 3382 - 3:2012 Acoustics – Measurement of Room Acoustic Parameters*.

Worked Example

Meeting room of dimension 3.0m width, 4.0m length, 2.5m height with 4 timber doors (1.0m x 2.4m).
Volume of room = 30m^3

Step 1: Calculate the surface area related to each absorptive material (e.g. floor, wall, door, ceiling)

Surface	Surface Finish	Area (m^2)
Floor	Carpet on concrete base	12
Doors	Timber	9.6
Walls (excluding door area)	Concrete block, painted	25.4
Ceiling		12

Step 2: Obtain values of absorption coefficients for the carpet, painted concrete block walls and the timber doors, and ceiling

Surface	Area (m^2)	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz
Floor	12	0.03	0.06	0.15	0.30	0.40
Doors	9.6	0.10	0.08	0.08	0.08	0.08
Walls	25.4	0.05	0.06	0.07	0.09	0.08
Ceiling	12	0.28	0.25	0.14	0.13	0.13

Step 3: Calculate the absorption area (m^2) related to each absorption surface (ie for floor, walls, doors, ceiling) in octave frequency bands.					
	Absorption area (m^2) [Absorption area = Surface area x Absorption coefficient]				
Surface	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz
Floor	0.03x12 = 0.36	0.72	1.80	3.60	4.80
Doors	0.96	0.77	0.77	0.77	0.77
Walls	1.27	1.52	1.78	2.29	2.03
Ceiling	3.36	3.00	1.68	1.56	1.56
Step 4: Calculate the sum of the absorption area (m^2) obtained in Step 3.					
	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz
Total absorption area (m^2)	0.36+0.96+1.27+3.36 =5.95	6.01	6.03	8.22	9.16
Step 5: T60 seconds averaged between 500,1000 and 2000Hz					
	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz
Reverberation Time RT = 0.163*V/A	0.163*30/5.95 =0.822	0.814	0.811	0.595	0.534
		0.74 [(0.814+0.811+0.595)/3] (*Fulfils requirement for meeting room ≤ 0.8)*			

4.2c Wellbeing

Intent

Wellbeing refers to the state of being comfortable, healthy or happy. Providing nurturing, healing and inclusive spaces can enhance the building occupant and user's environment, and overall wellbeing. This includes integrating within buildings places of respite, nature access, architecture that invoke a connection to nature as well as accessible and inclusive spaces.

Scope

Applicable to all building developments.

Assessment

A maximum of 2 points can be scored for the following:

(i) Biophilic Design

Points can be scored for architecture that reinforces the attributes and experience of nature to nurture the human-nature relationship:

- Provision of accessible sky gardens, sky terraces, internal courtyards and rooftop gardens as areas for respite – 1 point
- Building design that adopt biomimicry designs – 1 point
- Provision for at least 5% of the common areas or functional spaces to have fixed indoor planting – 0.5 point
- Building design that takes after any natural shapes and forms/ creates ecological attachment to the place – 0.25 point
- Provision of images of nature for 5% of common areas – 0.25 point

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Landscape plans of the relevant accessible sky gardens, sky terraces, internal courtyards and rooftop gardens with indication the outdoor furniture and refreshment area. • Plan layouts and perspectives of the interior planting design at the applicable areas with calculations that demonstrate the plant coverage as a percentage of the relevant floor areas. • Short description/ plans/ sketches to demonstrate and explain the adopted biomimicry/ natural shapes/ forms and the sense of ecological attachment • Layout identifying common area where images of natures has been incorporated.	As-Built

Worked Example

The façade of a building has been designed to look like part of a natural landscape. Potted plants and planter boxes have been placed at the lift lobbies, corridors and atrium. There are also multiple large landscape paintings hung in the atrium. The area of the common areas is 400m^2 while the area of the atrium is 40m^2.

Item	Details	Points
Façade of a building has been designed to look like part of a natural landscape	0.25 pt (Natural form)	0.25 pt (Natural form)
Potted plants and planter boxes at common areas	Potted plant area = π x r^2 where r is the radius of the plant Planter boxes area = Length x breadth of the planter box Assume total fixed planting area totals up to 20m^2 Percentage of common area with fixed indoor planting = 20 / 400 x 100% = 5%	0.5 pt (Indoor planting)
Multiple large landscape paintings hung in the atrium	Percentage of common area with images of nature = 40 / 400 x 100% = 10%	0.25 pt 0.26 (Images of Nature)
	Total	1 point

(ii) Universal Design (UD) Mark

The BCA UD Mark accords recognition to developments that adopt a user-centric philosophy in their design, operations and maintenance. Points can be scored for projects being awarded either:

- UD Mark Certified/ Gold Award – 0.5 point
- UD Mark Gold^{PLUS}/ Platinum Award – 1 point

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• UD Mark application form, accompanied with tender documents and written commitment from the developer / building owner on the targeted level of UD Mark award	• BCA UD Mark Letter of Award

4.3 Smart Building Operations (10 pts)

The use of automation, data and behavioural science can enable building professionals to optimise equipment and related processes in order to maintain equipment efficiency and building comfort requirements. A three-level taxonomy is defined to classify the maturity of smartness as a framework, namely basic monitoring of data, using feedback from data to control demand, and finally advanced integration and analytics of data. Additionally, a proper handover to the facilities and operations team is of fundamental importance to ensure that the systems work as per their intended function and that sustainable design is translated into actual operational performance.

- 4.3a Energy Monitoring (3 pts)
- 4.3b Demand Control (3 pts)
- 4.3c Integration and Analytics (3 pts)
- 4.3d System Handover and Documentation (1 pt)

4.3a Energy Monitoring

Intent

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.

Scope

Applicable to all buildings.

Assessment

(i) Energy Portal and Dashboard

Up to 2 points can be scored. This requires the provision of energy management portal, dashboard or other equivalent forms in the form of digital displays or web-based/ mobile application. 1 point each can be scored for the provision of following functions in the energy portal and dashboard:

- Display metered data, trending of energy consumption (historical data) and relevant parameters which facilitate better management of energy consumption during building operation.
- Enable individual tenants/space to monitor their own energy usages and consumption. Information will include monthly consumption of 50th percentile line of the tenants/space, based on operating hours, within the buildings. The information could also include 25th and 75th percentile line to facilitate understanding of consumption range.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Specifications of the energy portal, dashboard or other equivalent forms and relevant parameters such as areas, occupancy areas or use 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 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 a BMS or EMS	As-Built

(ii) BAS and Controllers with Open Protocol

1 point can be scored for using BACnet, Modbus or any other non-proprietary protocol as the network backbone for the building management system, with the system being able to provide scheduled export of a set of any chosen data points to commonly used file formats.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the BMS or other equivalent building management, control and monitoring system that demonstrates that the building automation network. Controllers should comply with open and non-proprietary protocols, such as BACnet, Modbus and KNX, and provide interfaces to enable the easy integration of new devices with subsystems and facilitate scheduled and automated data export to widely-used file format such as CSV	• Commissioning report of the building management or building automation system

Permanent M&V for VRF Systems (Advanced Green Effort)

An additional 2 points can be awarded for provision of permanent measuring instruments for monitoring of energy efficiency performance of Variable Refrigerant Flow (VRF) condensing units and air distribution subsystem. The installed instrumentation shall have the capability to calculate resultant system efficiency (i.e. kW/RT or COP) within 10% uncertainty. Each measurement system shall include the sensor, any signal conditioning, the data acquisition system and wiring connecting them. All data are to be logged at 5 minute sampling time interval, and recorded to at least 1 decimal place, and data shall be available for extraction for verification purposes.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Detailed catalogue and method explanation for resultant system efficiency within 10% uncertainty. • Technical specifications and / or sample data sheets/ product information for instruments and meters for data logging. • Calculation of end to end measurement uncertainty • Detailed drawings and schematics of the power measurement strategies for the air conditioning system (inclusive estimation of power consumption of air distribution equipment) • Details on how the owners or relevant parties are informed about the performance. • Commitment to comply with the requirements	• The performance verification may include on-site check by BCA officers. • Extracts of the instrumentation specifications calibration certificate and brochures • Extracts of data from logging system for verification of performance. Purchase Summary

Permanent M&V for Hot Water Systems (Advanced Green Effort)

1 point for incorporation of Permanent Measurement and Verification, with performance requirement similar to P.14, for central hot water system.

Documentary Requirement

As per *P.14 Permanent Instrumentation for the Measurement and Verification of Water-Cooled Chilled Water Plants* for central hot water system

4.3b Demand Control

Intent

Using occupancy based controls to monitor the usage of spaces and vary temperature, ventilation and lighting demand while maintaining room temperature effectiveness, good indoor environmental quality and lighting quality, can significantly reduce building energy consumption. The energy savings from such controls can be taken into account under the Energy Performance Points Calculator under *Part 2 Building Energy Performance*.

Scope

Applicable to buildings.

Assessment

A maximum of 3 points can be scored under this section.

(i) ACMV Demand Control

A maximum of 2 points can be scored for the use of the following controls to regulate the temperature and/ or airflow of spaces served by air-conditioning and/ or mechanical ventilation systems:

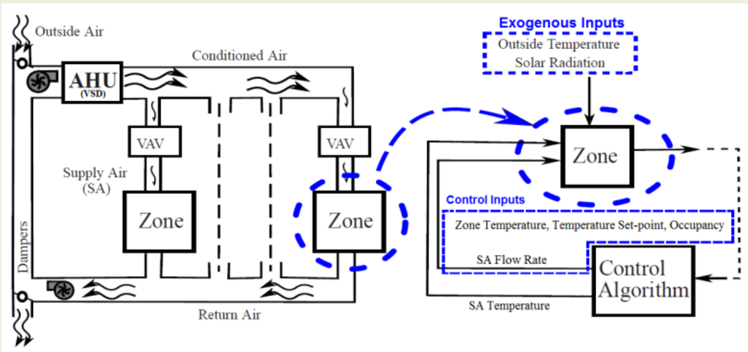
- Binary sensing controls
  - 0.5 point for ≥ 80% of all transient areas
  - 0.5 point for ≥ 80% of all occupied areas
- Occupancy-based sensing controls (for VAV systems)
  - 1 point for ≥ 80% of all transient areas
  - 1 point for ≥ 80% of all occupied areas

Definitions

- Binary sensing: Control is exercised based on whether the space is occupied (by one or more persons) or not
- Occupancy-based sensing: Control is exercised based on measured occupancy, e.g. number of occupants

Guidance Notes

- 1 point is scored if ≥ 80% of the applicable transient areas (by area) use occupancy-based sensing as a ACMV control strategy. 0.5 point is scored if binary sensing is used as a control strategy instead
- A further 1 point can be scored if ≥ 80% of the applicable occupied areas use occupancy-based sensing as a ACMV control strategy. 0.5 point is scored if binary sensing is used as a control strategy instead
- 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



Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• 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	As-Built; Purchase Summary

(ii) Lighting Demand Control

0.5 point each can be scored for the use of occupancy/ vacancy sensors to moderate brightness of the luminaries for ≥ 80% of transient and occupied areas respectively.

Definitions

Occupancy/ vacancy sensing: Control automatically turns light off when motion is no longer detected.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• 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).	As-Built; Purchase Summary

(iii) Carpark Guidance System

0.5 point for having carpark guidance system to guide car to available lot. This will include signage to state the number of lots in each segment of carpark. For building with no carpark, full point can be scored if building occupants is more than 10 pax.

Definitions

Provide information of the number of lots for key turning points within the carpark so as to reduce the time spent by cars to find nearest available parking lots.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Location signage for carpark guidance system and method of detection of available parking lots	As-Built

4.3c Integration and Analytics

Intent

The innovative and integrative use of data can optimise workflow or attain persistence of high performance and energy efficiency in a building. Basic integration and use of sensor data can optimise and operate the building in an informed and effective manner. The use of advanced integration and analytics can provide enhanced efficacy in lowering energy use, increase asset reliability, and improve the user experience.

Scope

Applicable to all buildings.

Assessment

A maximum of 3 points can be scored for the following:

(i) Basic Integration and Analytics

Assessment

0.5 point each can be scored for basic integration and analytics features such as (but not limited to):

Basic Features (Features displayed via BMS, BAS, website or mobile app)	Examples
Use adaptive control algorithms	• Adjust cooling tower approach based on wet bulb temperature
Exception handling by identifying systems that deviates from expected performance/setting	• When efficiency of chiller plant system (in kW/RT) deviates >10% • When a space setpoint is set below a typical value • When a space operates significantly below its setpoint
Detect equipment that run outside intended hours or settings	• AHUs/FCUs that run past regular office hours
Monitor equipment condition for preventive maintenance	• Use embedded sensors to predict mechanical wear and failure • Priorities equipment maintenance using machine condition monitoring
Basic fault detection and diagnostics (FDD) of sensors by finding failed or improperly operating sensors or actuators	• Compare set points to actual to find leaking valves or stuck dampers • Set algorithms to counter-check between sensors

(ii) Advanced Integration and Analytics

1 point each can be scored for advanced integration and analytics features such as (but not limited to):

Advanced Features (Features displayed via BMS, BAS, website or mobile app)	Examples
Whole system optimisation using a network of HVAC equipment	• Drive pumps minimally to satisfy the most demanding valve.
Integration of sub-systems to optimise resource use or improve user experience	• Integration of ID card access system to a hot-desk scheme
Use of Building Information Modelling (BIM) or similar applications that provide location-based visualisation of multiple sensors	• BIM for facilities and asset management such as energy and water use or temperature and relative humidity monitoring.
Participate in a Demand Response programme with electricity retailer	• Reduce energy consumption of specific electrical items for short periods Pls refer to *Demand Response Programme by EMA.

*Link: https://www.ema.gov.sg/Demand_Response_Program.aspx

Guidance Notes

Both basic and advanced features needs to be displayed via BMS, BAS, website or mobile app.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Method statement and extracts of the tender documents showing the provision of system integration sensors and control strategies.	Purchase Summary

Additional Advanced Integration and Analytical Features (Advanced Green Effort)

An additional 1 point can be scored for additional advanced integration and analytical features beyond the points cap.

4.3d System Handover and Documentation

Intent

Design and delivery integration is essential to delivering an operationally energy efficient building. Control systems should be properly tested and verified and to ensure operational continuity from construction to building maintenance and operation. These criteria indicate the presence of a quality assurance plan to maintain the desired energy efficiency and indoor comfort.

Assessment

1 point can be scored for a proper system verification and handover of higher-order functional and system level performance of buildings control systems, mechanical systems and electrical systems. The project shall demonstrate a commitment to comply to verification requirements and show evidence of relevant schedules and documentation.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• List of relevant mechanical, electrical and control systems that are to be tested and verified. • Commitment letter from client to undertake system verification and handover.	• Written description of all the systems operation and control actions to meet the functional requirements of the system, including control strategy and logic diagrams • Integration test results of air and hydronic systems • Schematic of BMS network & Description of BMS point list including user adjustable points, hard and derived points, and their respective controller and register addresses • Handover of all technical , instruction(covering details of system operation) & training manuals, user guides and drawings, back-up copies of software, software configuration along with software routine and consumable spares • List of all updated as-built documents for Green Mark Assessment ➢ BIM, Energy modelling and CFD models ➢ As-built drawings and documents ➢ Photographic evidences ➢ Updated calculation for changes ➢ Summary of purchase from contractors, sub-contractors or suppliers

Expanded Post Occupancy Performance Verification by a 3rd Party (Advanced Green Effort)

0.5 point can be scored per energy subsystem (e.g. lighting controls, mechanical ventilation, hot water system, heat recovery system, renewable energy system) up to 2 points, where the owner engages an independent competent professional (either a BCA registered Energy Auditor or a Professional Engineer (PE) (Mech/Elect)) to verify the operational performance and provide recommendations on system performance enhancement. This should be conducted within one year from the building's TOP.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Method Statement & Extracts of the tender documents showing the involvement of third party to undertake performance verification.	• The verification report for each of the applicable building energy systems • The recommendation report for energy optimisation for all the major energy subsystems along with relevant operational manual.

Energy Performance Contracting (Advanced Green Effort)

1 point can be scored for engaging an Energy Performance Contracting (EPC) firm (accredited by SGBC) to implement and deliver energy efficiency, renewable energy and/or energy recovery projects with an energy performance contract wherein the EPC firm's remuneration is based on demonstrated energy savings. Operational system efficiency should be guaranteed over a minimum of 3 years.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of the tender documents including details on project deliverables, financial model and duration of performance contract	• Extracts of contract

5. Advanced Green Efforts

The Green Mark NRB: 2015 Advanced Green Efforts section recognises the implementation of industry leading performance or innovative strategies, designs or processes that demonstrate exceptional levels of sustainability. The 20 points in this section are bonus points that can be added to the base Green Mark score to help projects demonstrate their holistic environmental performance and achieve higher levels of Green Mark award.

The enhanced performance criteria have indicators placed within the 4 main sections of Climatic Responsive Design, Building Energy Performance, Resource Stewardship and Smart and Healthy Building that we have identified as practices that are pioneering initiatives in sustainable design.

The remaining criteria within this section recognise projects that undertake sustainability with the view of market transformation, such as demonstrating cost neutrality. Other criteria recognise broader aspects of sustainability including socio-economic indicators or global sustainability benchmarking that address issues outside of green building rating tools.

20 POINTS

5.1 Enhanced Performance (15 pts)

5.2 Complementary Certifications (1 pt)

5.3 Demonstrating Cost Effective Design (2 pts)

5.4 Social Benefits (2 pts)

5.1 Enhanced Performance

Intent

Points can be awarded based on the Advanced Green Efforts indicators that are highlighted within the Green Mark NRB: 2015 criteria. Alternatively, where projects can demonstrate substantial performance to a specific sustainability indicator or outcome addressed within Green Mark beyond what is specified in the criteria, points can be awarded on a case by case basis.

Assessment

A maximum of 15 points for enhanced performance indicators can be scored for each project. Submission requirements for assessment shall follow the guidance for each enhanced performance indicator within the main Green Mark sections, or for other outcome beyond what is specified, based on 2 points for high impact items, 1 points for medium impact items and 0.5 point for low impact items.

High Impact items (2 points each)

a) Inclusion of ACT Technologies (Annex D) for ≥50% of A/C areas/systems

Medium Impact items (1 point each)

b) Inclusion of ACT Technologies (Annex D) for ≥30% of A/C areas/systems

c) Achieve A/C system efficiency (excluding air distribution) better than 0.65kW/ton for whole range from 25% to 100% of the peak cooling load (based on A/C areas).

d) Adoption of Smart Facilities Management (FM)

Undertake to conduct a feasibility study using the 5-step SMART process template including cost benefit analysis (refer to Technical Guide on Smart FM) and undertake to implement at least 2 of smart technology solutions:

- Usage of robotics for feedback and optimisation of processes (e.g. cleaning, security)
- Usage of video monitoring coupled with facial recognition for incident detection in security function
- Workflow automation to streamline FM services with feedback loop
- Use of digital twin to monitor assets and enable predictive maintenance

e) Adoption of Design for Maintainability (DfM)

To adopt at least 25 strategies/provision for integrating operation and maintenance experience in planning and design process (refer to Design for Maintainability Guide: Non– Residential)

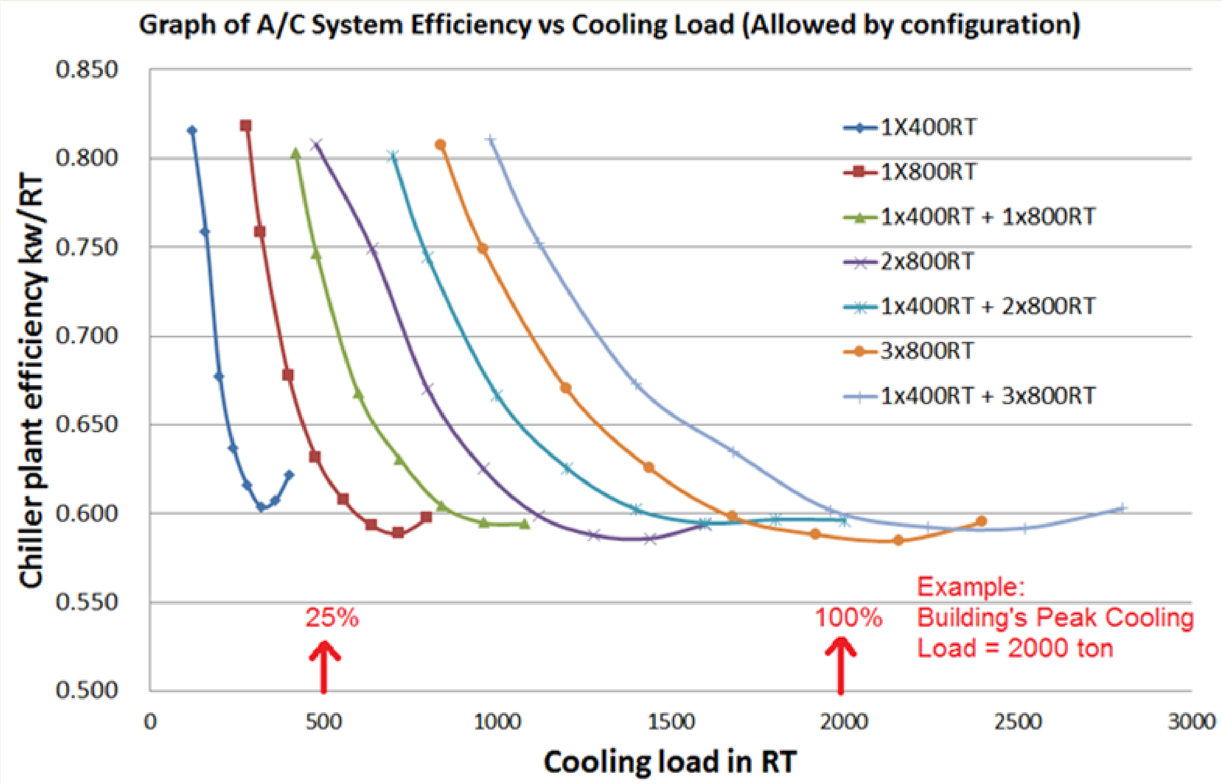
Low Impact items (0.5 point each)

f) Inclusion of ACT Technologies (Annex D) for ≥10% of A/C areas/systems

g) Undertake adoption of Smart FM in area such as M&E services, security, environmental services etc

Guidance Notes

- All projects should plot efficiency profile of all possible configurations of A/C equipment (as shown below), regardless if they are scoring for the additional credit. If A/C system efficiency for whole range from 25% to 100% of the peak cooling load is able to achieve better than 0.65kW/ton, the project will be able to score 1 point under medium impact item. Project teams are encouraged to review lower load efficiency if operation hours for these lower load are significant.



5.2 Complementary Certifications

Intent

Green Mark is an assessment tool that assesses the environmental sustainability of a building. However, the consideration of sustainability indicators beyond those relevant to the built environment is also important.

Assessment

1 point can be scored where the project demonstrates that it is certified through a local or international complementary certification or rating tool that assesses the project beyond the environmental indicators within Green Mark NRB: 2015.

5.3 Demonstrating Cost Effective Design

Intent

Projects that can demonstrate that they have achieved high levels of environmental performance without an increased capital expenditure are of great interest to promote market transformation and encourage the mass market to drive towards higher levels of environmental sustainability.

Assessment

1 or 2 points respectively can be scored for demonstration of cost effective or cost neutral design beyond the norm through a detailed quality surveyor's report of the building.

5.4 Social Benefits

Intent

While Green Mark focuses on environmental sustainability, this criterion rewards projects that are able to demonstrate that their project contributes to social sustainability.

Assessment

A maximum of 2 points can be scored for projects that demonstrate their social benefits or how social sustainability has been incorporated into the project, beyond core functionality of the building. This can (but not limited to) include efforts that demonstrate enhanced considerations to further wellbeing, welfare, community integration as well as the purchase of clean energy (e.g. solar energy) through third party leasing contracts. 0.5 point for each distinct benefit.

Annexes

Energy Efficiency & Other Green Features for Specialised Building (up to 15 pts)

The Green Mark NRB: 2015 recognises the need for context specific criteria to enhance the sustainability value to the project. Annexes for specialised building list the additional sustainability features relevant to specific building types. The points scored under the respective Annex are bonus points that can be added to the base Green Mark score (140).

- Annex 1: Hawker Centres (15 pts)
- Annex 2: Healthcare Facilities (10 pts)
- Annex 3: Laboratory Buildings (10 pts)
- Annex 4: Schools (10 pts)

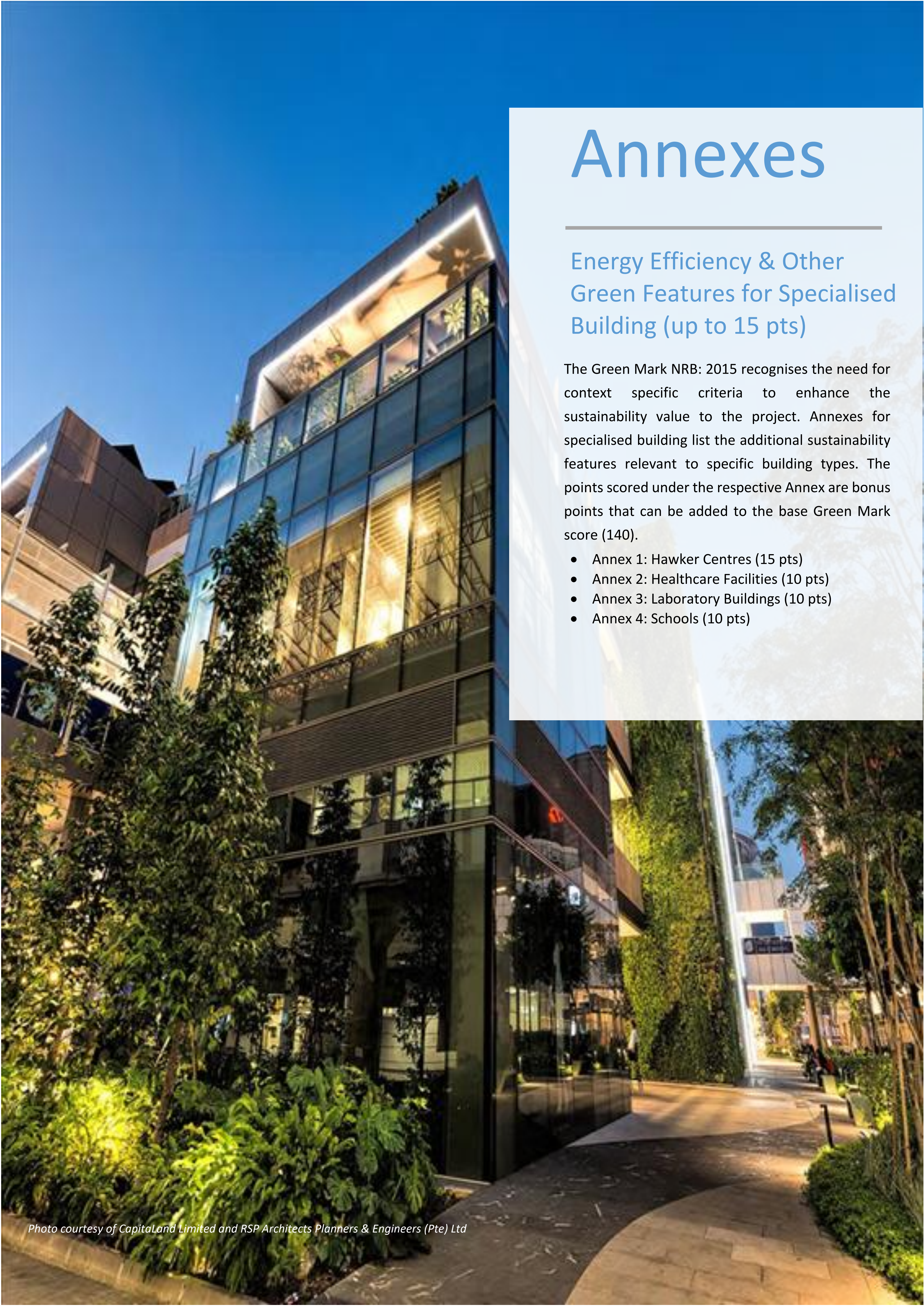


Photo courtesy of CapitaLand Limited and RSP Architects Planners & Engineers (Pte) Ltd

Quick References Table

Certain criteria in GM NRB:2015 may not be applicable to specialised buildings types such as Healthcare, Laboratories, School and hawker centers. Hence, additional criteria are added to the scoring for these specialised buildings types. Additional points for different building typologies can be prorated based on size of functional spaces.

The below quick references table, highlights the various scorable, possibly scorable and unlikely-scorable credits for the different annexes

✓ : Scorable credits

○ : possibly scorable credits

✧ : unlikely-scorable credits

Elective Requirements	Office/Retail /Commercial	Annex 1 Hawker Centres	Annex 2 Healthcare	Annex 3 Laboratories	Annex 4 School
Part 1 – Climatic Responsive Design					
P.1 Envelope and Roof Thermal Transfer		✧	✓	✓	✓
P.2 Air Tightness and Leakage		✧	✓	✓	✓
P.3 Bicycle Parking		✓	✓	✓	✓
1.1 Leadership					
1.1a Climatic & Contextually Responsive Brief		✓	✓	✓	✓
1.1b Integrative Design Process		✓	✓	✓	✓
1.1c Environmental Credentials of Project Team		✓	✓	✓	✓
1.1d Building Information Modeling *4D, 5D & 6D BIM (Advanced Green Efforts)*		○	✓	✓	✓
1.1e User Engagement		✓	✓	✓	✓
1.2 Urban Harmony					
1.2a Sustainable Urbanism					
Environmental Analysis *Creation of possible new ecology and natural ecosystems (Advanced Green Efforts)*		✓	✓	✓	✓
Response to Site Context		✓	✓	✓	✓
Urban Heat Island (UHI) Mitigation		✓	✓	✓	✓
Green Transport		✓	✓	✓	✓
1.2b Integrated Landscape and Waterscape					
Green Plot Ratio (GnPR) *GnPR ≥ 5.0 (Advanced Green Efforts)*		✓	✓	✓	✓
Tree Conservation		✓	✓	✓	✓
Sustainable Landscape Management		✓	✓	○	✓
Sustainable Storm Water Management		✓	✓	○	✓
1.3 Tropicality					
1.3a Tropical Façade Performance – *Low Heat Gain Façade (Advanced Green Efforts)* *Greenery on East and West Façade (Advanced Green Efforts)* *Thermal Bridging (Advanced Green Efforts)*		✓	✓	✓	✓
1.3b Internal Spatial Organisation		✓	✓	✓	✓
1.3c Ventilation Performance *Wind Driven Rain Simulation (Advanced Green Efforts)*		✓	✓	✧	✓
Part 2 – Building Energy Performance					
P.4 Air Conditioning Total System and Component Efficiency		✓	✓	✓	✓
P.5 Lighting Efficiency and Controls		✓	✓	✓	✓
P.6 Vertical Transportation Efficiency		✓	✓	✓	✓
2.1 Energy Efficiency					
Option 1: Energy Performance Points Calculator					
2.1a Air Conditioning Total System Efficiency		✓	✓	✓	✓
2.1b Lighting System Efficiency		✓	✓	✓	✓
2.1c Carpark System Energy		✓	✓	✓	✓
2.1d Receptacle Energy		✧	✧	✧	✓
2.1e Building Energy *Further Improvement in Design Energy Consumption (Advanced Green Efforts)*		✓	✓	✓	✓
Option 2: Performance-Based Computation					
2.1f Space Conditioning Performance (10 pts) *Efficient Space Conditioning Energy Design (Advanced Green Efforts*		✓	✓	✓	✓
2.1g Lighting System Performance (6 pts) *Efficient Lighting Design (Advanced Green Efforts)*		✓	✓	✓	✓
2.1h Building System Performance (6 pts) *Additional Energy Efficient Practices and Features (Advanced Green Efforts)*		✓	✓	✓	✓

2.2 Renewable Energy					
2.2a Solar Energy Feasibility Study		✓	✓	✓	✓
2.2b Solar Ready Roof		✓	✓	✓	✓
2.2c Adoption of Renewable Energy *Further Electricity Replacement by Renewables (Advanced Green Efforts)*		✓	✓	✓	✓
Part 3 – Resource Stewardship					
P.7 Water Efficient Fittings		✓	✓	✓	✓
3.1 Water					
3.1a Water Efficient Systems					
Landscape irrigation		✓	✓	○	✓
Water Consumption of Cooling Towers *Better Water Efficient Fittings (Advanced Green Efforts)*		✧	✓	✓	○
3.1b Water Monitoring					
Water Monitoring and Leak Detection		✓	✓	✓	✓
Water Usage Portal and Dashboard		✓	✓	✓	✓
3.1c Alternative Water Sources		✓	✓	✓	✓
3.2 Materials					
3.2a Sustainable Construction					
Conservation and Resource Recovery		✓	✓	✓	✓
Resource Efficient Building Design *Use of BIM to calculate CUI (Advanced Green Efforts)*		✓	✓	✓	✓
Low Carbon Concrete *Advanced Green Materials(Advanced Green Efforts)*		✓	✓	✓	✓
3.2b Embodied Carbon *Provide Own Emission Factors with Source Justification (Advanced Green Efforts)* *Compute the Carbon Footprint of the Entire Development (Advanced Green Efforts)*		✓	✓	✓	✓
3.2c Sustainable Products					
Functional Systems		✓	✓	✓	✓
Singular Sustainable Products outside of Functional Systems *Sustainable Products with Higher Environmental Credentials (Advanced Green Efforts)*		✓	✓	✓	✓
3.3 Waste					
3.3a Environmental Construction Management Plan		✓	✓	✓	✓
3.3b Operational Waste Management		✓	✓	✓	✓
Part 4 – Smart & Healthy Building					
P.8 Thermal Comfort		✧	✓	✓	✓
P.9 Minimum Ventilation Rate		✧	✓	✓	✓
P.10 Filtration Media for Times of Pollution		✧	✓	✓	✓
P.11 Low Volatile Organic Compound (VOC) Paints		✓	✓	✓	✓
P.12 Refrigerants		✧	✓	✓	○
P.13 Sound Level		✓	✓	✓	✓
P.14 Permanent Instrumentation for the Measurement and Verification of Chilled Water Air-Conditioning Systems		✧	✓	✓	○
P.15 Electrical Sub-Metering & Monitoring		✓	✓	✓	✓
4.1 Indoor Air Quality					
4.1a Occupant Comfort					
Indoor Air Quality (IAQ) Surveillance Audit		✧	✓	✓	✓
Post Occupancy Evaluation		✓	✓	✓	✓
Indoor Air Quality Display *Indoor Air Quality Trending (Advanced Green Efforts)*		✧	✓	✓	✓
4.1b Outdoor Air					
Ventilation Rates		✧	✧	✓	✓
Enhanced Filtration Media		✧	✓	✓	✓
Dedicated Outdoor Air System		✧	✓	✓	✓
4.1c Indoor Contaminants					
Local Exhaust and Air Purging System		✧	✓	✓	○
Ultraviolet Germicidal Irradiation (UVGI) System		✓	✓	✓	○
More Stringent VOC Limits for Interior Fittings and Finishes		✓	✓	✓	✓
Use of Persistent Bio-cumulative and Toxic (PBT) free lighting *Zero ODP Refrigerants with Low Global Warming Potential (Advanced Green Efforts)*		✓	✓	✓	✓
4.2 Spatial Quality					
4.2a Lighting					
Effective daylighting for common areas		✓	✓	○	✓
Effective daylighting for occupied spaces		✓	✓	○	✓
Quality of Artificial Lighting		✓	✓	✓	✓
4.2b Acoustics					
Sound Transmission Reduction		✧	✓	✓	✓
Acoustic Report		✧	✓	✓	✓
4.2c Wellbeing					
Biophilic Design		✓	✓	○	✓
Universal Design (UD) Mark		✓	✓	✓	✓

4.3 Smart Building Operations					
4.3a Energy Monitoring					
Energy Portal and Dashboard		✓	✓	✓	○
BAS and Controllers with Open Protocol *Permanent M&V for VRF Systems (Advanced Green Effort)* *Permanent M&V for Hot Water Systems (Advanced Green Effort)*		✓	✓	✓	○
4.3b Demand Control					
ACMV Demand Control		✧	✓	✓	○
Lighting Demand Control		✓	✓	✓	✓
4.3c Integration and Analytics					
Basic Integration and Analytics		✧	✓	✓	○
Advanced Integration and Analytics *Additional Advanced Integration and Analytical Features (Advanced Green Effort)*		✧	✓	✓	○
4.3d System Handover and Documentation *Expanded Post Occupancy Performance Verification by a 3rd Party (Advanced Green Effort) Energy Performance Contracting (Advanced Green Effort)*		✓	✓	✓	✓
Part 5 – Advanced Green Efforts					
5.1 Enhanced Performance		✓	✓	✓	✓
5.2 Complementary Certifications		✓	✓	✓	✓
5.3 Demonstrating Cost Effective Design		✓	✓	✓	✓
5.4 Social Benefits		✓	✓	✓	✓

Annex 1: Energy Efficiency & Other Green Features [Hawker Centres]

Intent

Encourage use of innovative energy efficient equipment, system or design feature.

Scope

Applicable to naturally ventilated hawker centre building.

Assessment

A maximum of 15 points can be scored for the following:

a. Implementation of Environmental- friendly procurement & purchase policy – 0.5 point

Definitions	To set in place a policy statement that supports environmentally friendly procurement and purchases within the hawker centres, to reduce the adverse environmental impact of building owners' purchasing decisions by buying goods and products from environmentally responsible product/ service providers.	
Documentation Requirements		
Design Stage		**Operation Document (for handover to FM)**
• Establish the following policies with endorsement by Client's representative (not limited to): ➢ Environmental Policy for the organisation ➢ Organisation's procurement and purchase plans ➢ Key appointment holders for the operation including the persons responsible for review, implementation and roll-out of these action plans		Purchase Summary

b. All kitchen exhaust to be connected to centralised exhaust system with filter to remove odour or particulates – 2 points

Definitions	The kitchen exhaust shall dispel smells directly through a centralised exhaust system without spreading from the kitchen stove areas to the patrons' seating areas.	
Documentation Requirements		
Design Stage		**Operation Document (for handover to FM)**
• Drawings showing the schematic and layout of the proposed centralised kitchen exhaust system • Technical specifications and product information of the various components of the exhaust system designed and installed		As-Built; Purchase Summary

c. Provision of design to facilitate outflow of heated air to provide thermal comfort at seating area. – 2 points

Definitions	To identify optimum design to dissipate heat load from kitchen stoves, heat release from customers, typical winds and kitchen hood operations etc. away from patrons' seating area.	
Documentation Requirements		
Design Stage		**Operation Document (for handover to FM)**
• CFD simulation as per *Annex A: Computational Fluid Dynamics Simulation Methodology and Requirements*		As-Built

d. Provision of relevant information and guidance to facility management to main Indoor Air Quality performance in respect to cleaning, prevent migration of odors at cooking, dinning & toilets etc – 3 points

Definitions	To develop an active IAQ maintenance guidelines for Hawker Operators to maintain good IAQ in hawker centres.
Guidance Notes	2 points shall be awarded for the provision of good IAQ maintenance guidelines for Hawker Operators. A brief outline of the guidelines is as follows (not limited to): • Introduction – the intent of the guidelines • Strategies to minimise odours from kitchen stoves, toilet areas, cleaning products etc. • Preventive measures from birds and insects invading food accessible areas (e.g. seating areas, kitchens etc.) • Provision of feedback channel for corrective actions and follow-ups • Regular maintenance schedule and periodic review of the guidelines

Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Guidelines prepared and endorsed by the Client's representative, complete with commitment that the project team will brief the appointed Hawker Operator on the operational requirement.	• Guidelines and evidence on the handover process to the appointed Hawker Operator.

e. Provision of commitment to achieve "Happy Toilet" by Restroom Association Singapore (RAS) – 1 point

Definitions	To encourage and recognise toilet owners and operators for keeping their public toilets well-maintained.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Extract of the tender, or a signed commitment from the developer/ building owner that toilet operators shall apply for Restroom Association Singapore (RAS) Happy Toilet Programme.	• Letter of award or Happy Toilet certificate

f. Provision of commitment to undertake POE every 6 months – 0.5 point

Definitions	As part of the Smart Nation agenda, project is encouraged to adopt innovative and sustainable facilities management solutions to optimise management and operation.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Extracts of tender documents showing the provision of facilities management solutions • Method statements for the system integration/ operation	• User manuals and system integration and installation reports Purchase Summary

g. Provision of innovative and sustainable facilities management solutions to optimise management of Hawker Centres' operations such as of Internet of Things(IoT), cloud computing, cashless payment – 1 point.

h. Points achieved under the following credits carries double weightage;
   - 1.2a(iii) Urban Heat Island (UHI) Mitigation – 1 point
   - 3.3b Operational Waste management – 3 points
   - 4.2a Lighting – 6 points
   - 4.2c Wellbeing – 2 points
   - 4.3b(ii) Lighting Demand Control – 1 point

Annex 2: Energy Efficiency & Other Green Features [Healthcare Facilities]

Intent

Encourage use of innovative energy efficient equipment, system or design feature.

Scope

Applicable to healthcare facilities including hospitals, medical centres etc

Assessment

Min Point / Rating	Gold	Gold^PLUS	Platinum
Annex 2(d) Local Energy Generation for Centralised Service Hot Water Heating	-	-	1 pt
Annex 2(e) Onsite Airside Energy Recovery	-	-	1 pt

A maximum of 10 points can be scored for the following:

a. Use of energy efficient Uninterruptible Power Supply (UPS) systems – 1 point

Definitions

For all UPS rated >= 5 kVA operating in the following systems must meet the minimum efficiency:

Type	% Load	UPS Range (kVA)				
		≥5 to <10	10 to <20	20 - <40	40 - <200	≥200
Double conversion on-line mode	25% load	82.5%	86.5%	87.5%	89.0%	90.0%
	50% load	85.0%	91.0%	91.5%	92.0%	92.5%
	75% load	87.0%	92.0%	92.5%	93.0%	93.5%
	100% load	87.0%	92.0%	92.5%	93.0%	93.5%
Line interactive or ECO mode	25% load	85.5%	90%	91%	91.5%	93%
	50% load	91.5%	93%	93.5%	94%	95.5%
	75% load	92.5%	93.5%	94%	94.5%	96%
	100% load	92.5%	93.5%	94%	94.5%	96%
Stand-by mode	25% load	90%	94%	94.5%	95%	95.5%
	50% load	93%	96%	96.5%	97%	97.5%
	75% load	94%	96.5%	97%	97.5%	98%
	100% load	94%	96.5%	97%	97.5%	98%

Guidance Notes

The points awarded will be based on the aggregated kVA meeting the minimum efficiency as a proportion to the total installed kVA for UPS rated ≥ 5 kVA

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Drawing showing the schematic and layout of the proposed UPS system. • Technical specifications and product information of the various components of the UPS system.	Purchase Summary

b. Use of Low-loss service transformer – 1 point

Definitions

All the low-loss service transformers must meet the performance metric stipulated below:

Transformer capacity	No load loss at rated voltage	Full load loss at rated voltage
Transformer capacity > 1MVA	< 0.25% of rated load	< 2.5% of rated load
15 kVA ≤ Transformer capacity ≤ 1MVA	< 0.35% of rated load	< 2.5% of rated load

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Drawings showing the schematic of the proposed transformer system. • Technical specifications and product information of the various components of transformer system.	Purchase Summary

c. Computation of Service Hot Water Demand – for patients' wards, kitchen and restaurant/ café and additional service hot water demand for clinical & surgery, supply and sterilisation – 1 or 2 points respectively.

Definitions

To capture the actual service water heat load for healthcare facilities for domestic and service hot water demand and steam sterilization.

The SWH design flow rate is recommended to be computed based on the design flow rate per space type:

Space type	Design flow rate (litre/hr/person)	Space type	Design flow rate (litre/hr/person)
Patient room	69.6 (litre/hr) or 9 litre/min/person)	Imaging/laboratory	2.869
		Procedure room/trauma/triage	2.869
Kitchen	503.4 (litre/hr)	Operating suite	4.780
Café/Restaurant	1.434	Laundry/soiled linen	2.869
Examination/treatment room/intensive care	1.434	Sterilising	2.869

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Computation of service hot water demand. • Information in relation to the capability of the data acquisition system to store the measured hot water consumption data.	• Detailed record of hot water consumption.

d. Provision of solar thermal hot water system or heat pumps or combines heat & power (CHP) system or Photovoltaic Thermal (PV/T) or other low and zero carbon technology hot water system to meet service hot water heating demand. The performance of service hot water system shall meet the efficiencies as described below – 1 point. Thereafter, additional point for every 10% improvement from minimum efficiency stated for each category (max 5)

- Solar Thermal Hot water system – Solar Factor (SF) of 0.5 or Solar Energy Factor (SEF) of 2
- Hot Water System Ratio (HWSR) of 1.60 or Heat Pump – COP of 3.5
- Combustion turbine – based CHP – Effective electrical efficiency of 0.5
- Reciprocating engine based CHP – effective electrical efficiency of 0.7

Definitions

Provision of solar thermal hot water system or heat pumps or combines heat & power (CHP) system or Photovoltaic Thermal (PV/T) or other low and zero carbon technology hot water system to meet service hot water heating demand. The performance of service hot water system shall meet the efficiencies as described below:

- Solar Thermal Hot water system – Solar Factor (SF) of 0.5 or Solar Energy Factor (SEF) of 2
- Hot Water System Ratio (HWSR) of 1.60 or Heat Pump – COP of 3.5
- Combustion turbine – based CHP – Effective electrical efficiency of 0.5
- Reciprocating engine based CHP – effective electrical efficiency of 0.7

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Drawing showing the schematic and layout of the proposed centralised service hot water system. • Technical specifications and product information of the various components of the proposed centralised service hot water system.	

e. Promote airside energy recovery to all healthcare ventilation system through provision of energy – recovered device with no-recirculation (i.e. 100% of the room air to be exhausted). The energy transfers efficiency of energy – recovered device shall meet the below prescribed requirement – 1 point

- 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

Definitions

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). The energy transfers efficiency of energy – recovery device 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	
Design Stage	**Operation Document (for handover to FM)**
• 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.	Purchase Summary

f. Provision of process water management - 1 point

Definitions	To measure, manage and improve their efficiency in process water consumption using Water Efficiency Management Plan (WEMP) can be found in the PUB website: *www.pub.gov.sg/conserve/Documents/WEMP.xls*
Guidance Notes	This point is not applicable for mandatory WEMP submission in healthcare premises with water consumption >5,000m^3/month.

Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Extracts of tender documents showing the provision of process water management solutions. • Method statements for process water management plan.	• Detailed record of process water consumption.

g. Prevent air-borne contaminate releases and NOx emission from Fuel burning process – 1 point

Definitions

The emission limits of Carbon Monoxide (CO), Oxides of Nitrogen (NOx) and Particulate Matters (PM) from fuel burning process shall comply with the Code of Practice on Pollution Control (2000 edition) by NEA. In addition, Generator sets powered by engines up to 560kWm to meet hot water service demand shall meet Stage II emission:

Genset Power (kWm)	Oxides of Nitrogen (NOx) (g/kWhr)	Hydrocarbon (HC) (g/kWhr)	Carbon Monoxide (CO) (g/kWhr
18-36	8.0	1.5	5.5
37-55	7.0	1.3	5.0
56-74	7.0	1.3	5.0
75-129	6.0	1.0	5.0
130-560	6.0	1.0	3.5

OR

Generator sets powered by engines up to 560kWm to meet hot water service demand shall meet Stage III emission:

Genset Power (kWm)	Oxides of Nitrogen (NOx) (g/kWhr)	Hydrocarbon (HC) (g/kWhr)	Carbon Monoxide (CO) (g/kWhr
18-36	7.5		5.5
37-55	4.7		5.0
56-74	4.7		5.0
75-129	4.0		5.0
130-560	4.0		3.5

Guidance Notes

For generator sets ≥750kWm, it shall be installed, operated and maintained in calibration a NOx Continuous Emission System (CEMS) with data gathering and retrieval capability

Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Extracts of tender documents showing the emission of Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Particulate Matters (PM) and Hydrocarbon (HC) of generator sets.	Purchase Summary

h. Thermal comfort & control for each category of A/C space – 0.25 point each

- Public areas
- Patient and General Clinical Areas
- Clinical areas with Specialized Ventilation Systems
- Operating Theatre and Surgery

Definitions

Air-conditioning system is designed to ensure consistent indoor thermal comfort such that:

Area	Requirement
Public areas	The indoor operative temperature should be maintained between 24°C to 26°C, with relative humidity <65%, in accordance with SS553, Clause 7.2.
Patient and General Clinical Areas	The indoor operative temperature should be maintained at 24+2°C, with relative humidity <65%., or according to ASHRAE Handbook 2007 Table 3
Clinical areas with Specialized Ventilation Systems	The indoor operative temperature and relative humidity should be maintained according to HTM-03-01, Appendix 2 or equivalent international healthcare standards.
Operating Theatre and Surgery	The indoor operative temperature should be maintained between 18°C to 24°C with relative humidity ranging from 50% to 60% or according to HTM-03-01, Appendix 2.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of tender documents showing design specification to ensure consistent indoor thermal comfort for public area, patient and general clinic area, clinic area with specialized ventilation systems and operating theatre surgery. • Drawing showing the schematic and layout of the air conditioning systems. • Technical specifications and product information of the various components of the proposed energy-recovery device for re-heating.	• Detailed record of room air temperature and RH for public area, patient and general clinic area, clinic area with specialized ventilation systems and operating theatre surgery. Purchase Summary

i. Control of indoor thermal environment by re-heating the air by provision of site – recovered energy (including condenser heat) or site solar energy – 1 point

Definitions	Control of indoor thermal environment by re-heating the air is achieved by means of site-recovered energy (including condenser heat) or site solar energy.

Documentation Requirements

Design Stage	Operation Document (for handover to FM)
• Extracts of tender documents showing design specification to ensure consistent indoor thermal comfort for public area, patient and general clinic area, clinic area with specialized ventilation systems and operating theatre surgery. • Drawing showing the schematic and layout of the air conditioning systems. • Technical specifications and product information of the various components of the proposed energy-recovery device for re-heating.	Purchase Summary

Annex 3: Energy Efficiency & Other Green Features [Laboratories Buildings]

Intent

Encourage use of innovative energy efficient equipment, system or design feature.

Scope

Applicable to buildings with laboratories.

Assessment

Min Point \ Rating	Gold	Gold[PLUS]	Platinum
Annex 3(c) Onsite Airside Energy Recovery	-	-	1 pt

A maximum of 10 points can be scored for the following:

a. Use of energy efficient Uninterruptible Power Supply (UPS) systems – 1 point

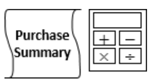
Definitions	As per *Annex 3 [Healthcare Facilities] item a.*
Documentation Requirements	As per *Annex 3 [Healthcare Facilities] item a.*

b. Design for variable ventilation and ventilation optimisation – 0.5 or 1 point per feature (up to 3 points)

Definitions	To reduce energy use in air-distribution systems through use of variable ventilation and ventilation optimisation.
Guidance Notes	Up to 3 points can be award for this item. 0.5 point or 1 point per feature.

Examples	Points per item
• Segregation of areas with different ACH design for more than 30% of applicable areas • Localised exhaust or provision of effective isolation zoning of heat-generating equipment for 30% of critical heat sources and instrument	0.5 point per feature
• Adopt risk based assessment to minimise lab ventilation rate • Segregation of areas with different ACH design for more than 70% of applicable areas • Localised exhaust or provision of effective isolation zoning of heat-generating equipment for 70% of critical heat sources and instrument • Reuse of return or recirculated cooled air from office/support areas for air make-up to laboratories areas or design for air recirculation within laboratory while meeting safety requirement. • Adopt VAV lab air flow and variable flow exhaust controls (Variable design) • Multi-stack exhaust plenum with staged-exhaust fans (Shut-off design)	1 point per feature

Documentation Requirements

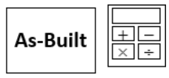
Design Stage	Operation Document (for handover to FM)
• Drawings showing the schematic and layout of the proposed variable ventiliation and/or ventilation optimisation strategies. • Computation of ventilation flowrate reduction and estimated energy saving.	

c. Promote airside energy recovery to all laboratory ventilation system through provision of energy – recovered device with no-recirculation (i.e. 100% of the room air to be exhausted). The energy transfers efficiency of energy – recovered device shall meet the below prescribed requirement – 1 point

- 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

Definitions	As per *Annex 3 [Healthcare Facilities] item e.*
Documentation Requirements	As per *Annex 3 [Healthcare Facilities] item e.*

d. Receptacle load benchmarking with existing lab to optimise cooling load design – 1 point

Definitions	Establish better operation estimate of proposed laboratory's receptacle load intensity through benchmarking with existing laboratory of similar nature. Computation of energy consumption will also take into consideration of diversity, occupancy and schedule of proposed laboratory.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Computation of receptacle load of existing laboratory with similar nature. • Comparison with established international reference. • Design to measure receptacle load of proposed laboratory and formulate methodology/guideline to facilitate that measurement in operation stage.	

e. Include lab specific energy-efficient items under Green Lease – 0.5 point
such as:
- Auto Sash Closure for Fume Hood
- Programmable timers for receptacles
- Use of energy efficient equipment

Definitions	Guide tenants to select and install more energy-efficient items under Green Lease to facilitate reduced energy consumption in operation. The list of items can include, but not limited to: • Auto Sash Closure for Fume Hood • Programmable timers for receptacles • Use of energy efficient equipment
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• List of lab specific energy-efficient items under Green Lease, align with 1.1d User Engagement – Green Lease. The list will include performance or certification requirement of these items.	

f. Green guideline to tenants/building users include monitoring of Air Change Rate or Air Changes per hour (ACH) – 1 point

Definitions	To ensure mechanisms are available to monitor air change rate operate as per required. Tenants should evaluate performance of systems and airflow needs, including non-occupancy hours, so as to reduce energy consumption within safety limits.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Details of guidelines stipulated to ensure tenants/building users monitor Air Change Rate or Air Changes per hour (ACH) for their laboratories.	• Air Change Rate or Air Changes per hour (ACH) chart for the laboratories. This could include strategies to improve the performance of systems and reduce airflow needs, including those during non-occupancy hours, in future. Strategies should reduce energy consumption while meeting safety requirements.

g. CFD study for exhaust air to prevent pollutants without sufficient dilution from entering neighbouring buildings – 4 points

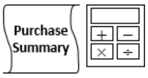
Definitions	The exhaust of laboratory buildings could harm occupants of neigbouring buildings if the air is taken as fresh air without sufficient dilution. Hence, it is necessary to evaluate exhaust air flow mechanism to prevent pollutant of exhaust from entering neighbouring building without sufficient dilution.
Guidance Notes	4 points shall be awarded conducting CFD study for exhaust air to prevent pollutants from entering neighbouring buildings without sufficient dilution. CFD study shall comply *Annex A: Computational Fluid Dynamics Simulation Methodology and Requirements*.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• CFD study with consideration of ➢ exhaust location and discharge height, ➢ wind speed and direction, ➢ terrain topology (including reasonable representation of surrounding buildings/structure), ➢ neighbouring buildings' fresh air intake locations, ➢ discharge elements, with reference to safety limit	• Onsite verification of installed exhaust system and neigbouring buildings with respect to study done during design stage.

h. (Option 1) Points achieved under 4.3 b(i) ACMV Demand Control credit carries double weightage
(Option 2) Setback control for Non-Occupancy Operation – 2 points

- ACH for non-occupancy hours to be <60% of maximum operating ACH (for Biological/Chemical Laboratories)
- Reduced ventilation/lighting operation during non-occupancy hours (for Physical Laboratories)

For Option 2

Definitions	During non-occupancy operation, pollutants that are harmful to human exposure could be of a higher value as long as they comply with fire safety requirements. During such a time, the dilution of air is set to a lower extent so as to facilitate energy saving with reduced air flow requirements.
Guidance Notes	2 points shall be awarded if there is setback control for non-occupancy operation which requires: - ACH for non-occupancy hours to be <60% of maximum operating ACH (for Biological/Chemical Laboratories) - Reduced ventilation/lighting operation during non-occupancy hours (for Physical Laboratories) This credit is scorable only if option 1 - double weightage for 4.03 b(i) ACMV Demand Control credit is not scored. It requires mechanism/systems in place to determine non-occupancy/occupany. Systems will need to resume back to occupancy mode when occupancy is determined and should cater for ramp-up for pre-occupancy.

Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Details of mechanisms to detect non-occupancy/occupancy and associated setback controls. • Specifications/catalogue of equipment (including sensors) to facilitate setback operations.	• Profile of setback due to non-occupancy and ramp-up due to occupancy for daily operations. 

Annex 4: Energy Efficiency & Other Green Features [Schools]

Intent

Encourage integration of environmental sustainability awareness into curriculum and enrichment education in schools.

To allow exposure and communication of environmental sustainability to the public in early ages.

Scope

Applicable to primary, secondary educational buildings.

Assessment

Min Point / Rating	Gold	Gold^{PLUS}	Platinum
Annex 4(b) Raising Awareness on Environmental Sustainability	-	-	1 pt
Annex 4(c) Communication of Efficiency Trends	-	-	0.5 pt

A maximum of 10 points can be scored for the following:

a. Provision, communication and dissemination of environmental policy that covers energy, waste and water management plan and green procurement– 0.5 point

Definitions	To set in place a policy statement that facilitates better environmental performance of energy and water management and promote waste minimisation, supports environmentally friendly procurement and purchases within the school. The communications and dissemination of environmental policy to school community increases awareness on the environmental responsibility of the school community.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Establish the following policies with endorsement by Client's representative (not limited to): ➢ Environmental Policy that covers energy, waste and water management plan for school community ➢ School's green procurement and purchase plans ➢ Key appointment holders for the operation including the persons responsible for review, implementation and roll-out of these action plans • State the target audience to disseminate the environmental policy	• Submission of evidence on the communication and dissemination of environmental policy to the school community (e.g. publish the policy on school website, emails, talks etc)

b. Raising Awareness on Environmental Sustainability through creation of Sustainability Education – 2 points (0.5 point each)

- Develop framework for Environmental Sustainability Education, such as incorporating bespoke curriculum to be taught to students of different levels,
- Setting up of environmental club
- Spread awareness on environmental sustainability amongst staff and students through posters, courses, competitions programmes or green corner.
- Implement student-led programmes or activities related to environmental sustainability.

Definitions	To increase environmental sustainability awareness amongst students and staff through proactive school wide efforts and sustainability education.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Commitment to raise environmental sustainability awareness through sustainability education.	• Framework developed for the Environmental Sustainability Education for students of different levels. • Document to show the environmental club activities and state the number of members in the club • Site visit to the green corner and poster displayed in school compound, documents on the courses and competitions carried out.

c. Communication of Energy and Water Efficiency Trends – 0.5 point

- Regular sharing of energy and water usage (minimally on monthly basis) through platforms such as newsletter, assembly and etc, with analysis on the reasons for the consumption trend.

Definitions	To encourage school to conduct continuous monitoring of their energy and water consumption and able to identify causes of sudden changes in energy and water consumption and implement necessary corrective actions. Through communication of the energy and water consumption trends, the school community can understand collective efforts from their action can adversely affect the school's energy and water consumption.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Commitment to continuous monitoring of their energy and water consumption and communicate to school community.	• Evidence on the materials used to communicate to the school community (e.g. tabulation of the monthly energy and water usage for the last 12 months and a graph showing the consumption trend). • Evidence on how energy and water trends is communicated to the school.

d. Higher ratio of functional areas with no air conditioning

- % of non-air-conditioned functional areas of total functional areas (based on table) – Up to 2 points

% Non-air-conditioned	Points
60% to ≤ 70%	1
70% to ≤ 80%	1.5
≥ 80%	2

Definitions	To encourage non-air conditioned functional areas within the school.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Relevant layout plans showing the non-air conditioned functional areas. • Calculations to determine the percentage of the non-air conditioned functional areas.	**As-Built**

Worked Example

A school has the following area in the school compound.

Functional Area	Air-con area	Non air-con Area
Classrooms, workshops	-	15,000 m^2
Staff room, administration block	500 m^2	
Multipurpose Hall, Library, Threatrette	6,000 m^2	
Indoor Sport Hall	-	1,000 m^2
Canteen	800 m^2	
Outdoor football field	-	1,000 m^2
Common areas (staircase, link bridge and walkway)	-	2,000 m^2

The total functional area *excludes outdoor football field and common areas (staircase, link bridge and walkway),* thus, the total functional area = 15,000 m^2 + 500 m^2 + 6,000 m^2 + 1,000 m^2 + 800 m^2 = 23,300 m^2

The percentage of non-air-con functional area = (15,000+1000) / 23,300 *100% = 68%

e. Minimising energy used to provide unnecessary or over-cooling – 2 points

- Setting room temperature of air-conditioned computer and LAN rooms to 24 degrees or above – 1 point
- Setting temperature of water in the water cooler to 15 degrees or above – 1 point

Definitions	To minimise energy used to provide unnecessary or over-cooling.
Documentation Requirements	
Design Stage	**Operation Document (for handover to FM)**
• Specification / documents which stated the room temperature of air-conditioned computer and LAN rooms will be set to 24 degrees or above. • Specification / documents which stated the water cooler used can be set to 15 degrees or above.	• Site visit to verify the temperature in the air-conditioned computer and LAN rooms is set to 24 degrees or above. • Site visit to verify the water temperature from the water cooler is higher than 15 degrees.

f. Points achieved under the following credits carries double weightage;

- 1.2a(iii) Urban Heat Island (UHI) Mitigation – 1 point
- 3.1b(ii) Water Usage Portal and Dashboard – 1 point
- 4,2a(ii) Quality of Artificial Lighting – 1 point
- 4.2c Biophilic Design –2 points
- 4.3a (i) Energy Portal and Dashboard – 1 point

Appendix A: Computational Fluid Dynamics Simulation Methodology and Requirements

General

The CFD simulation methodology requirements encompasses 4 segments: (i) Ventilation simulation, (ii) Thermal comfort, (iii) IAQ simulation and (iv) Wind driven rain.

Green Mark Scoring Requirements

To meet the intent of *1.3c Ventilation Performance* in the Green Mark NRB: 2015 Criteria, natural ventilation simulation shall be performed, and recommendations derived shall be implemented. Minimum average wind velocities at *Moderate* level shall be met for at least 70% of the NV occupied space to score.

For building developments with ≥ 2,000m^2 of naturally ventilated occupied spaces and targeting for Gold^{PLUS} or Platinum certification, the simulation results and the recommendations derived are to be implemented to ensure *Good* natural ventilation performance or *Very Good* natural ventilation performance respectively for at least 70% of the naturally ventilated occupied spaces.

In the event the wind velocity requirements to attain *Good* or *Very Good* natural ventilation performance are unable to be met due to certain constraints even after optimizing the building design, thermal comfort or air quality analysis shall be performed to meet the Thermal Comfort or Air Quality* requirements for naturally ventilated spaces in tropical climate. This is provided that the development has attained at least *Moderate* natural ventilation performance. All the occupied spaces shall satisfy the requirements for alternate compliance.

The requirements are summarised in the following table:

Points	Prerequisite for	Minimum Weighted Average Wind Velocity	Thermal Comfort	Air Quality
3	-	Moderate (0.2m/s)	-	-
4	Gold^{PLUS}	Good (0.4m/s)	-1.0 < PMV < +1.0	Air Change Rate ≥ 4 Air Exchange Effectiveness of ≥ 1.0
	Platinum	Very Good (0.6m/s)	-0.8 < PMV < +0.8	Air Change Rate ≥ 10 Air Exchange Effectiveness of ≥ 1.2

**The Air Quality criteria is only applicable for sports facilities and industrial buildings with occupancy densities less than 50m^2 per person.*

To score points under *Advanced Green Efforts*, wind driven rain simulation may be carried out for naturally-ventilated occupied spaces, to identify the most effective building design and layout that minimizes the impact of wind-driven rain ingress into the spaces.

Ventilation Simulation Methodology and Requirements

The natural ventilation simulation shall be carried out using Computational Fluid Dynamics (CFD) modeling to identify the most effective building design and layout for the development. The simulation results and recommendations derived are to be adopted to meet the intent of the criteria.

(i) Simulation Software

The CFD modeling shall be carried out using well validated software. The CFD solver shall have the minimum capability of solving the Navier-Stokes fluid flow equations for a three-dimensional incompressible flow at steady state. Turbulence modeling shall also be included with the minimum requirement of using the standard k-ε turbulence model, coupled with the standard wall function. (*Note: It is recommended to use the enhanced RANS eddy viscosity model (apart from the minimum realizable k-ε turbulence model) and RANS Reynolds Stress Model.*)

(ii) Conditions

All simulation models shall be carried out under isothermal conditions of 30.0°C air temperatures at steady state condition. If the impact of heat sources is significant, heat source modeling shall be included. (*Note: The aggregated heat load from heat dissipating devices shall be modelled. Boussinesq or variable density can be used.*)

(iii) Computational Domain and Surrounding Buildings

The computational domain shall include the development of interest and the far field boundary which should be located far enough from the building model to avoid artificial acceleration of the flow. As a general guideline, the direction blockage ratio (BR_L & BR_H) along lateral and vertical directions should be less than 17%.

$$BR_L = \frac{L_{Buildings}}{L_{Domain}} < 17\% \qquad BR_H = \frac{H_{Buildings,max}}{H_{Domain}} < 17\%$$

It is also important to ensure that the blockage ratio (BR) arising from the projection of building frontal to the domain enclosure is no larger than 3%.

The surrounding buildings residing within 500 m distance from the edge of development of interest should be modelled explicitly. In the event that the building and surrounding development are located within hilly terrain with elevation more than 10 m height, the topography information should also be included in the simulation models to capture the wind redistribution arising from terrain gradient and vicinity effect. The ground surface beyond surrounding buildings site can be modelled implicitly using the Davenport-Wieringa roughness classification.

(iv) Grid size

The computational grid generated for all simulations shall resolve the salient flow features in the naturally ventilated spaces and around the development. The recommended grid sizes are as follows:

Location	Grid Size (m)
Within the functional spaces of interest	0.1 – 0.5
Building of interest	0.5 – 1.0
Surrounding building	1.0 – 5.0
From ground surface to 10m height in vertical direction	0.5 – 1.0
From 10m height to H_{max} height in vertical direction, (H_{max} is the height of the tallest building among the group of buildings modelled explicitly)	1.0 – 5.0

As a guide, the dimension of the computational elements is advised to follow the principles such as:

- Proper domain decomposition should be carried out to ensure a good quality mesh can be obtained.
- Hexahedra or prism body-fitted grid are preferred.
- A grid independent test shall be performed at the functional space through grid refinements in areas with sharp gradients.
- In terms of the computational cell quality, the skewness of the cell is advised no greater than 0.9.
- The maximum stretching ratio for near building cell size should be kept to be less than 1.4.

Boundary Condition & Turbulence Modeling

(a) Inlet Atmospheric Boundary Condition

Based on local climatic wind conditions, meteorological data on the precise wind direction and velocity of the proposed site location for the months of December, March, June and September shall be used for the CFD simulation. The prevailing wind conditions, such as the mean speed and direction for Singapore, shall be based on NEA's 18-year data at a reference height of 15.0 m as follows:

Wind Direction	Mean Velocity (U_{ref}) (m/s)
North	2.0
North-East	2.9
South	2.8
South-East	3.2

The inbound vertical wind profile shall be assumed to be given by the Logarithmic Law with reference height at 15.0 m. The wind profile shall be determined by using the following equations:

$$U(z) = \frac{u^*_{ABL}}{\kappa} \ln\left(\frac{z+z_0}{z_0}\right); \quad k(z) = \frac{u^{*2}_{ABL}}{\sqrt{C_\mu}}; \quad \varepsilon(z) = \frac{u^{*3}_{ABL}}{\kappa\,(z+z_0)}; \quad u^*_{ABL} = \frac{U_{ref}\,\kappa}{\ln\left(\frac{h+z_0}{z_0}\right)}$$

Where

u^*_{ABL}: Atmospheric boundary layer (ABL) friction velocity
κ: von Karman constant (0.42)
C_μ: A constant, generally taken equal to 0.09
z_0: Aerodynamic roughness length
U_{ref}: The specified velocity at reference height h

The aerodynamic roughness length z_0 for wind profile should be selected from the updated Davenport-Wieringa roughness classification as follows, to match the terrain category of the development site of interest, including the tree/greenery effect.

z_0 (m)	Landscape Description
0.0002 Sea	Open sea or lake (irrespective of the wave size), tidal flat, snow-covered flat plain, featureless desert, tarmac, concrete, with a free fetch of several kilometres
0.005 Smooth	Featureless land surface without any noticeable obstacles and with negligible vegetation; e.g. beaches, pack ice without large ridges, morass, and snow-covered or fallow open country.
0.03 Open	Level country with low vegetation (e.g. grass) and isolated obstacles with separations of at least 50 obstacle heights; e.g. grazing land without windbreaks, heather, moor and tundra, runway area of airports.
0.10 Roughly open	Cultivated area with regular cover of low crops, or moderately open country with occasional obstacles (e.g. low hedges, single rows of trees, isolated farms) at relative horizontal distances of at least 20 obstacle heights.
0.25 Rough	Recently-developed "young" landscape with high crops or crops of varying height, and scattered obstacles (e.g. dense shelterbelts, vineyards) at relative distances of about 15 obstacle heights.
0.50 Very rough	"Old" cultivated landscape with many rather large obstacle groups (large farms, clumps of forest) separated by open spaces of about 10 obstacle heights. Also low large vegetation with small interspaces such as bush land, orchards, young densely-planted forest.
1.0 Closed	Landscape totally and quite regularly covered with similar-size large obstacles, with open spaces comparable to the obstacle heights; e.g. mature regular forests, homogeneous cities or villages.
≥ 2.0 Chaotic	Centres of large towns with mixture of low-rise and high-rise buildings. Also irregular large forests with many clearings.

(b) <u>Ground Surface</u>

Using appropriate roughness parameters is an essential component for accurate simulation of Atmospheric Boundary Layer (ABL) flow. The two types of roughness parameters, (i) aerodynamic roughness length z_0 and (ii) equivalent sand-grain roughness height k_S, should be applied on different surface areas as listed:

Ground Surface Area	Roughness Parameter
Area 1: From domain Inlet boundary to the boundary of explicitly modelled buildings	Aerodynamic roughness length z_0
Area 2: Within the region of explicitly modelled buildings	Aerodynamic roughness length z_0
Area 3: Within the site boundary of the development of interest	Equivalent sand-grain roughness height k_S

The region of inlet, approach and incident flow at the upstream of computational domain should be modelled with appropriate aerodynamics roughness length z_0 as well as the relationship between equivalent sand-grain roughness height k_S with the corresponding aerodynamics roughness length z_0.

(c) Top and Lateral Surface of Domain

Use zero velocity gradients and zero normal gradients, i.e. "symmetry" condition, for all variables at the top and lateral surface when the top and lateral boundaries of the domain are far away enough from the buildings (refer to the requirements on the domain size).

(d) Outlet Surface of Domain

Use zero static pressure as the boundary condition at the outlet surface of computational domain.

(v) Discretization Schemes

In all circumstances, the users should attempt to apply 2nd order discretization schemes, which are preferred over 1st order discretization schemes to avoid numerical diffusion.

(vi) Convergence Criteria

To ensure the changes in solution variables from one iteration to the next are negligible, residuals with at least 4 orders of magnitudes shall be achieved. In addition, monitoring points should be defined in the region of interest and the velocities at those points should be recorded to ensure that the flow has reached steady values when simulation is converged properly.

(vii) Design Iteration

There shall be at least two iterations of simulation models to assess the wind flow conditions and air-flow pattern within the development to demonstrate the improvement in natural ventilation design. The simulation modeling can be conducted based on the two best prevailing wind directions for the building development that is North or North-East and South or South-East.

The naturally ventilated occupied spaces at the lowest level shall be selected for simulation. All naturally ventilated functional spaces at the selected floor are to be included in the simulation model except for enclosed spaces such as storerooms or CD shelters.

From the simulation results, the area-weighted average wind velocity of each simulated space shall be determined by considering the air flow conditions of the applicable areas. The area-weighted average wind velocities of these areas are to be computed at a horizontal-plane of 1.2 m above the floor level.

Thermal Comfort Simulation Methodology and Requirements

The thermal comfort assessment, where required, shall be carried out using Predicted Mean Vote (PMV) equation to identify the most effective building design and layout for the development. The assessment and simulation results and recommendations derived are to be adopted to meet the intent of the criteria.

For occupied spaces with natural ventilation performance unable to satisfy the minimum velocity prerequisites for the corresponding Green Mark ratings, mechanically assisted ventilation shall be provided and thermal comfort modeling shall be performed. The Predicted Mean Vote (PMV) shall meet the thermal comfort criteria for naturally ventilated spaces in tropical climate. Thermal comfort assessment shall be based on the PMV equation as follows:

$$PMV = a + b \times DBT + c \times WIND$$

Building Type	Value of a	Value of b	Value of c	Baseline of DBT(°C)
Industrial buildings	-4.974	0.202	-0.181	30
Healthcare facilities	-8.405	0.322	-0.686	30
Commercial atrium	-9.252	0.343	-0.747	31*
Hawker centres	-13.075	0.443	-0.460	32
Sport faciliteis	-9.945	0.379	-1.658	30
Schools	-6.805	0.267	-0.87	31
Note: The PMV value is to be rounded up to one decimal point.				

Where

DBT: Indoor air temperature (°C).

**DBT value for commercial atrium can be derived from the result of simulation that considers solar radiation, thermal load from human and equipment for event.*

WIND: Indoor wind velocity (m/s). The value shall be derived from the result of indoor ventilation simulation via the Ventilation Simulation Methodology and Requirements in this annex. Natural ventilation simulation with fan modeling can be performed based on occupied spaces alone, without the inclusion of external domain with prevailing wind flow condition.

IAQ Methodology and Requirements

The Air Quality simulation shall be carried out using computational fluid dynamics (CFD) modeling to identify the most effective building design and layout for the development. The assessment and simulation results and recommendations derived are to be adopted to meet the intent of the criteria. This option is only applicable for sports facilities and industrial buildings with occupancy densities less than 50m^2 per person.

(i) Air Change Rate

The air change rate calculation shall be calculated based on the following equation:

$$ACH = \frac{3600\ Q}{Vol}$$

Where

Q: Air flow through the occupied spaces (m^3/s), determined from the result of indoor ventilation simulation via the Ventilation Simulation Methodology and Requirements in this annex
Vol: Volume of the room (m^3)

Air Exchange Effectiveness (AEE)

In addition to ventilation simulation, species transport modeling shall be performed based on steady state. The tracer gas is recommended to be released through constant volume dosing within the occupied spaces of the natural ventilated building. In order to avoid the impact of gravity on the concentration distribution, the molecular weight of the injected tracer gas should be similar to air. The calculation of air exchange effectiveness shall be based on the concentration of tracer gas within the occupied spaces following the rule of mass balance.

The AEE shall be calculated based on the following equation:

$$\varepsilon_a = \frac{\frac{1}{\sum A_i}\sum C_{i,out}A_i}{C_{eq}}$$

Where

ε_a: Air exchange effectiveness
A_i: Face element area at the out-flow openings
$C_{i,out}$: Concentration of tracer gas in the outflow air
C_{eq}: Average tracer gas concentration in the room when steady state is reached, which represents the equilibrium conditions

Wind Driven Rain Methodology and Requirements

If the project is targeting to score for Wind driven rain (WDR) simulation under *Advanced Green Efforts*, WDR shall be carried out to identify and to reduce the severity of rain penetration into functional spaces of the development. Four different raindrop sizes are to be analyzed. From the simulation results, the depth of rain penetration (measured from the fenestration opening) into the functional spaces of the development shall be determined, and the most effective mitigation method to reduce the severity of rain penetration without manual behavioural intervention identified. The simulation results and recommendations derived are to be adopted to meet the intent of the criteria if points are to be scored.

Green Mark points = Overall WDR points x Multiplier
The severity of rain penetration into functional spaces (per analysed wind direction) may be broken down into the following 3-scale rating system as follows:

Mitigation of WDR	Depth of rain penetration						WDR Points
	Industrial Building	Healthcare facilities	Commercial atrium	Hawker centre	Sports Facility	Schools	
1. Very good (no noticeable penetration of WDR)	≤ 0.20 m	≤ 0.10 m	≤ 2.00 m	≤ 1.60 m	≤ 1.60 m	≤ 0.50 m	1.0 pt
2. Good (some but acceptable degree of penetration of WDR)	≤ 0.40 m	≤ 0.20 m	≤ 4.00 m	≤ 3.00 m	≤ 3.20 m	≤ 0.90 m	0.9 pt
3. Moderate (substantial penetration of WDR, barely acceptable)	≤ 0.75 m	≤ 0.30 m	≤ 6.00 m	≤ 4.40 m	≤ 4.80 m	≤ 1.40 m	0.8 pt

The multiplier takes into account of the frequency of WDR occurrence which is broken down into the following 3-scale rating system as follows:

Type of Rain	Return Period	Multiplier
1. Type 1 Rain (no WDR risk)	Return Period ≤ 2 months	0.8
2. Type 2 Rain (low WDR risk)	Return Period ≤ 6 months	0.9
3. Type 3 Rain (high WDR risk)	Return Period > 6 months	1.0

The methodology will use the CFD methodology outlined within the section on *Ventilation Simulation Methodology and Requirements* and adapt it to the following requirements as highlighted below:

(ii) Software

The software shall be also be capable of second-order discretization schemes with Lagrangian particle tracking.

(iii) Boundary Condition & Turbulence Modeling

(a) Inlet Atmospheric Boundary Condition

The inbound vertical wind profile shall be assumed to be given by the Logarithmic Law with reference height at 15.0 m. The prevailing wind condition during raining period such as the wind velocity magnitude of different return periods for Singapore shall be based on NEA 32-year data at a reference height of 15.0 m as follows:

Wind Direction [deg]	N 000□	NE 045□	E 090□	SE 135□	S 180□	SW 225□	W 270□	NW 315□
Return Period (months)	Wind Velocity (m/s)							
1	2.9	3.8	4.4	4.5	4.4	3.5	3.4	3.0
2	3.9	4.9	5.0	5.2	5.2	4.4	4.1	3.6
3	4.8	5.8	5.5	5.9	5.8	5.2	4.8	4.1
4	5.4	6.3	5.9	6.3	6.3	5.7	5.2	4.4
6	6.2	7.1	6.3	6.8	6.8	6.3	5.7	4.8
9	7.0	7.8	6.7	7.3	7.4	7.0	6.3	5.2
12	7.5	8.4	7.0	7.7	7.8	7.4	6.6	5.5

(b) Rain Drop Size

Four different raindrop sizes shall be analysed, and the respective terminal velocity ($V_{terminal}$) of different raindrop sizes are as follows:

Raindrop Diameter [mm]	$V_{terminal}$ (m/s)
0.5	-2.0
1.0	-4.0
2.0	-6.5
5.0	-9.0

(c) Drag Coefficients

The drag coefficients for the raindrops (C_d) is a function of the relative Reynolds n umber (Re) and shall be taken from the table as follows:

Re (-)	C_d (-)	Re (-)	C_d (-)	Re (-)	C_d (-)	Re (-)	C_d (-)
1.80	15.0	269.0	0.671	1,461.0	0.498	2,772.0	0.615
9.61	4.20	372.0	0.607	1,613.0	0.503	2,905.0	0.635
23.4	2.40	483.0	0.570	1,764.0	0.511	3,033.0	0.660
43.2	1.66	603.0	0.545	1,915.0	0.520	3,164.0	0.681
68.7	1.28	731.0	0.528	2,066.0	0.529	3,293.0	0.700
98.9	1.07	866.0	0.517	2,211.0	0.544	3,423.0	0.727
134.0	0.926	1,013.0	0.504	2,357.0	0.559	3,549.0	0.751
175.0	0.815	1,164.0	0.495	2,500.0	0.575		
220.0	0.729	1,313.0	0.494	2,636.0	0.594		

(d) Other Settings

Piecewise integration of raindrop equation of motion performed under Lagrangian Particle Tracking shall not be larger than 0.05 m length step size.

The injection location of raindrops shall be located inside the computational domain and outside the zone that is influenced by the buildings. The raindrops shall be released high enough to enable them to reach their terminal velocity of fall. It is recommended to use the following general rules to select the raindrop injection planes inside the computational domain:

- The width and length of the plane should be larger than that of the building of interest
- The vertical location of the plane depends on the velocities and raindrop diameters:
  - Higher velocities require a lower vertical location
  - Larger raindrops require a higher vertical location
- The horizontal location depends on the chosen height of the injection plane, the raindrop diameter and the reference wind velocity chosen for the simulation (recommended to be located at least 15H from the target building)

Guidance Notes

The following are guidance notes to help project teams keep track of their natural ventilation design and simulation progress.

Guidelines	Description/Selection	Response & Criteria
Submission Details		Provide the project details (especially information on natural ventilated design, building massing/orientation, GFA of natural ventilated spaces, % of opening & windows, credible source of site information with surrounding buildings, vegetation and terrain, future development etc.)
Building Type	Hospitals, schools, hawker centres, sports facilities, commercial atriums or industrial facilities	Describe building functionality, targeted natural ventilated spaces and occupants, transit area
Problem Statement	Objective & Work Scope	Describe natural ventilated challenges, proposed solution, desired outcome and work scopes from the simulation model. Whenever necessary, use the architectural drawing for explanation. Describe design stages and fix simulation details. Subsequent design change has to be supported by simulation results.
Site Information	Within 500m distance stream wise and span wise from the edge of development of interest	Describe the site information (including surrounding buildings, terrain, greenery), and illustrate how the geometrical info is incorporated into the simulation model (conversion process). Surrounding buildings within 500m distance stream wise and span wise from the edge of development of interest should be modelled explicitly; while the greenery can be modelled implicitly with tree canopy approach. Terrain effect can be ignored if elevation is less than 10m.
CFD Approach	Simulation Methodology	The CFD solver shall have the minimum capability of solving the Navier-Stokes fluid flow equations for a three-dimensional incompressible flow at steady state. Turbulence modeling shall also be included with the minimum requirement of using the standard k-ε turbulence model, coupled with standard wall function

Guidelines	Description/Selection	Response & Criteria
	Assumption & Simplification	Describe simulation model assumption, limitations and geometrical simplification. Whenever necessary, use the published literature data (including software manual) and comparison between architectural & CFD model for explanation
CFD Domain	Computational Domain	Describe the domain decomposition methodology; and relevant meshing type for each domain within the site. Describe the domain that be modelled implicitly with Davenport Roughness classification
CFD Meshing	Mesh independence study	To perform mesh independence study for natural ventilated occupied spaces
	Mesh size, distribution and quality	To carry out proper domain decomposition. To use hexahedral cells in the rectangular domain of NV space. Tetrahedral cells can be used to model the surrounding site features of the NV space. Hybrid pyramid or cut-cell mesh can be adopted at the interface. For implicit modeling of terrain roughness effect, prismatic or hexahedral cells is recommended to be used. As a guide, the dimension of the computational mesh should be set at 0.1 to 0.5 m within the functional space of interest, 0.5 to 1.0 m for building of interest and 1.0 - 5.0 m for surrounding buildings. The computational element size in vertical direction should be set at 0.5 - 1 m from ground surface to 10m height; followed by 1 - 5m to H_{max} height. Reporting on skewness and aspect ratio of the mesh is required.
CFD Model	Atmospheric Boundary Layer	1. To ensure horizontal ABL homogeneity in upstream and downstream 2. To ensure sufficiently high mesh resolution in vertical direction near ground (e.g. height of first cell < 1m) 3. To know the relationship between equivalent sand-grain roughness height (k_s) and corresponding aerodynamic roughness height, z_o 4. To ensure first cell center point (y_p) to be larger than physical roughness height (k_s)
	Buoyancy	To use Boussinesq or variable density and check gravity direction, if thermal simulation is performed.
	Turbulence model	To use the steady Reynolds-Average Navier Stokes (RANS), with minimum requirement k-ε turbulence model equation for NV flow.
CFD Boundary Conditions	Inlet wind profile	To ensure the vertical profile for wind velocity and turbulence in the ABL should be modelled by assuming constant shear stress with height.
	Top & lateral sides of domain	To use zero velocity gradients and zero normal gradients of all variables.
	Outlet plane	To use zero static pressure.
	Window modeling	To use actual window opening size. Attach window schedule and drawing for verification.
	Mechanical fan modeling	To use fan input with appropriate swirl radial and swirl flow components.
	Louver modeling	To use simplified porous zone with appropriate pressure drop components and directional effect.
	Heat source modeling	To use aggregated heat load from heat dissipating devices, such as cooking stalls for hawker center facilities, heat generators for industrial facilities and etc.
CFD Numerical	Discretization scheme	To use 2nd order for momentum equations
	Convergence criteria	To ensure solution is converged and monitored points at functional space reach steady values
User		Training, experience, consult expert
Documentation		Full documentation of parameters, readable scale
Design Iteration	Baseline case Modified case Optimal case	Baseline case – fixed building massing and layout Modified case – to highlight improvement on NV design Optimal case – final design with incorporation of NV features or passive innovative ideas

Documentation Requirements

Design Stage

The Qualified Person (QP) and the other appropriate practitioners shall ensure that the following report and building 3D model are available as evidences to demonstrate compliance with the ventilation simulation framework. The report should comprise the following items:

1.0 Cover page with a proper title, design image of development, developer's information (including developer's name and address and person-in-charge), consultant's detail (including the principal's name and authorized signature, firm's address and person-in-charge)

2.0 Table of Contents

3.0 Executive Summary

- Background of the development
- Main findings
- Concluding remarks

4.0 Background/ Introduction

- Building and site information
- Design strategies
- Detail of natural ventilation spaces (location, area, window to wall ratio etc.)

5.0 Methodology

- Describe methodology used in the study

6.0 Geometrical Model

- Isometric view of the development from various angles
- Domain size used
- Plan and 3D isometric model of units from various angles

7.0 Simulation settings

- Boundary conditions
- CFD software/ models used/ numerical scheme
- Mesh / cell sizing
- Solution control-convergence criteria

8.0 Result and Discussions

- Simulation results for the development for all directions showing the main graphical plots of the plan pressure and velocity vector and salient findings
- Tabulation showing the listing and details of all simulated NV spaces and the area-weighted average wind velocity within each simulated space where applicable

9.0 Conclusion

10.0Appendix: The following plots are to be placed in the appendices:

- Simulation results for the development for each direction
  - Static pressure (plan view-ground & mid elevation and at the level of simulated NV space, isometric views on building façade)
  - Velocity vector and contour showing the plan view at ground & mid elevation and at the level of simulated NV space, and a few isometric sectional cut plans to show air-flow patterns across the development
- Simulation results for the natural ventilated spaces for each direction
  - Static pressure (plan view at the level of simulated NV space)
  - Velocity vector and contour showing the plan view at the level of simulated NV space, and a few isometric sectional cut plans to show air-flow patterns across the NV space

If thermal comfort modeling or air quality assessment is attempted, a corresponding chapter in the report shall be added to show the relevant calculations.

If WDR simulation is carried out, a chapter in the report shall be added to show the results of Wind Driven Rain penetration under different wind directions and the calculation of Green Mark points for WDR performance. The report also shall contain the following information:

- Injection location of the raindrop into the computational domain (plan and sectional views)
- Raindrop trajectory into functional spaces (plan and sectional views)
- Tabulation showing the listing and details as well as the corresponding depth of rain penetration of all occupied spaces where applicable.

Verification Stage

- The project team shall declare if any changes had been made in actual built layout compared to the submitted 3D ventilation simulation model in the design stage. The re-assessment of ventilation simulation will depend on the extent of changes and their impacts on NV performance.
- If thermal comfort modeling assessment is attempted, the post occupancy survey on the thermal comfort level is required.

Appendix B: Effective Daylighting Simulation and Pre-Simulated Daylight Availability Tables Methodology and Requirements

General

The extent of effective daylighting in buildings may be determined using the (i) simplified pre-simulated Daylight Availability tables for standard designs building and spaces, or (ii) through detailed daylighting simulations. Both of these methods are outlined in this appendix. The following terms are used in order to describe the lighting quality of the design of an entire building or a specific space:

(a) Daylit area: Daylight Autonomy (DA) is a metric that describes the annual sufficiency of natural lighting levels in an indoor space relative to a desired illuminance level. The daylit area is defined as the unit area of space which has a daylight illuminance level meeting or greater than the code lux requirement (N lx) for more than 50% of the building's occupied hours, denoted by $DA_{N\ lx}$, 50%

(b) Overlit areas: Useful Daylight Illuminance Exceeded (UDIe) is a metric that describes the frequency of which daylight illuminance levels reach or exceed an acceptable threshold of 3000 lx. The overlit area is defined as the area of space where daylight illuminance levels area equal to or greater than 3000 lx for 10% or more of the building's occupied hours, denoted by $UDIe_{3000\ lx,\ 10\%}$. Overlit areas are likely to lead to increased potential for visual discomfort in a space. $UDIe_{3000\ lx,\ 10\%}$ may be also be expressed or calculated as $DA_{3000\ lx,\ 10\%}$, its equivalent

Daylight Autonomy Requirements

The specific daylight autonomy requirements are detailed for the various types of occupied spaces:

S/N	Space Occupancy Type	Daylight Autonomy requirement per unit area of space
1	Offices and 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 and residential style occupancy where lux requirement is 200 lux	$DA_{200lx,\ 50\%}$
Note: The minimum lighting level is given by SS531 for non-residential type buildings and CP38 for residential type buildings		

Overlit areas should not be counted as comfortably daylit for occupants. The total comfortable daylit area should be calculated as $UDIe_{3000\ lx,\ 10\%}$ subtracted from $DA_{N\ lx,\ 50\ \%}$. The $DA_{N\ lx}$ and $UDIe_{3000\ lx}$ are to be calculated using the following program-specific occupied periods:

- Hotels and residential-style occupancy: 7:00 AM to 10:00 AM and 4:00 PM to 7:00 PM every day of the year
- Others: 8:00 AM to 5:00 PM every day of the year

Buildings with a consistently unusual occupancy schedule may seek approval to pursue a custom occupancy period.

Note: The project is required to show that effectively daylit areas are integrated with automated lighting controls, i.e. the design and installation and operation of artificial lighting are integrated with the availability of daylighting to the space. Project is required to show that effective mitigation strategies are provided to spaces found to have the risk of overlighting or are overlit.

Effective Daylighting Simulation Methodology

Buildings with unusual forms, double-height spaces, complex facades, top-lighting strategies, advanced daylight redirection systems or other specialized design strategies, should use the full detailed daylighting simulation method to quantify the availability of natural daylighting specific in terms of Daylight Autonomy (DA) requirement. The results and recommendations derived from the simulation are to be used for assessment of criteria requirement.

(i) Simulation Software

The computational modeling shall be carried out using well documented software that has the capability to carry out daylighting simulation as per the stipulated details and granularity of the methodology. A tool should be chosen that can accurately account for geometry and material properties of buildings for an annual, 8760-hour, lighting calculation while producing the $DA_{N\ lx}$ and $UDIe_{3000\ lx}$ metrics. Simulation parameters should be chosen, regardless of the tool, which are capable of accurately representing the complexity of the interaction between light, geometry and material being considered. The tool should be capable of calculating enough bounces of light to represent the reflections of ambient light deep into the space. The following minimum parameters are recommended in Radiance and Daysim-based analysis engines:

Parameter Name	Command Line Shorthand	Value
Ambient bounces	-ab	6
Ambient divisions	-ad	1500
Ambient accuracy	-aa	0.1
Ambient supersamples	-as	500
Direct threshold	-dt	0

Below are examples (non-exhaustive) of acceptable simulation software tools. Most of these tools are interfaces to the Radiance and/ or Daysim lighting simulation engines.

Software Name	Plug-in for (if applicable)	Remarks
DIVA-for-Rhino	Rhinoceros 3D	
Ecotect	-	$UDIe_{3000\ lx}$ must be simulated separately as $DA_{3000\ lx}$.
Groundhog	Sketchup	
IES-VE	-	
Ladybug	Rhinoceros 3D	$UDIe_{3000\ lx}$ must be simulated separately as $DA_{3000\ lx}$.
Lightstanza	-	Availability of required output metrics should be verified.
OpenStudio	Sketchup	Results are only available as tabulated results, not spatial visualizations.
Sefaira	Sketchup & Revit	Availability of required output metrics should be verified.
SPOT	Excel	
VI-Suite	Blender	

(ii) Analysis Points and Sensor Grids

Sensor points for analysis should be placed in every space being analysed using a uniform grid where the spacing between adjacent sensors is no further apart than 60 cm. A 30 cm grid is recommended, and denser grids are permitted in the analysis. Analysis points that receive a maximum instantaneous lighting level of 1 lux throughout the year can be excluded from the analysis, presuming they are contained within an opaque object or non-daylit space such as a wall or closet.

(iii) Climate Data

All annual simulations should be run using hourly climate data input from IWEC weather data. The sky luminance distribution should be approximated at each hour using the Perez all-weather sky model, which is the default calculation mode in Radiance and Daysim-based annual climate-based analyses and for all of the tools listed in the simulation software section above.

(iv) Computational Domain

The computational domain for all simulations shall include the development of interest, the characteristics of the immediate surroundings and buildings at a large scale level. Generally, all relevant storey levels of each building tower together with the interior design layouts (such as walls and partitions) and properties of the following are to be considered in the simulation of daylighting and overlighting in occupied spaces. However, it is permissible to analyse typical rooms for each orientation and urban context of the building and extrapolate those results to the entire built floor area using individual room data.

(v) Materials and Objects

3D models of buildings and occupied spaces should be modelled with appropriate geometric complexity, being as close to 'as-built' as possible including the physical form, placement of windows, mullion details, thickness of opaque building components, exterior and surrounding obstructions and material properties. Interior partitions and exterior walls should be modelled accurately and with their intended thicknesses. The floor-to-ceiling height should be accurate and account for architectural finish details such as dropped ceilings. Some aspects to highlight are as follows:

a) Exterior Obstructions and Shading Devices

Exterior obstructions within a distance of 40 m from the building façade being studied, which will cast shadows and reflect light, shall be modelled, e.g. louvers, overhangs, fins and balconies, exterior buildings. Exterior buildings adjacent to the site shall be modelled within 4 m of geometric accuracy. Trees may be modelled as appropriately dimensioned cones or spheres with material properties.

b) Furniture and Partitions

When a furniture design is known, furniture surfaces and half-height partitions (cubicle walls, for example) that are higher than 90 cm above the finished floor height shall be modelled within 15 cm of geometric accuracy.

c) Skylight and Window Details

Skylight and window details greater than 5 cm in any direction, including sills, jambs, sashes and mullions shall be modelled in 3 dimensions, taking into account, the thickness of the wall or ceiling in which they are set, e.g. the skylight well (a vertical offset between its glazing surface and the ceiling). When the details of window framings and skylights are not known, a 20% and 10% reduction to the visible transmittance of the glass (T_{vis} value of 0.45) may be applied respectively instead.

d) Small Details

Small details that will have little impact on the lighting distribution need not be modelled, e.g. door handles, HVAC diffuser grills, wall electrical panels, etc. An object should be modelled separately when it is larger than 3 m^2, is parallel to and near a larger surface, and with material reflectance more than 20% from the surrounding surfaces.

e) Transmittance and Reflectance Properties of Materials

The transmittance and reflectance properties of materials shall be defined based on measurements, construction finish specifications or glazing specifications where known. The value of the glazing visible light transmittance (T_{vis}) shall be extracted from the glazing specifications used for the project, such as in ETTV calculation. Otherwise, T_{vis} value of 0.45 (transmissivity of 0.491) may be used for glass materials. For reflectance values, the following default values may be used:

Materials		Reflectance Value
Wall or partition		0.70
Floor	Carpet	0.20
	Tiles	0.40
	Plasters	0.70
Furniture	Any type	0.50
Ceiling	Any type	0.80
Roof	Any type	0.10
Exterior	Asphalt pavement	0.10
	Grass	0.20
	Tree	0.20
	Paving blocks	0.30
	Building facades	0.35
	Stainless steel	0.85
	Swimming pool water	0.90

(vi) UDIe and Potential for Overlighting

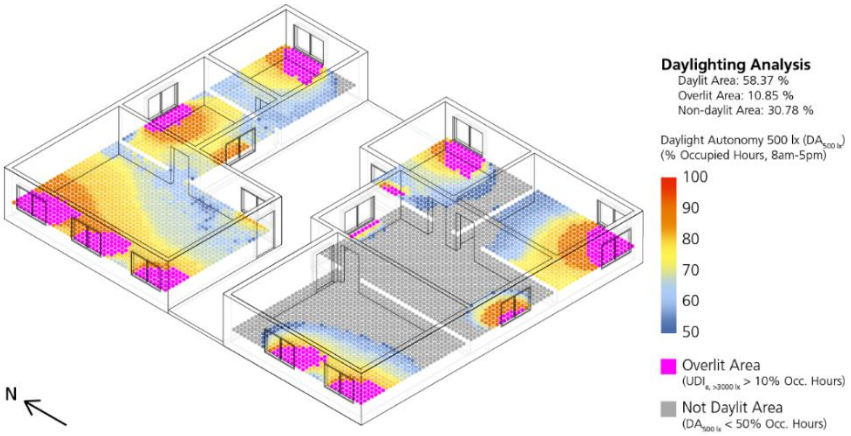
Building spaces with $UDIe_{3000\ lx,\ 10\%}$ covering 15% or more of the floor area in a simulation-based or exceeding 1.3 m depth of penetration measured from the façade using the pre-simulated tables are considered to be overlit and are considered not meeting the requirement for effective daylight.

In this case, design modifications and mitigation strategies for overlighting should be incorporated to reduce overlighting. For example, fixed shading devices can be added or the area of glazing reduced. Fully automated dynamic shading systems or operable light-redirecting systems critical to the daylighting performance of a space, as well as their realistic geometry and material properties can also be accounted for. This can be done in the simulation engine of choice using a geometric model as in the Daysim calculation engine or using a bidirectional scattering and distribution function (BSDF) as in the Radiance three-phase method.

Worked Example

Effective Daylighting Simulation

The below image represents an example calculation for the bottom floor of a stacked 4-story block with a courtyard and presumed office-type lighting requirement and occupancy profile (500 lux from 8:00 AM to 5:00 PM). The results shown are from a single annual illuminance calculation, which is visualized such that areas with $DA_{500\,lx,\,50\%}$ and $UDIe_{3000lx,\,10\%}$ are shown using a gradient colour scale from blue ($DA_{500\,lx,\,50\%}$) to yellow ($DA_{500\,lx,\,75\%}$) to red ($DA_{500\,lx,\,100\%}$). Areas that are overlit with $UDIe_{3000\,lx}$ > 10% of occupied hours are displayed in pink, and non-daylit areas with $DA_{500\,lx}$ < 50% of occupied hours are displayed in grey. The analysis of the spatial percentages of this floor area indicate that $DA_{500\,lx,\,50\,\%}$ is achieved in 58.37% of occupied spaces without being overlit. Overlit areas, $UDIe_{3000\,lx,\,10\,\%}$, account for 10.85% of occupied spaces due to the relatively significant East and West glazing.



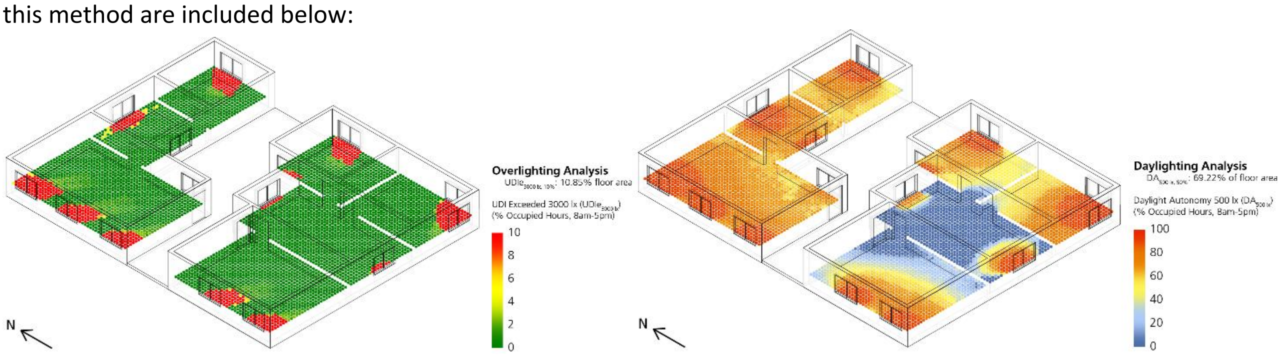
An example composite results view of a daylighting calculation. The analysis is of the bottom floor of a 4-storey office block using a 25 cm spacing sensor grid.

Besides a plan-based visualization of the results, values should be tallied on a room-by-room basis using an implement such as the table below, which is keyed to the representative floor plans, in this case by room numbers. Any space with greater than 15% overlit area should be removed from the whole-building daylit area calculations. In the table below, column values not included in whole-building calculations due to being in an overlit space are coloured red.

Floor	Room #	Total Area (m^2)	Daylit Area (m^2)	Overlit Area (m^2)	Comfortable Daylit Area (m^2)	Overlit Area (%)	Comfortable Daylit Area (%)
1	1	72.1	**72.1**	11.4	**60.7**	15.8	84.1
1	2	26.5	26.5	2.5	24.0	9.3	90.7
1	3	24.5	23.6	3.5	20.1	14.1	82.1
1	4	60.1	27.6	6.1	21.5	10.2	35.7
1	5	55.6	8.4	1.1	7.3	2.0	13.1
1	6	29.3	20.7	3.9	16.8	13.2	57.3
1	7	33.0	30.2	4.5	25.7	13.6	77.8
Total		301.1	137.0	33.0	115.4	11.0	38.3

*Note: **Red bold** values not used in column summations due to room being >15% overlit.
Overall, 11% of the floor area is overlit, and 38.3% is comfortably daylit.

While the composite visualization above is an efficient way of displaying the pertinent simulation results for Green Mark qualification, it is acceptable to show simulated results in multiple steps. For example, a practitioner might plot the results of $UDIe_{3000\,lx}$ separately from those of $DA_{500\,lx}$ and perform the area calculations separately, subtracting the overlit area from the underlit area in each given space and checking that the overlit area is less than 15%. Example visualizations using this method are included below:



Example separated results views of $DA_{500\,lx}$ and $UDIe_{3000\,lx}$ calculations.

Pre-Simulated Tables and Methodology for Standard Designs

The Pre-Simulated Daylight Autonomy tables were derived from more than 4,000 simulated results using a reference shoebox model. The tables can be used as a simplified method to determine the comfortable daylighting for each space. They are suitable for use for spaces with standard designs in the Space Occupancy Type listed. The tables may be found in Appendix B2 and at the following link:
https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/GMNRB2015-Daylight-Availability-Tables.pdf

Standard designed spaces are defined by the following building characteristics and urban parameters:

(a) Spaces with simple façade designs that can be described by orientation, window-to-wall ratio (WWR), and glazing visible light transmittance (T_{vis})
(b) Spaces with typical room floor-to-ceiling heights between 2.5 m and 3.1 m

Note: In spaces with different ceiling heights, the depth of daylight penetration would naturally change due to different contributions from the ceiling. Such cases may wish to consider using a full simulation in order to show the daylit area more accurately.

(c) Spaces with simple horizontal overhang shading devices or no shading devices
(d) Relatively unobstructed spaces with average urban obstruction angles ≤ 57.25°

The tables display results from pre-simulation daylight autonomy of spaces for the respective occupied hours stipulated for the specific Space Occupancy types. There are 3 associated pre-simulated tables for each Space Occupancy type representing differing levels of obstruction from the urban context. Each table contains 24 main blocks organized in a grid, each of which contain 60 smaller squares containing numerical values. The numerical values within each squares indicate the depth of comfortable daylight, defined as the depth of $DA_{Nlx,\ 50\%}$ measured from the façade subtract the depth of $UDIe_{3000\ lx,\ 10\%}$ (not exceeding 1.3m) measured from the facade. In this way, the tables represent an effective tallying of comfortable daylight penetration within a space—equivalent to the simulation-based methodology of subtracting $UDIe_{3000\ lx,\ 10\%}$ from $DA_{Nlx,\ 50\%}$; however, the distances indicated in the tables cannot be directly compared to simulated results.

Blue squares indicate designs which have minimal overlighting risk ($UDIe_{3000\ lx,\ 10\%}$ < 1.3 m from the façade), whereas red and pink squares indicate depths of daylight which are at risk of being overlit or overlit ($UDIe_{3000\ lx,\ 10\%}$ ≥ 1.3 m or 2.0 m from the façade). Spaces which are at risk of overlit (red squares) or spaces overlit (pink squares) will be deemed not complied with the daylight requirement, as such, the areas are not to be counted as part of the daylit area. The numerical values for the red or pink squares are not provided.

Using the Pre-simulated Tables has its benefits for projects at conceptual design stage, as the designers may consider varying the design parameters or shading provision to provide spaces with comfortable daylight condition. The Pre-Simulated Tables can be used as a simple and quick design guide for this purpose.

Alternatively, designers could incorporate mitigation strategies, such as, complex shading, opaque bottom-up blinds, translucent, adjustable venetian blind systems, etc.to address overlighting to the overlit spaces. A detailed simulation shall be carried out to show that the strategies is effective.

(i) Urban Context Obstructing Daylight

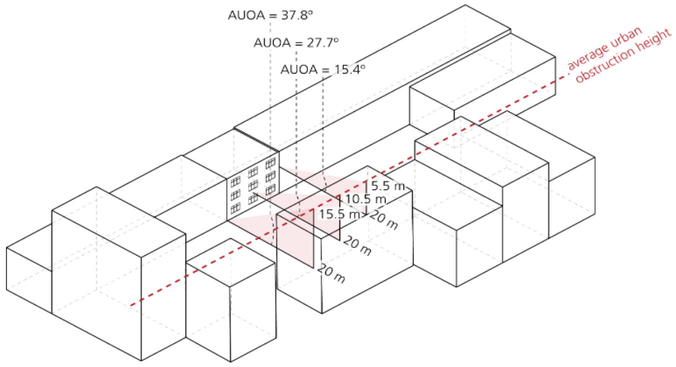
The Average Urban Obstruction Angle (AUOA) describes the average portion of sky blocked by surrounding obstructions opposite a façade, e.g. neighbouring buildings. It can be determined as follows:

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

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 street, between the building and its surrounding obstructions.

The following diagram shows an example of the derivation of the average urban obstruction angle for the three floors of a building based on the average urban obstruction height of 15.5 m, the building-to-building distance of 20 m and the floor height of each level:



With the AUOA known; select the chart with the appropriate "Degree Sky Obstruction" for use. The AUOA (Degree Sky Obstruction) are grouped into the following range; shown in three separate tables:

- AUOA of 0–11.25°- Relatively unobstructed spaces
- AUOA of 11.25–33.75°- Moderately obstructed urban contexts
- AUOA of 33.75–57.25°- Significantly obstructed urban contexts

(ii) Window-to-Wall Ratio (WWR)

There are 10 WWRs included in the pre-simulated daylight autonomy tables: 10%, 20%, 26%, 32%, 39%, 43%, 52%, 60%, 70% and 87%. The WWR value closest to the actual façade WWR from this list should be used.

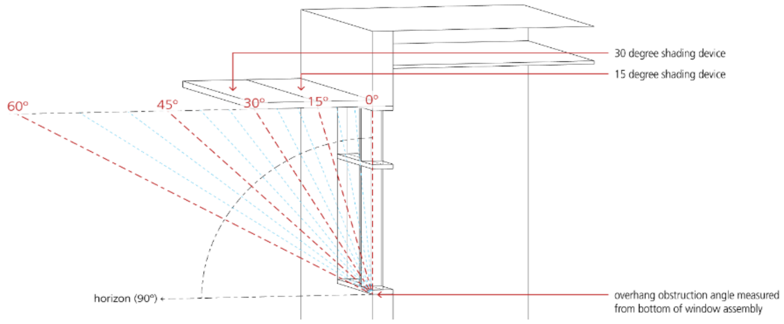
(iii) Overhang Obstruction Angle (OOA)

The OOA is the angle describing the portion of 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 following diagram depicts the measurement of the overhang obstruction angle from the bottom window sill:



Within each Pre-Simulated Daylight Availability table, results are grouped in columns by the Overhang Obstruction Angle (OOA). There are three column groupings for OOA; i.e. 0°, 10° and 15°. The closest value to the actual project OOA value should be used.

(iv) Orientation

Within each table, each row grouping indicates one of the 8 major cardinal directions in which the façade is oriented. The façade orientation should fall within 11.25° of the chosen orientation from the tables.

(v) Visible Light Transmittance (T_{vis})

Within each grouping, results are ordered by T_{vis} along the vertical axis. Six T_{vis} values are represented in the pre-simulated Daylight Availability tables: 25%, 35%, 45%, 55%, 65% and 75%. A project's T_{vis} should be derived from window material specifications for the project, and the closest value to the represented T_{vis} should be chosen for use in the tables.

(vi) Limitations Regarding the Pre-Simulated Daylight Availability Tables

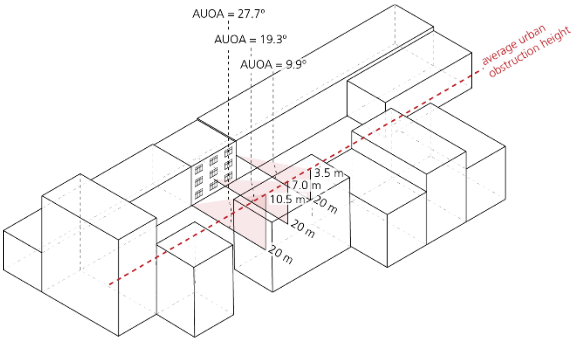
While the simplified Pre-Simulated Daylight Availability Tables effectively represents results for standard designs, there are limitations that should be considered when using them. Some of the considerations when using them are described as follows:

- Underestimation of lighting in spaces with opposing glazed façades: In spaces with windows on two opposing facades, the depth of daylight penetration would naturally increase due to contributions from opposing sides of the space. Such cases may wish to consider using a full simulation in order to increase their daylit area.
- Potential for double counting: If two glazed facades are located about a single corner, the daylit areas will overlap. The total daylit area in these cases should be calculated using a floor plan drawing in order to avoid double-counting

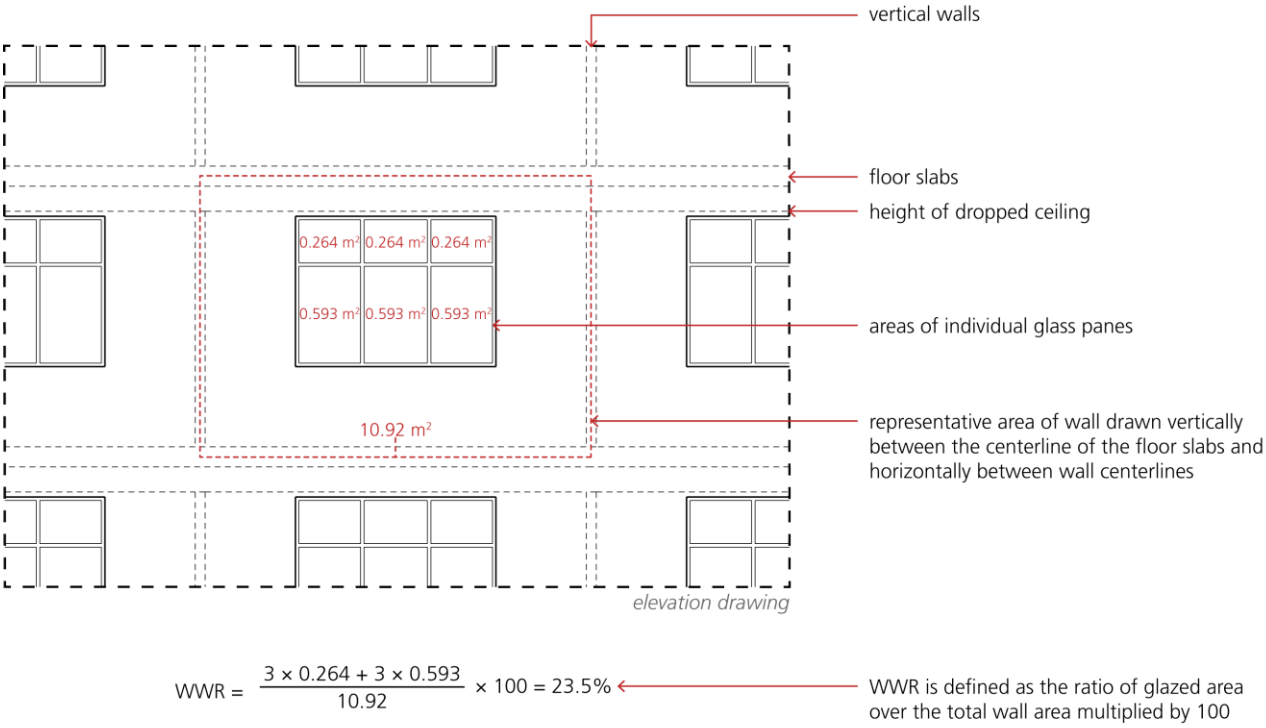
Worked Example

Pre-Simulated Tables and Methodology for Standard Designs

Building X is a small three-storey commercial office building. The building has three floors, with the height of the finished floor at 0 m, 3.5 m and 7.0 m above grade, with a floor-to-ceiling height of 2.8 m. Based on an average urban obstruction height of 10.5 m and a building-to-building distance of 20 m, its three South-facing facades have an AUOA of 27.7°, 19.3° and 9.9° as seen in the diagram below:



In the example WWR calculation, a representative section of façade is identified that spans vertically from the midpoint of each floor slab and is horizontally equidistant between identical windows. The vertical area of this representative façade section is 10.92 m². The façade section has 3 nos. of 0.264 m² and 3 nos. of 0.593 m² panes of glazing. This results in a WWR of 23.5%.



The following table indicates the building properties:

Floor	Urban Context	Shading	Orientation	WWR	T_{vis}
Floors 1-3	Unobstructed	0° (None)	North	20%	65%
Floor 1-2	11.25-33.75°	0° (None)	South	20%	65%
Floors 2-3	Unobstructed	0° (None)	South	20%	65%

Therefore, two Pre-Simulated Daylight Autonomy Tables for the $DA500_{lx,\ 50\%}$ lighting conditions will be used: the Table between 0 and 11.25° and between 11.25 and 33.75°. The following table illustrates the results extracted from the Pre-Simulated Daylight Autonomy Tables:

Floor	Comfortably Daylit Depth	Potential or Risk of Overlighting?
Floors 1-3 North	1.7 m	No
Floors 1-2 South	1.2 m	No
Floors 3 South	-	Yes

Note that Floor 3 South will be overlit and therefore cannot be included in the results unless the design is changed. Next, the results should be applied to the building floor plans. The space is a simple, open-plan rectangle with 11.4 m long daylit facades and is 10 m deep. Looking at the case of Floor 1 in detail, this means that from the North, 1.7 m x 11.4 m = 19.4 m^2 area is comfortable daylit. For the South bottom two floors, 1.2 m x 11.4 m = 13.7 m^2 area is comfortably daylit. The percentage of daylit area can be obtained by simply summing the daylit area from each façade and dividing by the total floor area. As an example, 33.1 m^2 / (11.4 m x 10 m) = 29.0% of Floor 1 is daylit.

These results should be tallied per floor.

- Floor 1: 33.1 m^2 Daylit
- Floor 2: 33.1 m^2 Daylit
- Floor 3: 19.4 m^2 Daylit (Southern portion overlit)

As a result, percentage of the building which is daylit as per the Pre-Simulated Method for Standard Designs is as follows:

$$\frac{33.1\ m^2\ +\ 33.1m^2\ +\ 19.4\ m^2}{3 \times 114\ m^2} = 25.0\%$$

The result (percentage of daylight spaces) is then used to refer to the Daylight criteria for eligibility of Green Mark points.

It is worth noting that in the case of this building design, daylight coming in from opposing façade was not able to be shown using the simplified method. The project team may want to consider a full simulation which is likely to show the higher daylit area.

Appendix B2: Pre-Simulated Daylight Autonomy Tables

Unobstructed Urban Context (0-11.25 degree Urban Obstruction)

0 Degree Shading Overhang

Direction	Glazing T_{vis}(%)	10	20	26	32	39	43	52	60	70	87
N	75	2.9	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪
N	65	2.6	3.5	3.9	🟥	🟥	🟥	🟥	🟥	🟥	🟪
N	55	2.5	3.3	3.8	4.3	🟥	🟥	🟥	🟥	🟥	🟥
N	45	2.4	3.1	3.7	4.1	4.3	4.2	4.5	4.8	5.1	🟥
N	35	2.2	2.7	3.4	3.6	3.9	3.6	4.0	4.2	4.3	5.0
N	25	1.5	2.6	2.9	3.3	3.7	3.1	3.6	3.7	3.8	4.1
NE	75	2.5	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
NE	65	2.5	🟥	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪
NE	55	2.2	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪
NE	45	2.2	2.9	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
NE	35	1.9	2.7	3.1	3.3	3.6	3.5	3.8	🟥	🟥	🟥
NE	25	1.7	2.2	2.6	2.8	3.3	3.1	3.1	3.5	3.5	🟥
E	75	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	65	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	55	2.2	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	45	2.1	🟥	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪
E	35	1.7	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
E	25	2.0	2.0	2.5	2.5	2.9	2.9	🟥	🟥	🟥	🟥
SE	75	2.4	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
SE	65	2.4	🟥	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪
SE	55	2.1	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪
SE	45	1.9	2.6	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
SE	35	1.5	2.3	3.0	3.1	🟥	🟥	🟥	🟥	🟥	🟥
SE	25	1.7	1.9	2.4	2.6	3.0	3.1	3.2	3.3	3.4	🟥
S	75	2.8	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪	🟪
S	65	2.6	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
S	55	2.5	3.0	3.7	4.0	🟥	🟥	🟥	🟥	🟥	🟪
S	45	2.4	2.9	3.4	3.6	4.0	4.0	4.4	🟥	🟥	🟥
S	35	2.4	2.5	3.2	3.4	3.8	3.6	3.9	4.2	4.3	4.8
S	25	2.0	2.5	3.2	3.3	3.6	3.1	3.3	3.7	3.8	4.1
SW	75	2.6	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
SW	65	2.2	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪	🟪
SW	55	2.1	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪
SW	45	2.0	2.7	3.1	🟥	🟥	🟥	🟥	🟥	🟥	🟪
SW	35	1.2	2.2	2.8	3.0	3.4	3.4	3.7	🟥	🟥	🟥
SW	25	1.8	1.8	2.7	2.8	3.2	2.9	3.2	3.4	3.6	🟥
W	75	2.4	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
W	65	2.3	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
W	55	1.9	🟥	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪
W	45	1.8	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
W	35	1.5	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
W	25	1.6	1.8	2.5	2.7	3.1	2.7	3.0	3.2	3.2	🟥
NW	75	2.3	🟥	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪
NW	65	2.4	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪	🟪
NW	55	2.1	2.9	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
NW	45	1.7	2.8	2.9	🟥	🟥	🟥	🟥	🟥	🟥	🟪
NW	35	1.7	2.3	2.8	3.3	3.5	3.6	3.7	4.0	🟥	🟥
NW	25	1.7	2.1	2.9	3.6	3.1	2.9	3.1	3.3	3.2	3.8

15 Degree Shading Overhang

Direction	Glazing T_{vis}(%)	10	20	26	32	39	43	52	60	70	87
N	75	2.8	3.6	4.0	4.4	🟥	🟥	🟥	🟥	🟥	🟥
N	65	2.8	3.5	3.9	4.5	4.8	4.7	🟥	🟥	🟥	🟥
N	55	2.9	3.3	3.9	4.1	4.4	4.2	4.8	5.2	5.4	5.7
N	45	2.5	3.3	3.9	4.1	4.3	4.0	4.5	4.6	4.9	5.4
N	35	1.9	3.0	3.3	3.8	4.3	3.6	3.8	4.2	4.3	5.6
N	25	1.4	2.3	2.5	3.0	3.3	3.0	3.2	3.6	3.8	4.4
NE	75	2.8	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪
NE	65	2.6	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
NE	55	2.3	3.3	3.5	🟥	🟥	🟥	🟥	🟥	🟥	🟥
NE	45	2.3	3.1	3.3	3.6	3.9	3.9	🟥	🟥	🟥	🟥
NE	35	2.2	2.7	3.1	3.1	3.7	3.4	3.9	3.9	4.2	4.8
NE	25	1.6	2.7	2.9	3.3	3.8	2.8	3.1	3.6	3.5	4.1
E	75	2.5	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	65	2.1	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	55	2.1	🟥	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	45	1.8	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪	🟪
E	35	2.0	2.1	2.7	3.1	3.6	🟥	🟥	🟥	🟥	🟥
E	25	1.7	2.3	2.2	2.4	2.8	2.6	2.8	3.3	3.4	4.0
SE	75	2.3	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪	🟪
SE	65	2.3	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪
SE	55	2.1	2.8	3.3	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SE	45	1.9	2.6	3.1	3.2	🟥	🟥	🟥	🟥	🟥	🟥
SE	35	1.7	2.3	2.5	3.1	3.4	3.3	3.6	4.0	4.1	4.7
SE	25	1.7	2.3	2.7	3.2	3.5	2.9	3.0	3.3	3.6	3.8
S	75	2.8	3.4	4.0	🟥	🟥	🟥	🟥	🟥	🟥	🟪
S	65	2.8	3.3	4.0	4.3	🟥	🟥	🟥	🟥	🟥	🟥
S	55	2.8	3.2	3.7	4.1	4.3	4.4	4.6	🟥	🟥	🟥
S	45	2.7	3.0	3.8	3.9	4.2	4.1	4.1	4.5	4.8	5.5
S	35	2.3	3.0	3.4	3.6	4.3	3.8	3.9	4.3	4.4	4.9
S	25	1.8	2.3	2.5	2.8	3.4	3.1	3.2	3.9	3.9	4.2
SW	75	2.2	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪
SW	65	2.2	3.1	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SW	55	2.2	3.0	3.2	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SW	45	1.8	2.7	3.1	3.4	3.8	3.7	3.9	🟥	🟥	🟥
SW	35	1.9	2.4	2.7	3.2	3.5	3.4	3.6	3.9	4.2	4.7
SW	25	1.5	2.4	2.5	3.0	3.4	2.7	3.1	3.4	3.5	4.0
W	75	2.0	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪	🟪
W	65	2.1	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟪
W	55	2.1	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
W	45	1.9	2.4	2.9	3.4	🟥	🟥	🟥	🟥	🟥	🟥
W	35	1.8	2.1	2.6	3.0	3.3	3.1	3.5	3.9	4.0	4.6
W	25	1.7	2.3	3.0	3.2	3.2	2.4	2.7	3.0	3.2	3.7
NW	75	2.3	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
NW	65	2.1	3.1	3.5	🟥	🟥	🟥	🟥	🟥	🟥	🟥
NW	55	2.1	2.8	3.4	3.9	🟥	🟥	🟥	🟥	🟥	🟥
NW	45	1.9	2.8	3.2	3.6	4.0	3.8	4.1	4.4	4.6	5.4
NW	35	1.9	2.4	2.6	3.2	3.7	3.6	3.7	3.8	4.2	4.8
NW	25	1.5	2.5	2.6	3.2	3.4	2.8	3.2	3.3	3.3	4.1

15 Degree Shading Overhang

Direction	Glazing T_{vis}(%)	10	20	26	32	39	43	52	60	70	87
N	75	3.0	3.8	4.2	4.5	5.0	5.2	5.5	5.9	5.6	🟥
N	65	2.7	3.7	4.3	5.1	4.7	4.6	5.1	5.5	5.6	6.4
N	55	2.4	3.5	4.0	4.6	5.0	4.4	4.8	5.0	5.5	5.7
N	45	2.1	3.1	3.5	4.0	4.5	4.1	4.4	4.8	5.1	5.9
N	35	1.6	2.7	3.0	3.3	3.9	3.5	3.9	4.2	4.4	5.0
N	25	1.2	2.0	2.4	2.6	3.0	2.7	3.1	3.4	3.4	3.9
NE	75	3.4	3.6	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
NE	65	2.9	3.3	3.6	4.2	🟥	🟥	🟥	🟥	🟥	🟥
NE	55	2.4	3.3	3.5	4.0	4.1	4.4	4.4	4.9	5.1	🟥
NE	45	2.3	3.5	4.0	3.6	4.1	3.8	4.1	4.3	4.8	5.6
NE	35	1.8	3.1	3.2	3.8	4.2	3.5	3.6	3.8	4.2	5.6
NE	25	1.3	2.2	2.5	3.0	3.3	3.0	3.2	3.3	3.6	4.1
E	75	2.5	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
E	65	2.1	🟥	🟥	🟪	🟪	🟥	🟥	🟥	🟥	🟥
E	55	2.2	🟥	🟥	🟪	🟪	🟥	🟥	🟥	🟥	🟥
E	45	1.7	2.7	2.8	🟥	🟥	🟥	🟥	🟥	🟥	🟥
E	35	2.0	2.4	2.6	3.2	3.3	3.8	3.4	3.8	3.9	5.4
E	25	1.5	2.3	2.4	3.0	3.1	2.7	3.1	3.5	3.6	4.3
SE	75	2.5	3.2	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
SE	65	2.1	3.1	3.3	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SE	55	2.4	3.1	3.5	3.6	🟥	🟥	🟥	🟥	🟥	🟥
SE	45	2.3	3.2	3.6	3.6	3.7	3.5	3.9	4.2	4.6	5.2
SE	35	2.1	2.7	3.0	3.6	4.0	3.4	3.7	3.9	4.0	5.3
SE	25	1.1	2.0	2.4	2.7	3.2	2.9	3.1	3.5	3.7	4.1
S	75	2.9	3.5	4.0	4.4	4.7	5.2	5.1	🟥	🟥	🟥
S	65	2.9	4.0	4.5	4.2	4.9	4.8	4.8	5.3	5.5	6.0
S	55	2.5	3.5	4.1	4.5	4.5	4.4	4.6	4.9	5.2	6.1
S	45	2.1	3.3	3.7	4.2	4.6	4.0	4.2	4.4	4.8	5.7
S	35	1.8	2.6	3.1	3.5	3.9	3.5	3.9	4.2	4.4	5.0
S	25	1.3	2.0	2.4	2.7	3.0	2.9	3.2	3.5	3.5	3.9
SW	75	2.3	3.2	3.7	🟥	🟥	🟥	🟥	🟥	🟥	🟥
SW	65	2.5	3.1	3.6	3.8	🟥	🟥	🟥	🟥	🟥	🟥
SW	55	2.2	3.0	3.2	3.6	4.0	3.9	4.2	4.6	4.9	5.5
SW	45	2.0	3.1	3.3	4.1	3.9	3.7	4.0	4.4	4.6	5.2
SW	35	1.6	2.5	3.1	3.3	3.8	3.3	3.7	4.0	4.2	5.3
SW	25	1.2	2.0	2.4	2.8	3.1	2.8	3.0	3.3	3.5	4.0
W	75	2.3	3.2	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪
W	65	2.1	3.0	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
W	55	1.8	2.7	3.1	3.6	🟥	🟥	🟥	🟥	🟥	🟥
W	45	2.0	2.5	3.0	3.4	3.8	3.5	4.0	4.2	4.5	5.0
W	35	1.7	2.1	2.2	3.5	3.1	3.3	3.6	3.9	4.4	5.0
W	25	1.2	2.2	2.7	2.8	3.0	2.5	3.2	3.5	3.5	4.0
NW	75	2.9	3.3	3.7	4.2	🟥	🟥	🟥	🟥	🟥	🟥
NW	65	2.6	3.2	3.5	4.0	4.3	4.5	4.6	🟥	🟥	🟥
NW	55	2.3	3.1	3.4	3.6	4.1	4.0	4.6	4.8	5.2	5.8
NW	45	2.0	3.0	3.5	4.2	4.5	3.7	4.1	4.4	4.6	5.4
NW	35	1.6	2.7	3.1	3.4	3.9	3.5	3.7	4.3	4.2	5.2
NW	25	1.1	2.0	2.5	2.7	3.0	2.8	3.1	3.7	3.3	4.0

Window-to-Wall Ratio (WWR) (%)

Unobstructed Urban Context for DA of 200 lux

Depth of $DA_{200lux, 50\%}$ daylit area
minus $UDIe_{3000lux, 10\%}$ overlit area
(commercial occupancy schedule)

🟦 (0.00 to 1.50) m daylight depth
🟦 (1.50 to 2.25) m daylight depth
🟦 (2.25 to 3.00) m daylight depth
🟦 (3.00 to 3.75) m daylight depth
🟦 (3.75 to 4.75) m daylight depth
🟦 (4.75 to 5.25) m daylight depth
🟦 > 5.25 m daylight depth

🟥 Potential Overlighting [1.3–2.0) m overlit depth
🟪 Risk of Overlighting >=2.0 m overlit depth

22.5 degree Urban Context for DA of 200 lux

22.5 degree Urban Context (11.25-33.75 degree Urban Obstruction)

0 Degree Shading Overhang

Direction	Glazing T_{vis} (%)	10	20	26	32	39	43	52	60	70	87
N	75	2.3	2.8	3.0							
N	65	2.3	2.6	3.0	3.1						
N	55	2.0	2.3	2.8	3.2	3.3	3.0	3.6	3.9	4.1	
N	45	2.1	2.4	2.8	3.0	3.2	3.1	3.5	3.6	3.8	4.1
N	35	2.1	2.1	2.7	2.7	3.1	2.7	3.1	3.1	3.3	3.9
N	25	1.5	2.3	2.3	2.4	2.8	2.2	2.7	2.9	2.9	3.2
NE	75	2.0									
NE	65	2.0									
NE	55	1.9	2.5								
NE	45	1.6	2.4	2.4	2.7						
NE	35	1.3	2.2	2.4	2.5	2.7	2.6	2.9	3.0	3.2	
NE	25	1.6	1.7	2.5	2.3	2.4	2.3	2.4	2.7	2.7	2.9
E	75										
E	65	1.9									
E	55	1.6									
E	45	1.8									
E	35	1.4									
E	25	2.0	1.4	1.7	1.9	2.1	2.0	2.1	2.3	2.6	
SE	75	1.8									
SE	65	2.0									
SE	55	1.8									
SE	45	1.6	2.0	2.4							
SE	35	1.1	1.8	2.0	2.1	2.2	2.3	2.6	2.8	3.1	
SE	25	1.6	1.5	1.8	2.1	2.2	2.2	2.2	2.5	2.5	2.8
S	75	2.2									
S	65	2.0	2.4	2.8							
S	55	1.9	2.4	2.6	3.0	3.1	3.2	3.3			
S	45	1.9	2.1	2.6	2.8	3.2	3.0	3.2	3.5	3.6	
S	35	1.9	2.0	2.3	2.6	3.0	3.0	3.1	3.3	3.3	3.8
S	25	1.7	2.2	2.4	2.7	2.8	2.3	2.6	2.9	3.0	3.6
SW	75	1.7									
SW	65	1.7									
SW	55	1.9									
SW	45	1.4	1.9	2.5	2.6						
SW	35	1.2	1.8	2.0	2.3	2.4	2.5	2.6	2.9	3.0	
SW	25	1.6	1.4	2.4	2.2	2.2	2.1	2.3	2.5	2.8	3.0
W	75	1.9									
W	65	1.8									
W	55	1.9									
W	45	1.6									
W	35	1.5	1.8	2.1	2.3						
W	25	1.5	1.6	1.8	2.0	2.3	2.1	2.3	2.5	2.6	3.0
NW	75	1.8									
NW	65	1.8									
NW	55	1.7	2.1	2.3							
NW	45	1.6	2.2	2.3	2.7	2.9	3.1	3.1			
NW	35	1.4	1.9	2.1	2.3	2.7	2.7	2.8	3.0	3.2	
NW	25	1.5	1.8	2.5	2.7	2.8	2.5	2.6	2.6	2.5	3.2

15 Degree Shading Overhang

Direction	Glazing T_{vis} (%)	10	20	26	32	39	43	52	60	70	87
N	75	2.2	2.5	2.5	3.1	3.4	3.7	4.0	4.5	4.6	5.1
N	65	2.3	2.5	2.7	2.6	3.3	3.4	3.8	4.2	4.4	4.5
N	55	2.5	2.4	2.6	2.8	2.9	3.1	3.4	3.9	4.1	4.3
N	45	1.9	2.5	3.0	2.7	3.2	2.9	3.2	3.5	3.8	3.8
N	35	1.6	2.5	2.4	2.7	3.0	2.4	2.7	2.9	3.0	4.0
N	25	1.3	1.9	1.9	2.2	2.3	2.1	2.4	2.5	2.6	3.2
NE	75	1.8									
NE	65	1.8	2.5	2.7							
NE	55	1.9	2.1	2.4	2.7	2.9	3.0	3.3			
NE	45	1.6	2.2	2.1	2.3	2.7	2.7	3.0	3.2	3.4	3.8
NE	35	1.7	2.1	2.1	2.2	2.8	2.4	2.6	3.0	3.0	3.4
NE	25	1.4	2.0	2.2	2.4	2.6	2.2	2.2	2.3	2.3	2.9
E	75	1.7									
E	65	1.5									
E	55	1.5									
E	45	1.4									
E	35	1.3	1.4	1.6	1.8	2.2	2.0	2.4	2.7	2.7	3.2
E	25	1.5	1.8	2.1	2.0	1.9	1.9	2.0	1.9	2.0	2.6
SE	75	1.9									
SE	65	1.9	2.2	2.4							
SE	55	1.7	1.9	2.4	2.6						
SE	45	1.5	2.1	1.9	2.5	2.5	2.5	2.9	3.0	3.3	3.8
SE	35	1.3	1.7	1.7	2.1	2.2	2.4	2.6	2.8	2.8	3.3
SE	25	1.2	1.9	2.0	2.3	2.6	1.8	2.0	2.2	2.1	2.6
S	75	2.1	2.4	2.8	3.3						
S	65	2.1	2.6	2.6	2.9	3.1	3.2	3.5	3.9	4.0	4.6
S	55	1.9	2.2	2.4	2.8	3.0	3.0	3.2	3.6	3.9	4.2
S	45	2.2	2.3	2.6	2.6	2.9	3.1	3.0	3.4	3.4	3.8
S	35	1.8	2.4	2.5	2.9	3.0	2.4	2.8	3.1	3.2	4.0
S	25	1.4	1.8	2.0	2.2	2.6	2.2	2.2	2.4	2.5	3.2
SW	75	1.7	2.4								
SW	65	1.7	2.3	2.2							
SW	55	1.6	2.1	2.2	2.5	2.7	2.8	3.2			
SW	45	1.6	1.9	2.1	2.4	2.4	2.5	2.9	3.1	3.4	3.9
SW	35	1.6	1.9	1.7	2.1	2.3	2.3	2.4	2.7	2.9	3.4
SW	25	1.3	1.9	2.1	2.2	2.5	1.9	2.1	2.2	2.2	2.7
W	75	1.7									
W	65	1.7									
W	55	1.3	2.0	2.4							
W	45	1.4	1.8	1.9	2.4	2.8	2.6	2.8	3.1	3.4	3.9
W	35	1.4	1.5	1.6	1.9	2.2	2.1	2.3	2.6	2.8	3.3
W	25	1.5	2.0	2.0	2.4	2.5	2.0	2.0	2.2	2.2	2.9
NW	75	1.8	2.4	2.6							
NW	65	1.7	2.3	2.4	2.6						
NW	55	1.7	2.0	2.1	2.8	2.9	3.1	3.3	3.5	3.8	4.4
NW	45	1.6	1.9	2.1	2.5	2.7	2.8	3.0	3.1	3.3	4.0
NW	35	1.6	1.7	1.8	2.4	2.4	2.4	2.7	2.9	2.9	3.5
NW	25	1.3	1.9	2.0	2.4	2.5	2.1	2.2	2.3	2.3	3.4

15 Degree Shading Overhang

Direction	Glazing T_{vis} (%)	10	20	26	32	39	43	52	60	70	87
N	75	2.2	3.0	2.6	3.0	3.2	3.8	4.0	4.2	4.6	4.7
N	65	2.1	2.9	2.9	3.4	3.7	3.3	3.5	3.8	4.3	4.4
N	55	1.8	2.6	2.8	3.0	3.3	3.0	3.3	3.7	4.0	4.7
N	45	1.6	2.3	2.5	2.7	3.0	2.8	3.1	3.4	3.6	3.9
N	35	1.3	2.0	2.2	2.4	2.6	2.4	2.6	2.8	2.6	3.1
N	25	1.0	1.5	1.7	2.0	2.1	1.9	2.1	2.2	2.1	2.3
NE	75	2.2	3.0	2.6	3.0	3.2	3.8	4.0	4.2	4.6	4.7
NE	65	2.1	2.9	2.9	3.4	3.7	3.3	3.5	3.8	4.3	4.4
NE	55	1.8	2.6	2.8	3.0	3.3	3.0	3.3	3.7	4.0	4.7
NE	45	1.6	2.3	2.5	2.7	3.0	2.8	3.1	3.4	3.6	3.9
NE	35	1.3	2.0	2.2	2.4	2.6	2.4	2.6	2.8	2.6	3.1
NE	25	1.0	1.5	1.7	2.0	2.1	1.9	2.1	2.2	2.1	2.3
E	75	1.5									
E	65	1.7	1.8								
E	55	1.3	1.7	1.8							
E	45	1.1	1.7	1.9	2.0	2.3	2.5	2.8	2.8	3.5	3.3
E	35	1.4	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.8	3.6
E	25	1.2	1.7	1.9	2.1	2.3	1.8	2.1	2.2	2.3	2.5
SE	75	1.8	2.1	2.2	2.5						
SE	65	2.1	2.1	2.1	2.4	2.7	3.0	3.3	3.8	4.0	4.5
SE	55	1.9	2.0	2.0	2.1	2.6	2.6	3.0	3.3	3.6	4.2
SE	45	1.7	2.4	2.5	2.8	2.5	2.4	2.8	3.0	3.3	4.3
SE	35	1.4	2.0	2.3	2.4	2.7	2.3	2.6	2.7	2.9	3.5
SE	25	1.0	1.6	1.9	2.1	2.2	1.9	2.1	2.3	2.3	2.5
S	75	2.3	2.4	2.6	2.8	3.4	3.5	3.6	4.1	4.4	4.7
S	65	2.1	2.7	3.0	3.5	3.1	3.4	3.4	3.7	3.9	4.3
S	55	2.0	2.5	2.9	3.0	3.5	2.9	3.1	3.4	3.8	4.6
S	45	1.8	2.3	2.7	2.8	3.1	2.8	2.9	3.2	3.6	3.9
S	35	1.5	1.9	2.3	2.5	2.6	2.6	2.6	2.8	2.8	3.3
S	25	1.0	1.6	1.8	2.0	2.3	1.9	2.1	2.3	2.2	2.5
SW	75	1.8	2.2	2.3	2.6	3.1	3.2	3.6	4.0	4.3	4.7
SW	65	2.0	2.0	2.1	2.3	2.7	2.9	3.4	3.8	4.0	4.6
SW	55	1.8	2.0	2.4	2.2	2.6	2.7	3.0	3.4	3.6	4.2
SW	45	1.6	2.3	2.5	2.7	2.9	2.7	2.8	3.2	3.6	4.3
SW	35	1.3	2.0	2.2	2.4	2.7	2.4	2.6	2.9	2.9	3.4
SW	25	0.9	1.6	1.8	2.0	2.2	1.9	2.1	2.4	2.3	2.6
W	75	1.5	2.3	2.3							
W	65	1.4	2.0	2.0	2.4	3.0	3.1	3.5	3.8	4.2	4.5
W	55	1.2	2.0	2.1	2.3	2.7	2.8	3.0	3.6	3.8	4.4
W	45	1.7	1.7	1.8	2.1	2.4	2.5	2.8	3.2	3.5	4.3
W	35	1.4	1.5	1.5	2.6	2.2	2.2	2.4	2.6	2.8	3.6
W	25	1.0	1.6	1.9	2.1	2.3	1.9	2.2	2.3	2.3	2.6
NW	75	2.2	2.3	2.3	2.7	3.2	3.5	3.8	4.1	4.3	4.9
NW	65	2.1	2.2	2.4	2.5	3.0	3.2	3.5	3.9	4.2	4.9
NW	55	1.9	2.6	2.8	2.5	2.4	2.9	3.3	3.8	3.7	4.2
NW	45	1.6	2.5	2.6	2.8	3.0	2.7	2.9	3.2	3.4	4.2
NW	35	1.3	2.1	2.3	2.4	2.7	2.4	2.7	2.9	2.7	3.4
NW	25	1.0	1.6	1.8	2.0	2.2	2.0	2.2	2.3	2.3	2.5

Window-to-Wall Ratio (WWR) (%)

Depth of $DA_{200lux,\ 50\%}$ daylit area minus $UDIe_{3000lux,\ 10\%}$ overlit area (commercial occupancy schedule)

- (0.00 to 1.50) m daylight depth
- (1.50 to 2.25) m daylight depth
- (2.25 to 3.00) m daylight depth
- (3.00 to 3.75) m daylight depth
- (3.75 to 4.75) m daylight depth
- (4.75 to 5.25) m daylight depth
- > 5.25 m daylight depth

- Potential Overlighting [1.3–2.0) m overlit depth
- Risk of Overlighting >=2.0 m overlit depth

45 degree Urban Context for DA of 200 lux

45 degree Urban Context (33.75-57.25 degree Urban Obstruction)

Depth of $DA_{200lux,\ 50\%}$ daylit area minus $UDIe_{3000lux,\ 10\%}$ overlit area (commercial occupancy schedule)

- (0.00 to 1.50) m daylight depth
- (1.50 to 2.25) m daylight depth
- (2.25 to 3.00) m daylight depth
- (3.00 to 3.75) m daylight depth
- (3.75 to 4.75) m daylight depth
- (4.75 to 5.25) m daylight depth
- > 5.25 m daylight depth

- Potential Overlighting [1.3–2.0) m overlit depth
- Risk of Overlighting >=2.0 m overlit depth

0 Degree Shading Overhang

Direction	Glazing T_{vis}(%)	10	20	26	32	39	43	52	60	70	87
N	75	1.0	1.6	2.2	2.6	2.9	3.0	3.4	3.7	3.9	3.9
N	65	1.1	1.4	1.9	2.3	2.8	2.6	3.1	3.5	3.6	3.7
N	55	1.1	1.4	1.6	2.1	2.4	2.4	2.7	3.0	3.3	3.2
N	45	1.0	1.1	1.4	1.8	2.1	1.9	2.3	2.5	2.7	2.9
N	35	1.1	1.0	1.2	1.6	1.7	1.4	1.7	1.9	2.0	2.7
N	25	0.9	1.3	1.2	1.4	1.5	1.3	1.3	1.5	1.5	2.0
NE	75	0.9	1.7	2.1	2.6	2.9	2.9	3.0	3.4	3.8	
NE	65	0.9	1.5	1.8	2.3	2.4	2.7	2.7	3.1	3.3	
NE	55	0.9	1.4	1.5	2.0	2.3	2.4	2.7	3.1	3.2	3.1
NE	45	0.9	0.9	1.4	1.8	2.2	2.0	2.3	2.5	2.8	2.9
NE	35	1.1	1.0	1.2	1.6	1.8	1.7	1.8	2.2	2.2	2.5
NE	25	0.9	1.0	1.3	1.4	1.5	1.3	1.3	1.6	1.5	2.1
E	75	0.9	1.8	2.0	2.6	3.0	3.1	3.4	3.8	4.0	
E	65	0.9	1.6	1.9	2.4	2.7	2.7	3.1	3.5	3.7	
E	55	0.8	1.3	1.5	1.9	2.4	2.3	2.7	3.1	3.2	3.7
E	45	0.9	1.0	1.4	1.5	1.9	1.8	2.1	2.6	2.7	3.2
E	35	0.9	1.0	1.1	1.4	1.6	1.6	1.9	2.3	2.3	2.4
E	25	1.0	1.3	1.4	1.4	1.5	1.4	1.5	1.6	1.6	2.3
SE	75	0.9	1.6	2.1	2.5	2.8	2.8	3.3	3.7	3.8	
SE	65	0.8	1.4	1.8	2.1	2.4	2.4	3.0	3.4	3.5	
SE	55	0.8	1.2	1.5	1.8	2.1	2.0	2.6	2.9	3.2	3.3
SE	45	0.9	0.9	1.2	1.7	1.9	1.8	2.2	2.7	2.6	3.1
SE	35	0.9	0.8	1.2	1.4	1.7	1.6	1.7	2.0	2.1	2.6
SE	25	0.9	1.3	1.4	1.4	1.5	1.3	1.3	1.6	1.6	2.1
S	75	1.0	1.5	2.2	2.6	2.8	2.9	3.2	3.6	3.8	4.0
S	65	1.1	1.4	1.8	2.3	2.7	2.6	2.9	3.3	3.4	3.7
S	55	1.0	1.2	1.8	1.9	2.4	2.4	2.6	2.9	3.2	3.2
S	45	0.9	1.0	1.4	1.6	2.0	1.9	2.2	2.6	2.6	2.8
S	35	1.1	1.0	1.5	1.2	1.8	1.5	1.6	1.9	2.1	2.7
S	25	0.9	1.2	1.3	1.4	1.4	1.3	1.4	1.5	1.5	2.2
SW	75	0.9	1.6	2.1	2.5	2.9	3.0	3.4	4.0	4.0	
SW	65	0.8	1.6	1.9	2.2	2.6	2.6	3.3	3.5	3.7	
SW	55	0.8	1.2	1.7	2.0	2.3	2.4	2.8	3.1	3.4	3.5
SW	45	0.9	1.0	1.2	1.6	2.2	1.9	2.3	2.6	2.8	3.3
SW	35	1.1	0.9	1.2	1.6	1.9	1.7	1.9	2.1	2.2	2.7
SW	25	0.9	1.3	1.4	1.5	1.6	1.4	1.5	1.7	1.7	2.2
W	75	0.8	1.9	2.2	2.8	3.1	3.2	3.6	4.0	4.1	
W	65	0.9	1.6	2.0	2.5	2.8	2.8	3.3	3.6	3.8	
W	55	0.8	1.3	1.5	2.1	2.5	2.5	2.9	3.1	3.4	3.7
W	45	0.8	1.0	1.5	1.7	2.0	2.1	2.3	2.6	2.8	3.2
W	35	1.0	0.9	1.3	1.5	1.9	1.7	2.1	2.3	2.3	2.6
W	25	1.0	1.3	1.4	1.4	1.6	1.4	1.5	1.7	1.7	2.4
NW	75	1.0	1.7	2.0	2.7	2.9	3.1	3.2	3.6	3.7	
NW	65	1.0	1.4	1.8	2.3	2.6	2.9	3.1	3.4	3.5	
NW	55	0.9	1.2	1.6	2.0	2.3	2.5	2.7	3.0	3.3	3.2
NW	45	0.9	0.9	1.4	1.8	2.0	2.1	2.4	2.7	2.8	3.1
NW	35	0.8	1.0	1.2	1.6	1.7	1.8	1.9	2.1	2.2	2.7
NW	25	0.9	1.2	1.4	1.4	1.5	1.3	1.3	1.5	1.6	2.1

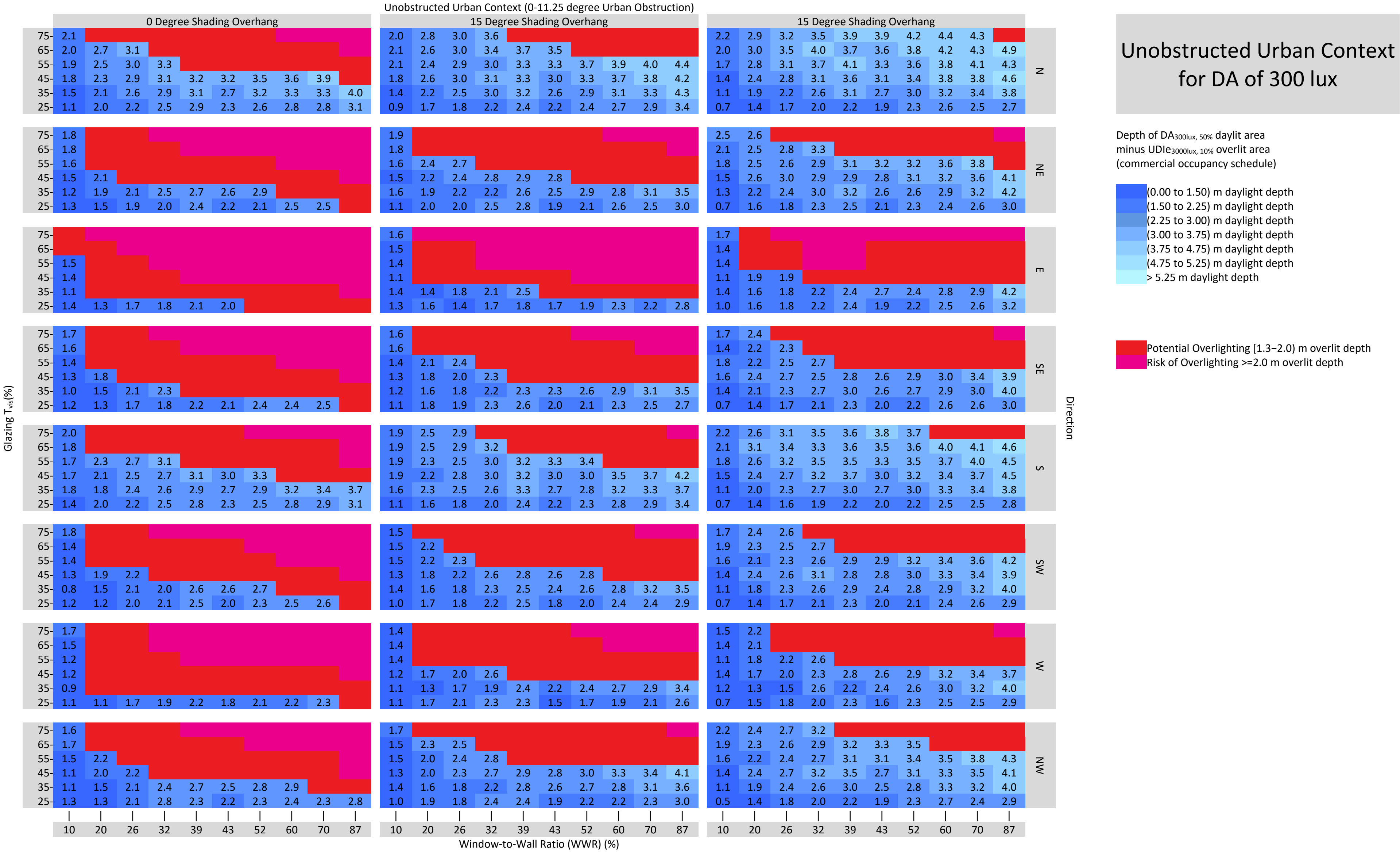
15 Degree Shading Overhang

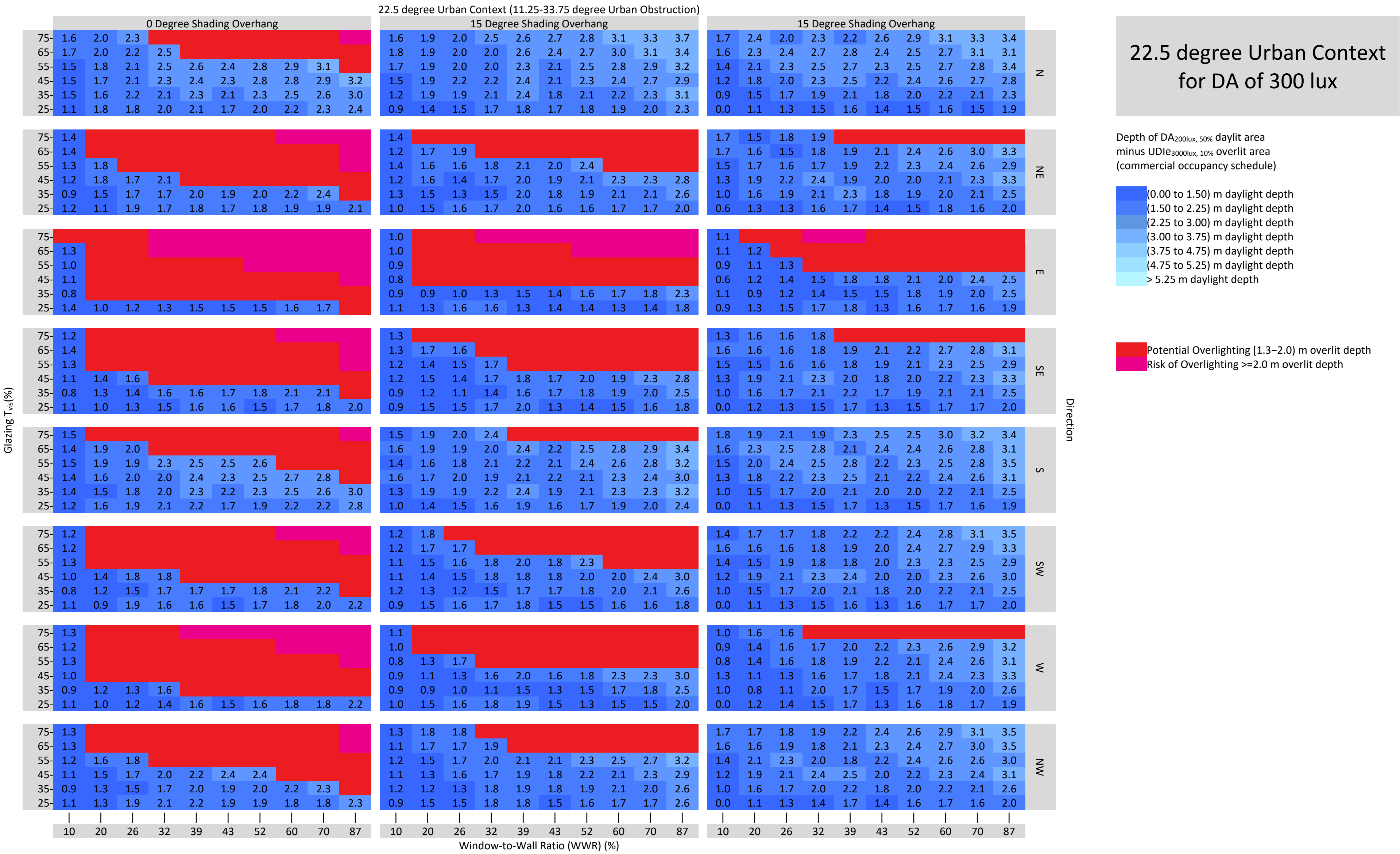
Direction	Glazing T_{vis}(%)	10	20	26	32	39	43	52	60	70	87
N	75	1.0	1.6	2.0	2.5	2.7	2.7	3.1	3.6	3.7	3.9
N	65	1.0	1.5	2.0	2.2	2.6	2.5	2.7	3.2	3.3	3.9
N	55	1.0	1.3	1.6	2.1	2.2	2.2	2.4	2.8	3.1	3.4
N	45	1.0	1.2	1.4	1.6	1.8	1.7	2.1	2.4	2.5	3.0
N	35	0.8	1.1	1.1	1.2	1.5	1.3	1.5	1.7	1.8	2.2
N	25	0.6	0.9	0.9	1.0	1.0	0.9	1.0	1.1	1.0	1.2
NE	75	0.8	1.7	1.8	2.4	2.7	2.6	3.0	3.3	3.6	4.0
NE	65	0.9	1.4	1.6	2.1	2.5	2.6	2.8	3.1	3.2	3.6
NE	55	0.8	1.1	1.4	2.0	2.4	2.3	2.5	2.7	2.9	3.4
NE	45	0.7	1.0	1.0	1.6	1.9	1.8	1.9	2.2	2.3	3.1
NE	35	0.9	1.1	1.1	1.4	1.7	1.4	1.7	1.8	1.9	2.3
NE	25	0.7	1.0	1.0	1.0	1.0	0.9	1.0	1.1	1.1	1.3
E	75	0.9	1.6	2.0	2.4	2.7	3.1	3.4	3.8	4.0	4.4
E	65	0.8	1.7	1.8	2.3	2.6	2.8	3.0	3.5	3.6	4.1
E	55	0.8	1.3	1.4	1.8	2.3	2.3	2.7	3.0	3.2	3.6
E	45	0.7	0.9	1.1	1.5	1.8	1.8	2.1	2.4	2.6	3.0
E	35	0.9	1.2	1.1	1.4	1.2	1.2	1.6	1.8	1.9	2.6
E	25	0.7	1.0	1.0	1.0	1.1	0.9	1.1	1.2	1.3	1.5
SE	75	0.8	1.6	1.8	2.1	2.6	2.5	2.9	3.3	3.5	3.8
SE	65	0.8	1.4	1.6	2.0	2.3	2.5	2.6	3.0	3.3	3.6
SE	55	0.7	1.1	1.2	1.6	2.0	2.1	2.3	2.7	2.9	3.2
SE	45	1.0	0.9	1.0	1.7	1.7	1.8	1.9	2.2	2.4	3.0
SE	35	0.9	1.1	1.1	1.3	1.6	1.3	1.6	1.7	1.8	2.3
SE	25	0.7	0.9	0.9	1.0	1.0	0.9	1.1	1.2	1.2	1.3
S	75	0.9	1.6	2.0	2.4	2.8	2.7	3.0	3.4	3.7	3.9
S	65	0.8	1.3	1.6	2.0	2.6	2.4	2.7	3.0	3.3	3.7
S	55	0.8	1.2	1.4	1.9	2.2	2.2	2.4	2.7	2.9	3.5
S	45	1.0	0.9	1.5	1.6	1.9	1.9	2.0	2.4	2.5	2.9
S	35	0.9	1.1	1.1	1.3	1.5	1.4	1.6	1.7	1.8	2.2
S	25	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.2
SW	75	0.8	1.7	1.7	2.3	2.6	2.7	3.0	3.4	3.7	4.1
SW	65	0.8	1.4	1.6	2.0	2.5	2.6	2.8	3.1	3.3	3.8
SW	55	0.7	1.2	1.2	1.7	2.1	2.3	2.4	2.9	3.0	3.4
SW	45	1.0	0.9	1.0	1.4	1.6	1.8	2.0	2.4	2.6	3.2
SW	35	0.9	1.1	1.1	1.3	1.6	1.5	1.5	1.8	2.0	2.5
SW	25	0.7	0.9	0.9	1.0	1.0	1.0	1.1	1.2	1.2	1.3
W	75	0.9	1.6	2.2	2.5	2.9	3.1	3.4	3.9	4.2	4.5
W	65	0.8	1.6	1.9	2.3	2.8	2.8	3.2	3.6	3.8	4.2
W	55	0.8	1.3	1.5	2.0	2.4	2.3	2.8	3.1	3.3	3.7
W	45	0.7	1.0	1.2	1.6	1.8	1.8	2.2	2.6	2.8	3.2
W	35	0.9	1.1	1.2	1.4	1.3	1.4	1.6	2.0	2.1	2.7
W	25	0.8	1.0	1.0	1.0	1.1	1.0	1.1	1.2	1.3	1.7
NW	75	0.9	1.5	1.8	2.3	2.7	2.7	3.2	3.6	3.8	4.2
NW	65	0.8	1.4	1.7	2.1	2.5	2.6	2.8	3.1	3.3	3.8
NW	55	0.8	1.3	1.3	1.9	2.3	2.2	2.5	2.9	3.1	3.5
NW	45	1.0	0.9	1.1	1.4	1.8	1.8	2.0	2.4	2.4	3.1
NW	35	0.9	1.1	1.1	1.3	1.5	1.4	1.7	1.9	1.9	2.4
NW	25	0.7	0.9	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.4

15 Degree Shading Overhang

Direction	Glazing T_{vis}(%)	10	20	26	32	39	43	52	60	70	87
N	75	0.8	1.6	1.9	2.4	2.7	2.6	3.1	3.4	3.5	3.8
N	65	0.8	1.4	1.7	2.1	2.4	2.3	2.7	3.0	3.1	3.4
N	55	0.7	1.2	1.4	1.7	2.1	1.8	2.2	2.5	2.6	2.9
N	45	0.6	0.9	1.0	1.4	1.6	1.4	1.8	2.1	2.1	2.4
N	35	0.5	0.6	0.7	0.8	1.1	0.9	1.1	1.3	1.3	1.7
N	25	0.0	0.0	0.0	0.5	0.6	0.4	0.4	0.5	0.5	0.6
NE	75	0.9	1.7	2.1	2.4	2.9	2.6	3.0	3.3	3.5	3.9
NE	65	0.8	1.5	1.8	2.2	2.5	2.3	2.6	3.0	3.2	3.6
NE	55	0.7	1.3	1.4	1.8	2.1	2.0	2.3	2.6	2.7	3.0
NE	45	0.6	0.9	1.1	1.4	1.7	1.5	1.7	2.1	2.1	2.4
NE	35	0.5	0.7	0.7	0.9	1.1	1.0	1.2	1.4	1.4	1.8
NE	25	0.0	0.5	0.5	0.6	0.6	0.4	0.5	0.6	0.5	0.7
E	75	1.0	1.8	2.1	2.5	2.9	2.8	3.2	3.6	3.7	4.1
E	65	0.8	1.6	1.9	2.3	2.6	2.5	2.9	3.2	3.3	3.7
E	55	0.7	1.3	1.5	1.9	2.3	2.1	2.3	2.8	2.8	3.2
E	45	0.6	1.0	1.2	1.5	1.7	1.6	1.9	2.2	2.2	2.6
E	35	0.6	0.7	0.8	0.9	1.1	1.1	1.3	1.5	1.5	1.9
E	25	0.0	0.5	0.5	0.6	0.7	0.5	0.6	0.7	0.6	0.7
SE	75	1.0	1.7	2.1	2.4	2.8	2.6	3.0	3.3	3.4	3.8
SE	65	0.8	1.5	1.7	2.2	2.5	2.3	2.6	3.0	2.9	3.4
SE	55	0.7	1.2	1.5	1.9	2.1	2.0	2.2	2.5	2.5	2.9
SE	45	0.6	0.9	1.1	1.4	1.7	1.6	1.8	2.0	2.0	2.3
SE	35	0.5	0.6	0.7	0.9	1.2	1.0	1.2	1.5	1.5	1.8
SE	25	0.0	0.5	0.5	0.5	0.6	0.4	0.6	0.7	0.6	0.7
S	75	0.9	1.6	2.1	2.4	2.8	2.7	2.9	3.3	3.4	3.8
S	65	0.8	1.4	1.7	2.2	2.5	2.3	2.6	2.9	3.0	3.4
S	55	0.7	1.2	1.5	1.8	2.1	2.0	2.2	2.5	2.6	2.9
S	45	0.6	0.9	1.1	1.4	1.7	1.5	1.7	2.1	2.0	2.4
S	35	0.5	0.6	0.8	0.9	1.1	1.1	1.2	1.4	1.4	1.8
S	25	0.0	0.4	0.0	0.5	0.6	0.4	0.5	0.6	0.5	0.8
SW	75	1.0	1.7	2.1	2.4	2.8	2.7	3.1	3.4	3.6	4.0
SW	65	0.8	1.5	1.7	2.2	2.5	2.3	2.6	3.0	3.2	3.6
SW	55	0.7	1.3	1.5	1.8	2.1	2.0	2.3	2.6	2.7	3.1
SW	45	0.6	1.0	1.1	1.5	1.7	1.5	1.8	2.1	2.1	2.5
SW	35	0.5	0.8	0.8	0.9	1.2	1.1	1.3	1.5	1.5	1.9
SW	25	0.0	0.5	0.0	0.6	0.6	0.5	0.6	0.8	0.7	0.7
W	75	1.0	1.9	2.2	2.6	3.0	2.9	3.3	3.7	3.9	4.3
W	65	0.9	1.6	1.9	2.3	2.6	2.6	3.0	3.3	3.5	3.8
W	55	0.7	1.4	1.6	2.0	2.3	2.2	2.5	2.9	2.9	3.4
W	45	0.7	1.1	1.3	1.6	1.9	1.6	2.0	2.3	2.3	2.7
W	35	0.5	0.8	0.8	1.1	1.4	1.2	1.4	1.6	1.6	2.0
W	25	0.0	0.6	0.5	0.6	0.7	0.5	0.6	0.8	0.8	1.0
NW	75	0.9	1.8	2.1	2.4	2.9	2.8	3.1	3.6	3.5	4.0
NW	65	0.8	1.5	1.7	2.2	2.5	2.4	2.7	3.1	3.2	3.6
NW	55	0.7	1.2	1.4	1.9	2.2	2.0	2.3	2.7	2.7	3.1
NW	45	0.6	1.0	1.1	1.4	1.7	1.6	1.9	2.1	2.1	2.5
NW	35	0.5	0.8	0.7	0.9	1.1	1.1	1.3	1.5	1.5	1.9
NW	25	0.0	0.5	0.5	0.6	0.6	0.4	0.5	0.6	0.5	0.8

Window-to-Wall Ratio (WWR) (%)


Unobstructed Urban Context (0-11.25 degree Urban Obstruction)
0 Degree Shading Overhang
15 Degree Shading Overhang
15 Degree Shading Overhang
Glazing T_{vis}(%)
Window-to-Wall Ratio (WWR) (%)
Direction
N
NE
E
SE
S
SW
W
NW
Unobstructed Urban Context for DA of 300 lux
Depth of $DA_{300lux,\ 50\%}$ daylit area
minus $UDIe_{3000lux,\ 10\%}$ overlit area
(commercial occupancy schedule)
(0.00 to 1.50) m daylight depth
(1.50 to 2.25) m daylight depth
(2.25 to 3.00) m daylight depth
(3.00 to 3.75) m daylight depth
(3.75 to 4.75) m daylight depth
(4.75 to 5.25) m daylight depth
> 5.25 m daylight depth
Potential Overlighting [1.3–2.0) m overlit depth
Risk of Overlighting >=2.0 m overlit depth


22.5 degree Urban Context (11.25-33.75 degree Urban Obstruction)
0 Degree Shading Overhang
15 Degree Shading Overhang
15 Degree Shading Overhang
Glazing T_vis(%)
Window-to-Wall Ratio (WWR) (%)
Direction
N
NE
E
SE
S
SW
W
NW
75-
65-
55-
45-
35-
25-
10
20
26
32
39
43
52
60
70
87
22.5 degree Urban Context
for DA of 300 lux
Depth of DA200lux, 50% daylit area
minus UDIe3000lux, 10% overlit area
(commercial occupancy schedule)
(0.00 to 1.50) m daylight depth
(1.50 to 2.25) m daylight depth
(2.25 to 3.00) m daylight depth
(3.00 to 3.75) m daylight depth
(3.75 to 4.75) m daylight depth
(4.75 to 5.25) m daylight depth
> 5.25 m daylight depth
Potential Overlighting [1.3–2.0) m overlit depth
Risk of Overlighting >=2.0 m overlit depth

45 degree Urban Context for DA of 300 lux

Depth of $DA_{300lux,\ 50\%}$ daylit area minus $UDIe_{3000lux,\ 10\%}$ overlit area (commercial occupancy schedule)

- (0.00 to 1.50) m daylight depth
- (1.50 to 2.25) m daylight depth
- (2.25 to 3.00) m daylight depth
- (3.00 to 3.75) m daylight depth
- (3.75 to 4.75) m daylight depth
- (4.75 to 5.25) m daylight depth
- > 5.25 m daylight depth

- Potential Overlighting [1.3–2.0) m overlit depth
- Risk of Overlighting >=2.0 m overlit depth

45 degree Urban Context (33.75-57.25 degree Urban Obstruction)

0 Degree Shading Overhang

Direction	Glazing T_{vis} (%)	WWR 10	20	26	32	39	43	52	60	70	87
N	75	0.9	1.0	1.4	1.8	2.1	2.0	2.4	2.7	2.8	2.8
N	65	0.9	1.0	1.3	1.6	1.9	1.8	2.1	2.5	2.6	2.7
N	55	0.9	1.0	1.1	1.3	1.7	1.6	1.8	2.1	2.3	2.3
N	45	0.8	0.9	1.1	1.2	1.4	1.2	1.4	1.6	1.8	2.0
N	35	0.8	0.9	0.9	1.3	1.4	1.1	1.1	1.2	1.2	1.7
N	25	0.6	1.0	0.8	1.0	1.0	0.9	1.0	1.2	1.2	1.6
NE	75	0.7	1.0	1.3	1.8	1.9	1.9	2.1	2.4	2.7	
NE	65	0.7	0.9	1.1	1.5	1.5	1.8	1.8	2.1	2.3	
NE	55	0.7	0.9	0.9	1.2	1.5	1.4	1.7	2.2	2.2	2.0
NE	45	0.6	0.7	0.9	1.1	1.3	1.2	1.5	1.6	1.8	1.9
NE	35	0.9	0.8	1.0	1.3	1.2	1.2	1.2	1.3	1.3	1.5
NE	25	0.7	0.8	0.9	1.0	1.2	1.0	1.2	1.2	1.2	1.5
E	75	0.7	1.0	1.2	1.6	2.1	2.0	2.5	2.8	2.9	
E	65	0.7	0.8	1.1	1.5	1.8	1.8	2.1	2.5	2.6	
E	55	0.6	0.8	0.8	1.1	1.4	1.5	1.7	2.1	2.2	2.6
E	45	0.6	0.7	1.0	0.8	1.0	0.9	1.2	1.6	1.7	2.2
E	35	0.7	0.7	0.9	1.0	1.1	1.1	1.1	1.3	1.3	1.4
E	25	0.7	1.0	1.0	1.0	1.2	1.0	1.3	1.3	1.3	1.7
SE	75	0.7	1.0	1.3	1.8	2.0	1.9	2.2	2.7	2.8	
SE	65	0.6	0.8	1.2	1.3	1.6	1.6	2.1	2.4	2.5	
SE	55	0.6	0.8	1.0	1.1	1.4	1.2	1.7	1.9	2.2	2.3
SE	45	0.7	0.7	0.8	1.0	1.1	1.0	1.3	1.7	1.7	2.0
SE	35	0.6	0.7	1.0	1.1	1.2	1.1	1.0	1.2	1.2	1.6
SE	25	0.6	1.0	0.9	1.0	1.1	0.9	1.0	1.3	1.4	1.6
S	75	0.8	0.9	1.5	1.8	2.0	2.0	2.3	2.6	2.8	2.9
S	65	0.9	0.9	1.1	1.5	1.9	1.8	2.0	2.3	2.4	2.6
S	55	0.8	0.9	1.1	1.2	1.5	1.5	1.7	2.0	2.2	2.2
S	45	0.7	0.8	1.0	1.1	1.3	1.2	1.4	1.6	1.7	1.8
S	35	0.8	0.8	1.2	1.0	1.4	1.0	1.1	1.2	1.2	1.8
S	25	0.6	1.0	0.8	0.9	1.1	1.0	1.0	1.1	1.2	1.6
SW	75	0.7	1.0	1.3	1.7	2.0	2.1	2.4	2.9	3.0	
SW	65	0.6	0.9	1.1	1.4	1.7	1.8	2.3	2.6	2.7	
SW	55	0.6	0.8	1.0	1.2	1.5	1.5	1.8	2.2	2.3	2.4
SW	45	0.7	0.7	0.9	1.0	1.3	1.0	1.4	1.6	1.8	2.3
SW	35	0.9	0.7	1.0	1.1	1.2	1.2	1.2	1.3	1.3	1.7
SW	25	0.6	1.0	0.9	1.0	1.1	0.9	1.1	1.4	1.4	1.6
W	75	0.6	1.1	1.4	1.8	2.2	2.2	2.6	3.0	3.0	
W	65	0.7	0.9	1.2	1.6	1.9	1.8	2.3	2.6	2.7	
W	55	0.6	0.8	0.8	1.2	1.6	1.6	1.9	2.1	2.3	2.7
W	45	0.5	0.7	1.0	0.8	1.2	1.2	1.4	1.6	1.8	2.2
W	35	0.7	0.7	0.9	1.1	1.2	1.1	1.1	1.3	1.3	1.6
W	25	0.7	1.1	0.8	1.1	1.4	1.1	1.3	1.3	1.4	1.7
NW	75	0.8	1.0	1.3	1.8	1.9	2.1	2.2	2.5	2.7	
NW	65	0.8	0.8	1.1	1.5	1.8	1.9	2.1	2.4	2.4	
NW	55	0.7	0.8	0.9	1.2	1.5	1.6	1.7	2.0	2.2	2.2
NW	45	0.6	0.7	1.0	1.1	1.3	1.3	1.5	1.8	1.8	2.1
NW	35	0.5	0.8	1.0	1.2	1.2	1.2	1.1	1.2	1.3	1.7
NW	25	0.7	1.0	1.0	1.1	1.2	1.0	1.0	1.3	1.2	1.6

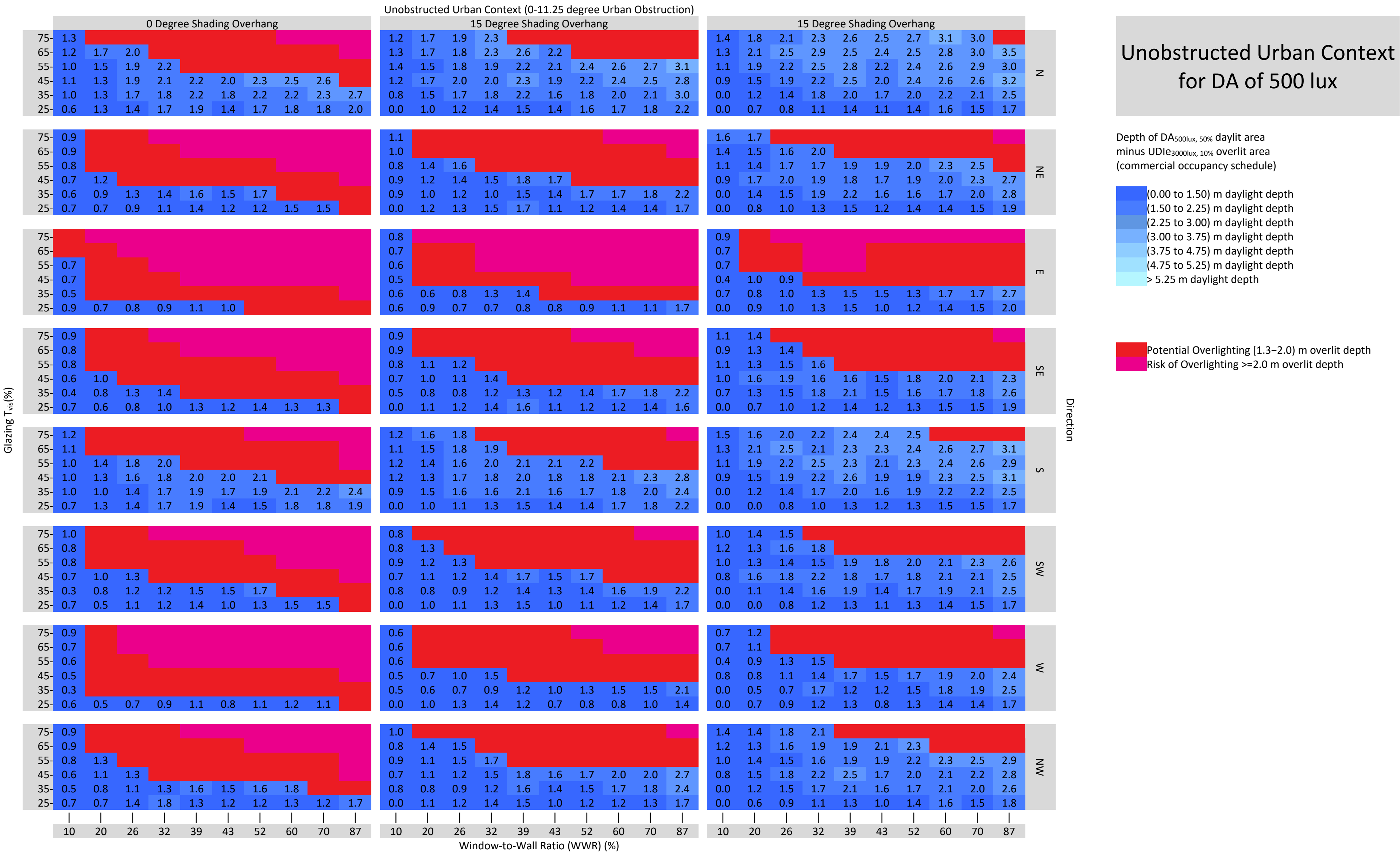
15 Degree Shading Overhang

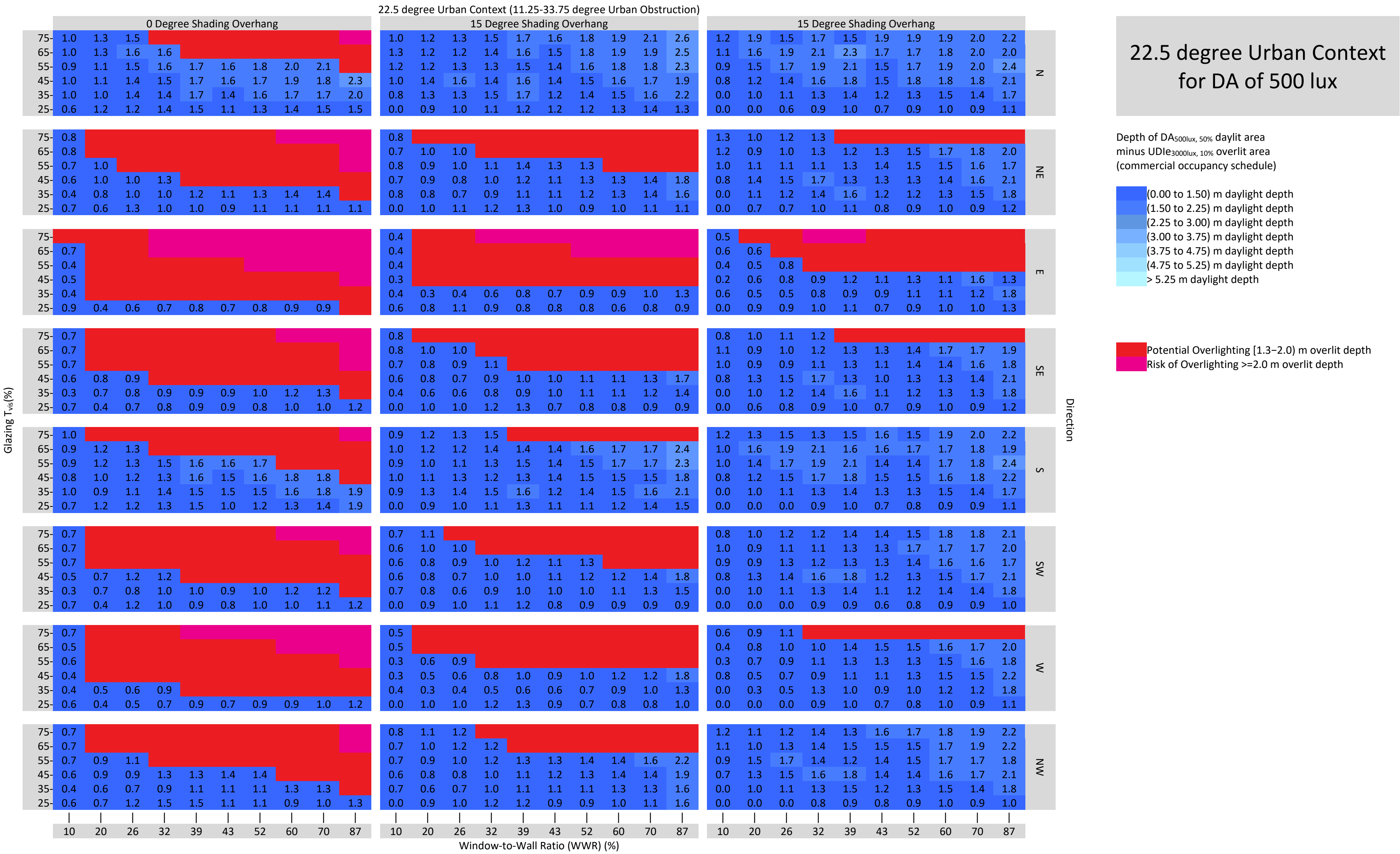
Direction	Glazing T_{vis} (%)	WWR 10	20	26	32	39	43	52	60	70	87
N	75	0.8	1.0	1.2	1.6	1.9	1.8	2.1	2.5	2.6	2.9
N	65	0.9	1.0	1.2	1.4	1.6	1.6	1.8	2.1	2.3	2.9
N	55	0.8	0.9	1.1	1.4	1.4	1.4	1.6	1.9	2.0	2.4
N	45	0.8	0.8	1.0	1.1	1.0	1.1	1.4	1.6	1.6	2.0
N	35	0.6	0.9	0.9	0.9	1.0	0.9	0.9	1.1	1.0	1.2
N	25	0.4	0.6	0.7	0.7	0.8	0.7	0.7	0.8	0.7	0.8
NE	75	0.7	1.0	1.0	1.4	1.8	1.7	2.0	2.3	2.5	2.9
NE	65	0.7	0.8	0.8	1.3	1.6	1.7	1.8	2.1	2.1	2.6
NE	55	0.6	0.7	0.8	1.1	1.5	1.5	1.6	1.8	1.9	2.3
NE	45	0.5	0.7	0.7	0.9	1.0	1.1	1.1	1.4	1.5	2.1
NE	35	0.7	0.9	0.9	1.0	1.1	0.9	0.9	1.1	1.0	1.2
NE	25	0.4	0.7	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.8
E	75	0.7	0.9	1.1	1.5	1.8	2.1	2.3	2.7	2.9	3.3
E	65	0.6	1.0	1.0	1.4	1.6	1.8	2.0	2.4	2.5	3.0
E	55	0.6	0.8	0.8	1.0	1.3	1.4	1.7	1.9	2.1	2.5
E	45	0.5	0.7	0.7	0.8	0.9	1.0	1.2	1.5	1.6	1.9
E	35	0.7	1.0	0.9	1.0	0.7	0.8	0.9	1.0	1.0	1.4
E	25	0.5	0.8	0.8	0.8	0.9	0.7	0.8	0.8	0.8	0.9
SE	75	0.7	1.0	1.0	1.4	1.7	1.6	1.9	2.2	2.3	2.7
SE	65	0.6	0.8	0.9	1.2	1.5	1.6	1.7	2.0	2.1	2.5
SE	55	0.6	0.6	0.7	0.9	1.3	1.3	1.5	1.7	1.9	2.2
SE	45	0.8	0.7	0.6	1.1	1.0	1.2	1.3	1.4	1.6	2.0
SE	35	0.7	0.9	0.9	1.0	1.0	0.8	0.9	1.1	1.1	1.3
SE	25	0.4	0.7	0.7	0.8	0.8	0.6	0.8	0.8	0.8	0.8
S	75	0.7	1.0	1.2	1.5	1.9	1.8	2.0	2.3	2.6	2.9
S	65	0.7	0.8	1.0	1.2	1.7	1.5	1.7	2.1	2.2	2.7
S	55	0.6	0.8	0.8	1.1	1.3	1.4	1.5	1.8	1.9	2.4
S	45	0.8	0.7	1.0	1.0	1.2	1.2	1.2	1.5	1.6	1.9
S	35	0.6	0.9	0.9	0.9	1.0	0.9	0.9	1.0	1.0	1.2
S	25	0.4	0.6	0.6	0.7	0.8	0.7	0.7	0.8	0.7	0.8
SW	75	0.7	1.1	1.0	1.4	1.7	1.7	2.0	2.4	2.6	3.0
SW	65	0.6	0.8	0.9	1.2	1.5	1.6	1.8	2.0	2.3	2.7
SW	55	0.5	0.7	0.7	1.0	1.3	1.5	1.5	1.8	2.0	2.3
SW	45	0.8	0.6	0.7	0.8	1.0	1.1	1.3	1.5	1.6	2.0
SW	35	0.7	0.9	0.9	1.0	1.1	0.9	0.9	1.1	1.1	1.2
SW	25	0.4	0.7	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.8
W	75	0.7	0.9	1.3	1.6	1.9	2.1	2.4	2.8	3.0	3.4
W	65	0.7	1.0	1.1	1.4	1.8	1.8	2.2	2.5	2.8	3.0
W	55	0.6	0.8	0.8	1.1	1.5	1.4	1.8	2.0	2.2	2.6
W	45	0.5	0.7	0.7	0.8	1.0	1.0	1.3	1.5	1.7	2.1
W	35	0.7	1.0	1.0	1.0	0.8	0.8	0.9	1.1	1.2	1.5
W	25	0.5	0.8	0.8	0.8	0.9	0.7	0.8	0.9	0.8	0.9
NW	75	0.8	0.9	1.0	1.4	1.8	1.8	2.1	2.5	2.7	3.1
NW	65	0.7	0.8	0.9	1.2	1.6	1.7	1.7	2.0	2.3	2.7
NW	55	0.6	0.8	0.7	1.1	1.3	1.5	1.6	1.8	2.0	2.4
NW	45	0.8	0.8	0.7	0.8	1.0	1.1	1.2	1.5	1.6	2.0
NW	35	0.7	0.9	0.9	1.0	1.0	0.9	0.9	1.0	1.0	1.4
NW	25	0.4	0.7	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.8

15 Degree Shading Overhang

Direction	Glazing T_{vis} (%)	WWR 10	20	26	32	39	43	52	60	70	87
N	75	0.6	1.1	1.3	1.6	1.9	1.7	2.1	2.4	2.4	2.7
N	65	0.6	0.8	1.0	1.3	1.5	1.5	1.7	2.0	2.0	2.3
N	55	0.5	0.7	0.8	1.0	1.3	1.1	1.4	1.6	1.6	1.9
N	45	0.0	0.6	0.6	0.6	0.8	0.7	0.9	1.2	1.1	1.5
N	35	0.0	0.4	0.0	0.5	0.5	0.4	0.4	0.5	0.4	0.6
N	25	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.0	0.0
NE	75	0.7	1.1	1.3	1.7	2.0	1.8	2.1	2.4	2.4	2.7
NE	65	0.6	0.9	1.1	1.4	1.7	1.5	1.8	2.1	2.1	2.4
NE	55	0.6	0.8	0.8	1.1	1.3	1.2	1.4	1.6	1.7	2.0
NE	45	0.5	0.6	0.7	0.8	0.8	0.8	0.9	1.2	1.1	1.5
NE	35	0.0	0.5	0.0	0.5	0.6	0.4	0.4	0.6	0.5	0.7
NE	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.0
E	75	0.7	1.2	1.4	1.8	2.1	1.9	2.2	2.6	2.6	3.0
E	65	0.6	1.0	1.1	1.5	1.7	1.6	1.9	2.2	2.2	2.6
E	55	0.6	0.8	0.8	1.2	1.5	1.3	1.5	1.7	1.8	2.1
E	45	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.2	1.3	1.6
E	35	0.0	0.5	0.5	0.6	0.6	0.5	0.5	0.7	0.6	0.8
E	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.1	0.0
SE	75	0.7	1.2	1.4	1.7	2.0	1.8	2.0	2.4	2.4	2.7
SE	65	0.6	1.0	1.1	1.4	1.7	1.5	1.8	2.1	2.0	2.4
SE	55	0.6	0.8	0.8	1.1	1.3	1.2	1.4	1.7	1.6	1.9
SE	45	0.4	0.6	0.6	0.8	0.9	0.8	1.0	1.2	1.1	1.5
SE	35	0.0	0.5	0.4	0.5	0.6	0.4	0.5	0.7	0.6	0.7
SE	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0
S	75	0.7	1.1	1.4	1.7	2.0	1.8	2.0	2.3	2.4	2.8
S	65	0.6	0.9	1.1	1.4	1.7	1.4	1.8	2.0	2.0	2.4
S	55	0.5	0.7	0.8	1.0	1.3	1.2	1.4	1.7	1.6	1.9
S	45	0.0	0.6	0.6	0.8	0.9	0.8	1.0	1.2	1.2	1.5
S	35	0.0	0.0	0.0	0.5	0.5	0.4	0.5	0.6	0.5	0.7
S	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.0
SW	75	0.7	1.2	1.4	1.7	2.0	1.8	2.1	2.4	2.5	2.9
SW	65	0.6	1.0	1.1	1.4	1.7	1.6	1.8	2.1	2.1	2.5
SW	55	0.5	0.8	0.9	1.1	1.4	1.2	1.4	1.7	1.7	2.0
SW	45	0.4	0.6	0.6	0.8	0.9	0.8	1.0	1.2	1.2	1.5
SW	35	0.0	0.0	0.0	0.6	0.6	0.4	0.6	0.7	0.6	0.7
SW	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.1	0.0
W	75	0.7	1.3	1.5	1.8	2.2	2.0	2.3	2.6	2.7	3.1
W	65	0.6	1.1	1.3	1.6	1.8	1.7	2.0	2.3	2.3	2.7
W	55	0.6	0.8	0.9	1.2	1.5	1.3	1.6	1.8	1.8	2.2
W	45	0.5	0.7	0.7	0.8	1.0	0.9	1.1	1.3	1.3	1.7
W	35	0.0	0.5	0.5	0.6	0.7	0.5	0.6	0.8	0.7	0.9
W	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.1	0.0
NW	75	0.7	1.1	1.3	1.7	2.0	1.9	2.2	2.5	2.4	2.9
NW	65	0.6	0.9	1.1	1.4	1.7	1.6	1.9	2.1	2.1	2.5
NW	55	0.5	0.8	0.8	1.1	1.3	1.2	1.4	1.7	1.7	2.1
NW	45	0.4	0.6	0.6	0.7	0.9	0.8	1.0	1.2	1.2	1.6
NW	35	0.0	0.5	0.4	0.5	0.6	0.4	0.5	0.7	0.6	0.7
NW	25	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.0

Window-to-Wall Ratio (WWR) (%)


Unobstructed Urban Context (0-11.25 degree Urban Obstruction)
0 Degree Shading Overhang
15 Degree Shading Overhang
15 Degree Shading Overhang
Glazing Tvis(%)
Window-to-Wall Ratio (WWR) (%)
10 20 26 32 39 43 52 60 70 87
75 65 55 45 35 25
Direction
N NE E SE S SW W NW
Unobstructed Urban Context for DA of 500 lux
Depth of DA500lux, 50% daylit area minus UDIe3000lux, 10% overlit area (commercial occupancy schedule)
(0.00 to 1.50) m daylight depth
(1.50 to 2.25) m daylight depth
(2.25 to 3.00) m daylight depth
(3.00 to 3.75) m daylight depth
(3.75 to 4.75) m daylight depth
(4.75 to 5.25) m daylight depth
> 5.25 m daylight depth
Potential Overlighting [1.3–2.0) m overlit depth
Risk of Overlighting >=2.0 m overlit depth


22.5 degree Urban Context (11.25-33.75 degree Urban Obstruction)
0 Degree Shading Overhang
15 Degree Shading Overhang
15 Degree Shading Overhang
Glazing T_vis(%)
Window-to-Wall Ratio (WWR) (%)
Direction
N
NE
E
SE
S
SW
W
NW
22.5 degree Urban Context for DA of 500 lux
Depth of DA500lux, 50% daylit area minus UDIe3000lux, 10% overlit area (commercial occupancy schedule)
(0.00 to 1.50) m daylight depth
(1.50 to 2.25) m daylight depth
(2.25 to 3.00) m daylight depth
(3.00 to 3.75) m daylight depth
(3.75 to 4.75) m daylight depth
(4.75 to 5.25) m daylight depth
> 5.25 m daylight depth
Potential Overlighting [1.3–2.0) m overlit depth
Risk of Overlighting >=2.0 m overlit depth

45 degree Urban Context for DA of 500 lux

45 degree Urban Context (33.75-57.25 degree Urban Obstruction)

Depth of $DA_{500lux,\ 50\%}$ daylit area minus $UDIe_{3000lux,\ 10\%}$ overlit area (commercial occupancy schedule)

- (0.00 to 1.50) m daylight depth
- (1.50 to 2.25) m daylight depth
- (2.25 to 3.00) m daylight depth
- (3.00 to 3.75) m daylight depth
- (3.75 to 4.75) m daylight depth
- (4.75 to 5.25) m daylight depth
- > 5.25 m daylight depth
- Potential Overlighting [1.3–2.0) m overlit depth
- Risk of Overlighting >=2.0 m overlit depth

0 Degree Shading Overhang (Window-to-Wall Ratio (WWR) (%))

Direction	Glazing T_{vis} (%)	10	20	26	32	39	43	52	60	70	87
N	75	0.6	0.7	0.9	1.0	1.1	1.0	1.3	1.5	1.6	1.7
N	65	0.6	0.7	0.9	1.0	1.2	1.0	1.1	1.4	1.4	1.5
N	55	0.6	0.7	0.9	0.9	1.0	1.0	1.1	1.2	1.1	1.2
N	45	0.4	0.6	0.7	0.8	0.9	0.8	1.0	1.0	1.0	1.1
N	35	0.5	0.5	0.4	0.8	0.7	0.6	0.7	0.7	0.7	1.2
N	25	0.0	0.6	0.4	0.4	0.5	0.5	0.5	0.5	0.6	1.1
NE	75	0.5	0.6	0.7	0.9	1.0	1.0	1.1	1.3	1.5	
NE	65	0.5	0.6	0.7	0.8	0.7	0.9	0.8	1.0	1.1	
NE	55	0.4	0.6	0.7	0.7	0.9	0.8	0.8	1.0	1.0	0.9
NE	45	0.3	0.4	0.5	0.7	1.0	0.9	1.0	1.0	1.0	1.0
NE	35	0.5	0.5	0.4	0.9	0.7	0.7	0.7	0.9	0.9	1.0
NE	25	0.0	0.4	0.4	0.5	0.6	0.5	0.5	0.6	0.6	1.0
E	75	0.4	0.6	0.7	0.8	1.0	1.0	1.3	1.6	1.7	
E	65	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.3	1.4	
E	55	0.3	0.5	0.6	0.6	0.8	0.8	0.8	0.9	1.0	1.4
E	45	0.3	0.4	0.6	0.5	0.8	0.6	0.6	0.8	0.7	1.0
E	35	0.3	0.4	0.4	0.6	0.7	0.6	0.6	0.8	0.8	0.7
E	25	0.3	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.6	1.3
SE	75	0.4	0.6	0.8	0.8	1.0	0.9	1.2	1.6	1.5	
SE	65	0.3	0.6	0.8	0.7	0.8	0.8	1.1	1.2	1.3	
SE	55	0.3	0.6	0.8	0.6	0.8	0.7	0.9	0.9	1.1	1.1
SE	45	0.3	0.4	0.4	0.6	0.9	0.7	0.8	0.9	0.9	1.1
SE	35	0.3	0.3	0.4	0.5	0.7	0.7	0.6	0.7	0.7	1.1
SE	25	0.0	0.6	0.4	0.5	0.6	0.5	0.5	0.7	0.7	1.3
S	75	0.6	0.6	0.9	1.0	1.1	1.0	1.3	1.5	1.6	1.7
S	65	0.6	0.6	0.9	0.9	1.0	1.0	1.0	1.3	1.3	1.5
S	55	0.5	0.6	0.8	0.8	1.0	0.9	1.0	1.0	1.1	1.1
S	45	0.3	0.5	0.6	0.7	0.8	0.8	0.9	0.9	1.1	0.9
S	35	0.5	0.5	0.7	0.4	0.8	0.5	0.5	0.7	0.7	1.2
S	25	0.0	0.6	0.4	0.4	0.5	0.4	0.5	0.5	0.6	1.1
SW	75	0.4	0.6	0.8	0.8	1.0	1.0	1.3	1.7	1.7	
SW	65	0.3	0.6	0.8	0.8	0.8	0.8	1.1	1.4	1.4	
SW	55	0.3	0.6	0.8	0.8	0.9	0.8	0.9	1.1	1.1	1.2
SW	45	0.3	0.4	0.4	0.6	1.0	0.8	0.9	1.0	0.9	1.2
SW	35	0.5	0.3	0.4	0.6	0.7	0.7	0.7	0.7	0.7	1.1
SW	25	0.0	0.6	0.4	0.5	0.5	0.4	0.6	0.6	0.7	1.2
W	75	0.3	0.6	0.7	0.8	1.1	1.1	1.4	1.8	1.7	
W	65	0.4	0.6	0.7	0.8	0.8	0.8	1.1	1.4	1.4	
W	55	0.2	0.5	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.4
W	45	0.2	0.4	0.6	0.6	0.7	0.6	0.7	0.7	0.7	1.0
W	35	0.4	0.4	0.4	0.7	0.6	0.7	0.7	0.9	0.9	0.9
W	25	0.3	0.7	0.5	0.5	0.6	0.5	0.7	0.7	0.7	1.3
NW	75	0.5	0.6	0.7	0.9	0.9	1.1	1.1	1.3	1.4	
NW	65	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.2	1.1	
NW	55	0.4	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0
NW	45	0.3	0.4	0.6	0.9	1.0	1.0	0.9	1.0	1.0	1.0
NW	35	0.1	0.4	0.4	0.8	0.7	0.7	0.7	0.8	0.8	1.1
NW	25	0.0	0.6	0.4	0.5	0.6	0.5	0.5	0.6	0.6	1.2

15 Degree Shading Overhang (Window-to-Wall Ratio (WWR) (%))

Direction	Glazing T_{vis} (%)	10	20	26	32	39	43	52	60	70	87
N	75	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.4	1.3	1.6
N	65	0.6	0.7	0.9	0.8	0.8	0.9	0.8	1.0	1.2	1.5
N	55	0.6	0.7	0.8	0.9	0.8	0.8	0.9	1.0	1.1	1.2
N	45	0.5	0.6	0.8	0.8	0.8	0.7	0.8	0.9	0.8	0.9
N	35	0.0	0.6	0.6	0.6	0.7	0.6	0.7	0.7	0.6	0.7
N	25	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.3	0.4
NE	75	0.4	0.6	0.4	0.6	0.8	0.8	1.0	1.2	1.4	1.6
NE	65	0.5	0.5	0.5	0.6	0.6	0.8	0.9	1.1	1.1	1.4
NE	55	0.4	0.5	0.5	0.7	0.7	0.8	0.7	0.8	0.8	1.1
NE	45	0.2	0.4	0.5	0.6	0.7	0.6	0.6	0.6	0.6	0.9
NE	35	0.3	0.6	0.6	0.7	0.8	0.5	0.6	0.7	0.6	0.8
NE	25	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.3	0.5
E	75	0.5	0.5	0.6	0.6	0.8	1.0	1.2	1.4	1.6	2.0
E	65	0.4	0.6	0.6	0.7	0.7	0.8	1.0	1.2	1.3	1.5
E	55	0.3	0.6	0.6	0.6	0.7	0.7	0.7	0.9	1.0	1.1
E	45	0.2	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8	0.7
E	35	0.4	0.7	0.6	0.7	0.4	0.4	0.6	0.6	0.6	0.8
E	25	0.0	0.0	0.0	0.0	0.4	0.3	0.4	0.5	0.4	0.5
SE	75	0.5	0.5	0.4	0.6	0.8	0.9	1.0	1.2	1.3	1.5
SE	65	0.3	0.5	0.5	0.5	0.6	0.8	0.9	1.1	1.2	1.3
SE	55	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.9	1.0	0.9
SE	45	0.5	0.4	0.4	0.8	0.6	0.6	0.7	0.7	0.7	0.9
SE	35	0.3	0.6	0.6	0.7	0.7	0.5	0.6	0.7	0.6	0.8
SE	25	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5	0.4	0.4
S	75	0.5	0.6	0.7	0.7	0.9	1.0	1.1	1.3	1.4	1.7
S	65	0.4	0.6	0.6	0.6	0.7	0.8	0.9	1.1	1.2	1.4
S	55	0.4	0.5	0.6	0.7	0.7	0.7	0.8	0.9	1.0	1.1
S	45	0.5	0.4	0.8	0.8	0.7	0.7	0.7	0.8	0.8	0.9
S	35	0.0	0.6	0.6	0.6	0.7	0.5	0.6	0.6	0.6	0.7
S	25	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.3	0.3
SW	75	0.5	0.6	0.5	0.6	0.8	0.9	1.0	1.1	1.3	1.7
SW	65	0.3	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.4
SW	55	0.3	0.4	0.4	0.5	0.6	0.8	0.7	0.9	0.9	0.9
SW	45	0.5	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.7	0.9
SW	35	0.0	0.6	0.6	0.7	0.7	0.6	0.6	0.7	0.6	0.8
SW	25	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5	0.4	0.5
W	75	0.5	0.5	0.6	0.6	0.8	1.1	1.3	1.6	1.7	2.0
W	65	0.4	0.7	0.6	0.7	0.8	0.8	1.1	1.3	1.5	1.8
W	55	0.3	0.6	0.6	0.6	0.6	0.7	0.8	0.9	1.0	1.2
W	45	0.2	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8	0.7
W	35	0.4	0.7	0.7	0.7	0.5	0.5	0.6	0.7	0.7	0.8
W	25	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.5	0.4	0.5
NW	75	0.6	0.6	0.5	0.5	0.8	0.9	1.1	1.3	1.4	1.8
NW	65	0.5	0.5	0.5	0.5	0.7	0.8	0.8	1.0	1.2	1.4
NW	55	0.4	0.5	0.5	0.7	0.7	0.8	0.7	0.9	0.9	1.1
NW	45	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.9
NW	35	0.0	0.6	0.6	0.7	0.8	0.6	0.6	0.7	0.6	0.8
NW	25	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.5	0.4	0.5

15 Degree Shading Overhang (Window-to-Wall Ratio (WWR) (%))

Direction	Glazing T_{vis} (%)	10	20	26	32	39	43	52	60	70	87
N	75	0.4	0.6	0.7	0.8	0.9	0.8	1.0	1.3	1.2	1.6
N	65	0.0	0.5	0.5	0.6	0.7	0.6	0.8	0.9	0.9	1.1
N	55	0.0	0.4	0.0	0.5	0.5	0.4	0.5	0.6	0.5	0.7
N	45	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.2	0.0
N	35	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
N	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NE	75	0.5	0.6	0.7	0.8	1.0	0.9	1.1	1.2	1.2	1.7
NE	65	0.4	0.6	0.6	0.6	0.8	0.6	0.8	1.0	1.0	1.2
NE	55	0.0	0.5	0.5	0.6	0.6	0.4	0.5	0.6	0.6	0.7
NE	45	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.1	0.0
NE	35	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
NE	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	75	0.5	0.7	0.8	0.8	1.1	1.0	1.2	1.4	1.4	1.8
E	65	0.4	0.6	0.6	0.7	0.8	0.7	0.9	1.1	1.1	1.3
E	55	0.0	0.5	0.5	0.6	0.7	0.5	0.6	0.7	0.6	0.9
E	45	0.0	0.0	0.0	0.0	0.5	0.3	0.3	0.4	0.3	0.0
E	35	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.0	0.0
E	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	75	0.5	0.7	0.7	0.8	1.0	0.9	1.2	1.3	1.3	1.6
SE	65	0.0	0.6	0.6	0.7	0.8	0.7	0.8	1.0	1.0	1.2
SE	55	0.0	0.5	0.4	0.6	0.6	0.4	0.5	0.7	0.6	0.7
SE	45	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	0.2	0.0
SE	35	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.0
SE	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	75	0.4	0.6	0.6	0.8	1.0	0.9	1.1	1.3	1.3	1.6
S	65	0.0	0.5	0.5	0.6	0.8	0.6	0.8	1.0	0.9	1.3
S	55	0.0	0.0	0.0	0.5	0.5	0.4	0.5	0.6	0.5	0.7
S	45	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.2	0.0
S	35	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0
S	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	75	0.5	0.6	0.7	0.8	1.1	1.0	1.2	1.3	1.3	1.7
SW	65	0.0	0.6	0.6	0.6	0.8	0.7	0.9	1.0	1.0	1.3
SW	55	0.0	0.5	0.4	0.5	0.6	0.4	0.6	0.7	0.6	0.8
SW	45	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	0.2	0.0
SW	35	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.0	0.0
SW	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	75	0.5	0.7	0.7	0.9	1.1	1.0	1.2	1.5	1.5	1.9
W	65	0.4	0.6	0.7	0.7	0.8	0.8	0.9	1.1	1.1	1.5
W	55	0.0	0.5	0.5	0.6	0.7	0.5	0.6	0.7	0.7	1.0
W	45	0.0	0.0	0.0	0.0	0.5	0.3	0.3	0.3	0.3	0.0
W	35	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0
W	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NW	75	0.5	0.6	0.8	0.8	1.0	0.9	1.1	1.4	1.3	1.7
NW	65	0.0	0.6	0.6	0.7	0.8	0.7	0.9	1.0	1.0	1.3
NW	55	0.0	0.5	0.5	0.5	0.6	0.4	0.5	0.7	0.6	0.7
NW	45	0.0	0.0	0.0	0.0	0.5	0.3	0.3	0.4	0.2	0.0
NW	35	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0
NW	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix C: Energy Modeling Methodology and Requirements

General

The energy modeling 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. The energy savings shall be measured by comparing the annual energy consumption of the Proposed Model (designed building) against the Reference Model (baseline building).

Simulation Software

The simulation software used for energy modeling shall meet the following criteria:

(a) It must have the capability to model the thermal performance of buildings in a multi zone format and calculate the building's total energy consumption over a continuous 12-months period.

(b) It must be tested by a recognised institution in accordance with *ANSI/ASHRAE Standard 140 – Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs* (or other equivalent standards).

Reference Model

(i) Baseline Standards

The simulation model for calculating the baseline building performance (known as Reference Model) shall be developed in accordance with the requirements in the following table on Baseline Standards. The requirements are applicable to all buildings, including building served by new/ existing DCS plants.

<table>
<tr><th>S/N</th><th>Component</th><th>Baseline Standard</th><th>Minimum Requirement</th></tr>
<tr><td>1</td><td colspan="3">Building Description</td></tr>
<tr><td>1.1</td><td>Building Envelope Design</td><td>BCA Approved Document
Code on Envelope Thermal Performance for buildings

SS 212 : 2007 – Specification for Aluminium Alloy Windows</td><td>(a) ETTV shall not exceed 50 W/m^2
(b) For roof with skylight, RTTV shall not exceed 50 W/m^2
For roof without skylight, the average U value of the gross area of the roof shall not exceed the limits below:
<table>
<tr><th>Weight Group</th><th>Weight range (kg/m^2)</th><th>Max Thermal Transmittance (W/m^{2}k)</th></tr>
<tr><td>Light</td><td>Under 50</td><td>0.5</td></tr>
<tr><td>Medium</td><td>50 to 230</td><td>0.8</td></tr>
<tr><td>Heavy</td><td>Over 230</td><td>1.2</td></tr>
</table>
(c) All windows on the building envelope shall not exceed the air leakage rates specified in SS 212 : 2007.
(d) Where the door opening of any commercial unit is located along the perimeter of the building envelope, that unit shall:
(i) Be completely separated from the other parts of the building
(ii) Have its air-conditioning system separated from and independent of the central system.</td></tr>
<tr><td>1.2</td><td>Building Shape, Size and Configuration</td><td></td><td>Reference Model to be the same as Proposed Model</td></tr>
<tr><td>1.3</td><td>Building Zoning & Thermal Block</td><td></td><td>Reference Model to be the same as Proposed Model.
Zoning of air-conditioned and non-air conditioned areas shall be modelled based on the approved building plan except for floor areas that conform to the provisions for Passive Design Features under Para 3.9 to reduce air-conditioned spaces. Where ACMV zones are defined on the ACMV design drawings, each ACMV zone shall be modelled as a separate thermal block.</td></tr>
</table>

<table>
<tr><th>S/N</th><th>Component</th><th>Baseline Standard</th><th>Minimum Requirement</th></tr>
<tr><td>2</td><td colspan="3">System Description</td></tr>
<tr><td>2.1</td><td>Air-conditioning System Types</td><td>SS 530 : 2014 – Code of Practice for Energy efficiency Standard for Building Services and Equipment

ASHRAE 90.1: 2013 – Energy Standard for Buildings Except Low-Rise Residential Buildings</td><td>(a) Based on the peak building cooling load, the reference system shall be as follows:
(i) Peak building cooling load ≥ 500RT: Centrifugal chiller.
- Peak cooling load ≤ 800 RT: 1 number of centrifugal chiller
- Peak cooling load > 800 RT: N numbers of centrifugal chillers equally sized with each chiller ≤ 800 RT
(ii) Peak building cooling load < 500RT and air-conditioned area ≥ 5,000m^2: Screw chiller
- Peak cooling load ≤ 300 RT: 1 number of screw chiller
- Peak cooling load > 300 RT: 2 numbers of screw chillers sized equally sized with each chiller ≤ 300 RT
(iii) Peak building cooling load < 500RT and air-conditioned area < 5,000m^2: The reference system shall be of the same type as the proposed system.
(iv) For VRF systems, the baseline of constant COP of 3.28, 3.22 and 2.93 shall be adopted, with reference to SS 530 : 2014, Table 1B.
(b) Additional chiller or other air conditioning configuration may be considered if the reference chiller(s) operate at less than 50% of its capacity for more than 20% of the time.
(c) For buildings with chilled water supplied/ to be supplied by a District Cooling System (DCS) company*:
(i) Path A: The above item (a) and (b) are applicable to building with chilled water supplied by DCS company under Path A. All ACMV components dedicated to the DCS plant and building designed shall be included and considered. The energy efficiency and chilled water system of the Proposed Model shall be that of the DCS plant. The baseline efficiency will be 0.80kW/ton (with reference to DCS Plant Boundary stated in P.4 Air Conditioning Total System and Component Efficiency). Together with chilled water pumps within building (baseline = 0.0568 kW/RT), the total allowable reference efficiency of the chilled water system would be 0.8586 kW/RT.
(ii) Path B: The energy consumption contribution from the DCS plant may be excluded from the energy modeling provided the two criteria as follows are complied with:

<table>
<tr><th>Level of Green Mark Award</th><th>Cooling Load Savings</th><th>Energy Consumption Savings (exclude DCS plant)</th></tr>
<tr><td>Gold^{PLUS}</td><td>10%</td><td>27%</td></tr>
<tr><td>Platinum</td><td>15%</td><td>33%</td></tr>
</table>
Paths A and B shall be as per defined as per P.4 Air Conditioning Total System and Component Efficiency.
*Note: District Cooling System baseline is only used for buildings served by DCS supplier. It does not apply to large chiller plant system owned and operated by building owner serving their own buildings.</td></tr>
<tr><td>2.2</td><td>Chiller Efficiency</td><td>SS 530 : 2014</td><td>Minimum energy efficiency standard stated in SS 530 : 2014. Please refer below for the default chiller efficiency curve.
For District Cooling System, please refer to 2.1(c).</td></tr>
</table>

<table>
<tr><th>S/N</th><th>Component</th><th>Baseline Standard</th><th>Minimum Requirement</th></tr>
<tr><td>2.3</td><td>Air-Conditioning Hydronic Systems</td><td>SS 553 : 2016 - Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings

California Energy Commission Non-Residential Alternative Calculation Method Reference Manual 2013 Appendix 5.7</td><td>(a) Pumping system design criteria
(b) For air-conditioning hydronic systems having a total pump system power exceeding 7.5 kW, the pump power limitation for chilled water systems shall be 349 kW/m³/s. The pump power limitation for condensing water systems is 301 kW/m³/s.
(ii) For motors > 3.7 kW: The chilled water pump shall have VSD and the motor shall have controls and/ or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.
(iii) For motors ≤ 3.7 kW: The chilled water pump shall be the equivalent of a constant speed pump if motor is less than 3.7 kW.
(iv) Condenser water pump shall be the equivalent of a constant speed pump.
(v) Buildings served by DCS, code-compliance chilled water pump efficiency will be 0.0568 kW/RT for chilled water pumps within the building.
The above item (i) to (iv) are applicable to buildings with chilled water supplied by DCS companiess. For Path B, only the customer building pumps shall be considered.
(c) Calculation for part load performance of chilled water pump with VSD and the minimum operating load shall be capped at 50% (25 Hz) of the equipment capacity.

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

Values in table below are for reference only
(projects are advised to use actual value and formula for computation)
<table>
<tr><td>x</td><td>0.2</td><td>0.3</td><td>0.4</td><td>0.5</td><td>0.6</td><td>0.7</td><td>0.8</td><td>0.9</td><td>1</td></tr>
<tr><td>Pump ratio</td><td>0.025</td><td>0.059</td><td>0.111</td><td>0.185</td><td>0.284</td><td>0.413</td><td>0.573</td><td>0.770</td><td>1.006</td></tr>
</table>

Project team can propose other equivalent methodology but affinity law is not recommended as it does not take into account of loss in actual operating conditions.</td></tr>
<tr><td>2.4</td><td>Cooling Tower</td><td>SS 530: 2014

California Energy Commission Non-Residential Alternative Calculation Method Reference Manual 2013 Appendix 5.7</td><td>Performance requirement for heat rejection equipment:
a) Propeller or axial fan cooling towers: Cooling tower performance shall not be less than 3.23 L/s/kW.
b) Centrifugal fan cooling towers: Cooling tower performance shall not be less than 1.7 L/s/kW.
c) Calculation for part load performance of Cooling tower with VSD and the minimum operating load shall be capped at 50% (25 Hz) of the equipment capacity.
Cooling tower fan power ratio $= 0.331629 - 0.885676\,x + 0.605565\,x^2 + 0.948482\,x^3$
where x is the part load ratio
Values in table below are for reference only
(projects are advised to use actual value and formula for computation)
<table>
<tr><td>x</td><td>0.2</td><td>0.3</td><td>0.4</td><td>0.5</td><td>0.6</td><td>0.7</td><td>0.8</td><td>0.9</td><td>1</td></tr>
<tr><td>CT ratio</td><td>0.186</td><td>0.146</td><td>0.135</td><td>0.159</td><td>0.223</td><td>0.334</td><td>0.496</td><td>0.716</td><td>1.000</td></tr>
</table>
Project team can propose other equivalent methodology but affinity law is not recommended as it does not take into account of loss in actual operating conditions.</td></tr>
<tr><td>2.5</td><td>Air Conditioning Fan Systems</td><td>SS 553 : 2016
ASHRAE 90.1: 2013
Non-domestic Building Services Compliance Guide 2013 Edition</td><td>The ratio of fan system power to the supply fan air flow rate (main fan) of each air-conditioning system at design conditions shall not exceed the allowable fan system power.
<u>Airflow Rate for Reference Model</u>
(a) The airflow rate for the Reference Model shall be based on the auto-sizing function of the energy modeling software used.
(b) The Reference Model for spaces served by fan coil units (FCUs) shall be of constant flow system, and the airflow rate shall be auto-sized by the energy modeling software. For hotel guest room FCUs where the airflow rate simulated is less than that of the smallest FCU available in the market, the airflow rate of the proposed FCU can be adopted for the Reference Model.
<u>Fan System Design Criteria</u>
(c) For fan systems with a motor nameplate power ≥ 4 kW, the fan power limitation in air-conditioning system (the allowable fan system input power) shall be as follows:</td></tr>
</table>

S/N	Component	Baseline Standard	Minimum Requirement

(i) Constant volume shall not exceed 1.5 kW/m^3/s (or 0.42 W/CMH + A) of supply air. Reference control strategy for CAV system shall be constant speed.

(ii) Variable volume shall not exceed 2.1 kW/m^3/s (or 0.58 W/CMH + A) of supply air.

Note: Fan power limitation pressure drop adjustment is not applicable for the following devices:

- *Return and/or exhaust air systems*
- *Return and/or exhaust airflow control devices*
- *Exhaust filters or other exhaust treatment*
- *Particulate Filtration Credit: MERV 9 – 14*

Fan power limitation pressure drop adjustment can be considered for activities where higher fan power is expected to overcome the high static pressure of the specialized hardware such as kitchen exhaust, heap filter or high pressure exhaust system used in clean room, laboratories and hospitals. There is no exception to the reference for cases when the proposed fan power exceeds the reference power limitation in Table 2b of SS 553 : 2015

(d) For fan system having a motor nameplate power < 4 kW, the allowable fan system input power shall be ≤ 0.6 kW/m^3/s (0.17 W/CMH) of supply air. For cases where the proposed fan power exceeds the reference power limitation, the energy consumption of the proposed fan can be applied to the Reference Model.

(e) For computation of fan power, 5% driver loss needs to be accounted for the use of VSD. Project team can use lower value if they can substantiate VSD loss with documentation.

<u>Part load fan power limitation</u>

(f) The reference control strategy for VAV system shall come with VSD without exemption, applicable to all fans including small fan motors ≤ 7.4 kW.

(g) Individual VAV fans with motors of ≥ 7.4 kW shall meet one of the following requirements:
- Be driven by an electrical variable speed drive.
- Have other controls and devices for the fan that will result in fan motor demand of less than 30% of design wattage at 50% of design air volume when static pressure set point equals one-third of the total design static pressure based on manufacturer's certified fan data.
- Calculation for part load performance of VAV fan with VSD and the minimum operating load shall be capped at 50% (25 Hz) of the equipment capacity. The part load fan power calculator may be referenced from ASHRAE 90.1, Table G3.1.3.15, *Part-Load Performance for VAV Fan Systems, Method 2 – Part-Load Fan Power Equation* for part load fan power calculation.

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)

Values in table below are for reference only

(projects are advised to use actual value and formula for computation)

x	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Fan ratio	0.068	0.128	0.206	0.300	0.410	0.536	0.676	0.831	1.000

For laboratories, ACH baseline will reference to existing laboratory with similar function and there should be setback ACH during non-occupancy. Where information is not readily available, the following baseline can be considered after discussion with assessors. Projects should design for minimum flowrate to reduce energy consumption within safety limit.

Laboratories	ACH for unoccupied hours	ACH for occupied hours
BSL1	3	4
BSL2 & 3 (Sprinkled)	4	8
BSL2 & 3 (Non-Sprinkled)	6	12
CDSL 1, 2, 3	Minimum opening for fume hood(s)	Maintain minimum 0.5m/s airflow for fume hood(s) at working position. Reasonable diversity to be considered.

*ACH baseline for BSL4 / CDSL4 to be discussed with assessor(s) on case-by-case basis if baseline for BSL3/CDSL3 are not suitable.

S/N	Component	Baseline Standard	Minimum Requirement
2.6	Mechanical Ventilation Fan Systems	*SS 553 : 2016* *ASHRAE 90.1: 2013* *Non-domestic Building Services Compliance Guide 2013 Edition*	The ratio of fan system power to the supply fan air flow rate (main fan) of each ventilation system at design conditions shall not exceed the allowable fan system power. Fan system design criteria (a) Mechanical ventilation systems having a total fan system power ≥ 4kW shall refer to *SS 553 : 2015, Table 8 – Fan Power Limitation in Mechanical Ventilation Systems*. (a) Reference fan power limitation for mechanical ventilation system shall be constant volume type and the fan system input shall not exceed 0.3 W/CMH + A. *Note: The fan power limitation pressure drop adjustment is not applicable for the following devices:* - *Exhaust air systems* - *Exhaust airflow control devices* - *Exhaust filters* *Exceptions can be considered for activities where higher fan power are expected to overcome the high static pressure of the specialized hardware such as kitchen exhaust, heap filter or high pressure exhaust system used in clean room, and hospital. There is no exception to the Reference Model for cases when proposed fan power exceeds the baseline power limitation.* (b) For fan system with a motor nameplate power < 4 kW, the allowable fan system input power shall not exceed 0.6 kW/m3/s (or 0.17 W/CMH) of supply air. For cases where the proposed fan power exceeds the reference power limitation, the energy consumption of the proposed fan can be applied to the Reference Model.
2.7	Design Airflow Rates	*ASHRAE 90.1:2013 Section G3.1.2.9.1*	For systems serving laboratory spaces, use a supply-air-to-room-air temperature difference of 9°C or the required ventilation air or makeup air, whichever is greater.
2.8	Exhaust Air	*ASHRAE 90.1:2013 Section 6.5.7.2*	Buildings with laboratory exhaust systems having a total exhaust rate greater than 2360 L/s should adopt at least one of the energy efficient features as stated in *ASHRAE 90.1 Section 6.5.7.2*.
2.9	Lighting Systems	*SS 530 : 2014* *ASHRAE 90.1:2013*	(a) The maximum design lighting power (including ballast loss) for a building's interior lighting shall not exceed the sum of maximal power for various areas calculated in accordance with *SS 530 : 2014, Table 7A- Maximum Building Interior Lighting Power Density for Compliance (Space-By Space Method).* Particularly, the maximum design lighting power (including ballast loss) for laboratories shall be 16W/m^2. The allowable lighting power density stated in *ASHRAE 90.1:2013* can be considered if the lighting power budget for the types of usage is not available in *SS 530*. (b) The allowable building exterior and outdoor (uncovered area) lighting power shall be the combined total of the sum of the general hardscape lighting allowance determined in according to *SS 530, Table 7D* and the sum of the additional lighting power allowance for specific applications determined in accordance with Table 7E. The maximal power density requirements specified in Table 7D are tradable but those specified in Table 7E are not, unless stated otherwise.
2.10	Hot Water generation	*SS 530 : 2014* *SS 553 : 2016*	(a) For generation of hot water ≤ 60°C, the baseline shall be a heat pump with COP of 3.2. (b) Control of indoor thermal environment via reheat of the air shall not be allowed except for energy source from site-recovered energy (including condenser heat) or site-solar energy, referring to *SS 553, Section 8.14*. The baseline for this case will be heat pump with COP of 3.2.
2.11	Energy Recovery Systems	*SS 553 : 2016*	(a) Exhaust air of 2.5 m^3/s or greater from conditioned space in a single location shall have energy recovery system with at least 60% recovery effectiveness. 60% recovery effectiveness shall mean a change of enthalpy of the outdoor air supply equal to 60% of the difference between the outdoor air and return air at design conditions when tested under AHRI standard 1060. (b) Control of indoor thermal environment by reheating the air shall not be allowed except for energy source from site-recovered energy (including condenser heat) or site-solar energy, refer to SS553, Section 8.14. The baseline for this case will be heat pump with COP of 3.2.

S/N	Component	Baseline Standard	Minimum Requirement
3	Others		
3.1	Receptacle & Process loads	ASHRAE 2013 ASHRAE Fundamentals Handbook (SI)	In general, the receptacle value for both the Reference Model and proposed design shall be the same. Some default figures are as mentioned: **Receptacle Loads / Standard / Nominal Values** a. Computer intensive offices – 22.0 W/m² b. General office areas – 16.0 W/m² c. Large conference areas – 11 W/m² d. Data Centre – 540.0 W/m² e. Server Room – 270 W/m² f. Schools (Tertiary/IHLs) – 8 W/m² g. Schools (Primary/Secondary) – 5 W/m² Standard: Source: ASHRAE 90.1.2013 Receptacle load to be capped at 25% of baseline total energy building's energy consumption if it exceeds that value. <u>Office</u> Energy savings is allowed in the form of a lower W/m² for the proposed design (as compared to 16 W/m² for the Reference Model) if the project can commit to deliver lower receptacle density at verification. The project team must provide a green lease, dedicated energy meters and tenant engagement programme as evidences for Green Mark assessment. <u>Data Centres</u> Energy consumed by data centres must be included as receptacle loads in the model. The scope and the calculation methodology must take reference from the *BCA-IDA Green Mark for New Data Centre* Criteria. The PUE of data centres must be ≤ 2. The building owner is encouraged to apply for the *BCA-IDA Green Mark for New Data Centre scheme* if the share of the energy consumed by the data centre is substantial compared to the building's total energy consumption. <u>Laboratories</u> Project could take reference from the receptacle load values stated in the *ASHRAE Fundamentals Handbook (SI)* or other international recognised guides with diversity and should consider existing measured data. <u>Schools</u> Energy savings, for above listed area, are allowed in the form of a lower W/m2 for the proposed design if the project can commit to deliver lower receptacle density at verification. The project must be able to effectively measure the areas' energy consumption as evidences for Green Mark assessment
3.2	Occupancy Rates		Same as proposed design
3.3	Operation Schedules		Same as proposed design
3.4	Indoor Thermal Comfort Conditions	*SS554 :2016 – Code of Practice for Indoor Air Quality for Air-conditioned Buildings*	Same as proposed design
3.5	Minimum Ventilation Rates	*SS 553 : 2016* *NFPA 45* *EPA*	Same as proposed design except for laboratories. For laboratories, baseline air change rate would be: • 8 ACH (Occupied) • 4 ACH (Non-occupied) The project team can propose values for specific usages based on international/ Singapore recognised guidelines.
3.6	Heat Exchanger		Same as proposed design
3.7	Lift & Escalator without Regenerative Drive		Same as proposed design Both the reference and proposed design baseline should incorporate A/C VVVF features.
3.8	Modeling Limitation or Simulation Program		Same as proposed design

S/N	Component	Baseline Standard	Minimum Requirement
3.9	Passive Design Features		For projects that demonstrate considerable efforts to reduce air-conditioning energy consumption, a cap of 3% of additional energy savings from passive design features over its Reference Model can be considered. Total energy saving accounted for passive design features and renewable energy is capped at 5%. For savings to be justified, design strategies that enhance the ventilation and thermal comfort of the designated non air-conditioned spaces must be demonstrated. A written justification detailing the design strategies used and evidences accompanied with simulation and/or calculation of the energy saving estimate would be required for evaluation. Examples • Circulation spaces such as atria, can be considered if these spaces are largely designed to be non-air-conditioned and sizeable. This is not applicable to areas that would normally be non-air-conditioned, such as warehouses, school classrooms and pantries. • The introduction of air well or slopes to convert a mechanical ventilated car park to a code compliant natural ventilated car park is also acceptable. However, open air naturally ventilated carparks cannot be considered for energy savings.
4.0	Renewable Energy		Energy generated from renewable sources, such as solar photovoltaic (PV) systems, could be used to offset the 25% and 30% energy savings requirement for Gold^{PLUS} and Platinum projects respectively, up to a maximum of 3% energy savings against the annual energy consumption from the Reference Model. For example, if a project has annual energy consumption of 100 MWh simulated from the Reference Model and 72 MWh from the Proposed Model, the project can attain 28% energy savings. However, if it has solar PV installed to produce 2 MWh annually, it could offset a further 2% of the energy savings. This brings its total energy savings to 30%.

Note:
Where there is no baseline standard for certain energy related features such as chilled beams, underfloor air distribution systems, receptacle loads, lifts and escalators, hot water systems, reference can be made to ASHRAE 90.1:2013 Appendix G. For buildings with special requirements where there is no reference based on ASHRAE 90.1:2013 Appendix G, the baseline set for similar building type completed after 2005 can be considered. Detailed calculations must be provided to justify the savings in energy consumption from the use of salient energy efficient features /equipment. Where justification cannot be provided, the same input parameters for good design practice shall apply to both the Reference and Proposed Model.

(ii) Default Chiller Efficiency Curve

The default Chiller Curve and Chiller Configuration, references to *SS 530 : 2014, AHRI 551/591, Path A, Full Load Conditions*. The standard rating conditions are based on chilled water supply temperature at 7.0°C, chilled water return temperature at 12.0°C, condenser water entering temperature at 30.0°C and condenser water leaving temperature at 35.0°C. The default part load performance curves below are provided in DOE 2.2 and IESVE software 2014 which are compliant with California's TM24 requirement:

Equipment Type	Size Category	COP									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Rotary Screw and Scroll	< 263kW	3.125	3.581	3.809	3.970	4.105	4.228	4.345	4.461	4.576	4.694
	≥ 264 kW and < 528 kW	3.255	3.730	3.967	4.135	4.276	4.403	4.526	4.646	4.767	4.889
	≥ 528 kW and < 1055 kW	3.551	4.069	4.328	4.511	4.665	4.804	4.938	5.069	5.200	5.334
	≥ 1,055 kW and < 2110 kW	3.842	4.403	4.683	4.881	5.047	5.198	5.342	5.484	5.626	5.771
	≥ 2,110 kW	4.185	4.796	5.100	5.317	5.497	5.662	5.819	5.974	6.129	6.286
Centrifugal	< 1,055 kW	1.676	2.914	3.821	4.478	4.949	5.279	5.504	5.648	5.732	5.771
	≥ 1,055kW and < 1,407 kW	1.826	3.174	4.162	4.878	5.391	5.750	5.995	6.152	6.244	6.286
	≥ 1,407kW	1.826	3.174	4.162	4.878	5.391	5.750	5.995	6.152	6.244	6.286

Energy Modeling Methodology

The simulation model of the Proposed Model, as well as the Reference Model shall be:

(a) Developed in accordance with the design parameters of the building. This includes:

- Building design layout in terms of shape, size and orientation
- Materials for walls, windows, roofs, floors, doors and permanent shading devices, internal partitions between conditioned and non-conditioned spaces
- Internal loads such as levels and schedules for occupancy, lighting systems, equipment, appliances and machinery within the building
- ACMV equipment, controls and other associated components selected for use in the building

(b) Calculated using the same:

- Software
- Weather data: Appropriate up-to-date weather set should be used for energy modeling such as ASHRAE's International Weather for Energy Calculation data for Singapore.
- Operating schedules
- Occupancy rates
- Building design in terms of shape, size and orientation
- Receptacle loads (exception for office, see *3.1* under Table 1 for requirements)
- Indoor environmental conditions in terms of thermal comfort level: If a different condition such as higher space temperature is used in the Proposed Model, there must be evidence to demonstrate that the overall thermal comfort level is not lower than that of the Reference Model.
- Internal illuminance levels (lux) for space lightings

(c) Based on the overall energy consumption computed over a period of 1 year using the building envelope and all energy consuming equipment that are selected during the design stage. This includes energy consumed by chillers, air handling systems, plant equipment (e.g. water pumps, cooling towers, tube cleaning devices, chillers, etc.), and non-ACMV systems such as lighting, lifts, escalators, ceiling fans and receptacle loads from equipment (e.g. photo-copiers, printers, fax machines, computers, laptops, fridges, projectors, audio-cum video systems, water heaters, dryers, washers, etc.).

The basis for deriving the overall energy consumption and potential energy savings must be made clear and justifiable for consideration. Notwithstanding this, the potential energy savings for the following systems/devices shall be capped as follows:

List of Systems/Devices	Cap on Energy Savings Devices
Escalator	30%
Lift with regenerative features	18%
CO Sensors	15%
Occupancy sensors	15%
Photo sensors	15%
Renewable energy (e.g. solar energy)	3%*

* Total energy saving accounted for passive design features and renewable energy is capped at 5%.

The improved performance of the proposed building design can then be obtained by making comparison of the overall energy consumption of the Reference Model against the Proposed Model.

Calculation of Energy Efficiency Index (EEI) and Energy Use Intensity (EUI)

The normalised EEI based on the proposed model result shall be computed using the formula:

$$EEI_{Normalised,model} = \frac{TBEC - DCEC - CPEC}{GFA - DCA} \times \frac{NF}{OH}$$

The EEI shall be computed as follows:

$$EEI_{model} = \frac{TBEC - DCEC - CPEC}{GFA - DCA}$$

The building overall EUI, excluding car park shall be calculated as follows:

$$EUI_{model} = \frac{TBEC - CPEC}{GFA}$$

The car park EUI shall be calculated as follows

$$EUI_{Carpark,model} = \frac{CPEC}{CPFA}$$

TBEC: Total building energy consumption (kWh/year)
DCEC: Data centre energy consumption (kWh/year)
CPEC: Car park energy consumption (kWh/year)
CPFA: Total floor area for car park (m^2)
DCA: Data centre areas (m^2)
GFA: Gross floor area (m^2)
OH: Weighted weekly operating hours (hours/week)
NF: Normalising factor based on typical weekly operating hours of the following building types:
Office: 55 hours/week
Retail: 84 hours/week
Hotel and Industrial: 168 hours/week
Institutions: 60 hours/week
Carpark: 168 hours/week

Documentation Requirements

(A) Design Stage

The name and company of the Energy Modeling consultant, details of software used and its limitations, building type and complexity shall be submitted to BCA. The *Energy Modeling Form for Green Mark Scheme (Finalisation of Building Design)* following shall be submitted, of which the template may be found at the following link:
https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/em_form.docx

The Qualified Person (QP) and the appropriate practitioners shall certify that the energy modeling for the building has been carried out in accordance with the requirements using the energy modeling methodology. The appropriate practitioner shall ensure that the assumptions and inputs used for energy modeling are bona fide. The energy modeling specialist shall certify and be responsible for the correctness of the modeling included proper usage of the relevant software.

The QP and the appropriate practitioners shall ensure the following documents and records are available as evidences to demonstrate compliance with the energy modeling framework and validation of the potential energy savings during final assessment. They are:

(a) Certification showing that the simulation software is tested and meet the criteria in accordance with the ANSI/ASHRAE Standard 140

(b) Detailed drawings and other necessary information of proposed design

(c) Detailed system design calculation

(d) Summary of Space and Envelope Thermal Transfer Value (ETTV) of the Building Envelope as in *Energy Modeling Form for Green Mark Scheme (Finalisation of Building Design)*

(e) List of data such as:

- Space input data for all zones comprising detail information on construction materials and their properties designed for each individual zone. For example, room area, walls, windows, doors, floors, partitions, sensible and latent loads (lightings, occupancy rates, receptacles loads, outdoor ventilation rates, misc. loads etc.). Schedules for each individual operating zone (e.g. lighting, occupants, mechanical fans, AHUs, other mechanical and electrical equipment, etc.)
- Executable input data files used in the generation of the energy estimates for the Proposed and Reference Models
- Output data on the monthly energy consumption by mechanical and electrical system components (e.g. Air-conditioned systems, Lighting Systems, Receptacle Equipment, Lifts, Escalators etc.)

- One year simulated hourly cooling load data in the form of the Frequency vs Cooling Load (RT) plot, Cooling Load vs Time, A/C efficiency vs Time
- Detailed computation of the ETTV for both Reference and Proposed Models
- Comparison of Reference Model versus Proposed Model as in Form: Energy Modeling Form (Finalisation of Building Design)
- Summary of Energy of End Use including Efficiency Indicators for both Reference and Proposed Models as in *Energy Modeling Form (Finalisation of Building Design)*
- Summary printouts of energy modeling software for the Reference Model including summary of weather data results Monthly energy consumption of mechanical and electrical system components such as air-conditioned system, lighting systems, receptacle equipment's, lift and escalator etc.
- Assumptions and limitations in modeling with rectifications

(f) Executable file of the EM simulation for both the Proposed and Reference Models

(g) Recommendations (if any)

(B) Verification Stage 2

For Gold^{PLUS} and Platinum projects, when the building starts to operate in a steady state, the developer shall within 2 years after TOP, commence to gather data on actual site operation for the next 12 months period. Appropriate and adequate power meters shall be installed to measure and record the breakdown on the energy consumption from the utilities 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. Adequate meters shall be installed to data log and monitor and extract the necessary information, e.g. monthly and annual energy generated (kWh) from the Solar PV. Dedicated meters shall be installed to measure the operational energy consumption and intensities of receptacle load (W/m^2) of office space to verify on the energy savings claimed in energy modeling. Using the data on actual site operation, a revised energy modeling shall be performed to compare the annual energy consumption of the Reference Model with the actual consumption of the building.

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 Modeling Form for Green Mark Scheme (Validation After Project Completion)* - the template may be found at the following link: *https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/em_form.docx*
b) Electricity bills: Building landlord/ tenants/ DCS company bills for 12 months if applicable. Building cooling provision from DCS company (Path A and Path B) shall provide energy efficiency information (kW/RT) of the plant to facilitate the computation of EEI and EUI of the customer building. Monthly bills paid to DCS company shall be provided to facilitate EEI and EUI computation at verification stage.
c) Energy Audit Report (the template may be found the following link: *https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/annexb_energy_audit_report.doc*)
d) As-built electrical single-line schematics drawings
e) Description of deviations of the building operations to the Proposed Energy Model which was submitted for Green Mark Certification e.g. monthly building occupancy rate, receptacle loads, data centre addition etc.
f) BMS data log for the individual energy end use as in the actual energy breakdown under the Form for Energy Modeling for Green Mark Scheme (Validation After Project Completion); kWh raw data in softcopy Microsoft Excel file format and categorized according to the meters as-built schematics design.
g) Temporary logging of energy end use as in Form for Energy Modeling for Green Mark Scheme (Validation After Project Completion); kWh raw data in softcopy Microsoft Excel file format.
h) Data Centre Monthly Energy Consumption - kWh raw data in softcopy (if applicable).
i) BMS data log and monitoring of monthly and annual energy generated (kWh) from renewable energy

j) For actual building operations, state:
   (i) Operation hours for the spaces using the cooling load profiles
   (ii) Operation of chiller plant
   - Operating hours
   - Installed capacity
   - Duty and standby
   - Latest 1- week building cooling load
   - Latest 1-week chiller plant efficiency profile
   (iii) Operation hours of other air-con systems e.g. unitary system for after office hours cooling demand
   - Spaces with after office hours demand
   (iv) Human load schedules
   (v) Lighting schedules

k) EEI and EUI Calculation
   (i) The operational hours of the building and car park
   (ii) Area of the car park
   (iii) EUI information must tally with submission to BCA BESS system.

l) For Reference Energy Model, state:
   (i) Operation hours for the spaces (Must be similar to actual operation)
   (ii) Operation of chiller plant
   - Capacity and configuration in simulation
   - Simulated 1- week building cooling load
   - Simulated 1-week chiller plant efficiency profile
   (iii) Operation hours of other air-con systems e.g. unitary system for after office hours cooling demand (Must be similar to actual operation)
   - Spaces with after office hours demand
   (iv) Human load schedules (Must be similar to actual operation)
   (v) Simulation file in softcopy

A project will have deemed to have met the pre-requisite where the key energy consuming components are operating to their designed efficiencies. A calibrated reference model shall <u>not be</u> required except for circumstances including:

(a) A significant discrepancy in comparison with the energy model results
(b) Change of primary use
(c) A change of functional area distribution
(d) Changes in equipment specifications and performance
(e) Changes in GFA
(f) Change in ventilation modes

Guidance Notes

To assist in the generation of satisfactory results from the energy modeling simulation, the EM consultant should adhere to the following self-assessment checklist before the energy modeling assessment.

Checklist Item	Notes
A. Overview	1) Verify if Energy Modeling is required. 2) Verify the key performance indicators (KPI) a. EEI b. W/m^2 c. kW/RT
B. Input Checks (for both proposed and reference model)	1) General Setting a. Weather b. Elevation c. Orientation d. Area summary (discrepancies within 5%) 2) Façade a. Select at least 3 areas to verify façade selection b. Construction c. SC value of glass and U-Value of walls and windows.

Checklist Item	Notes
	3) Thermal Zoning 4) HVAC design a. Typical space W/m^2 and whole building W/m^2 b. Cooling load profile c. Cooling system • Compressor (e.g. chiller if applicable) • Condenser (e.g. cooling tower if applicable) • Pumps (if applicable) • Overall and individual efficiency (kW/RT) d. Air distribution (baseline - provide oversizing factor) • Individual W/CMH • Typical CMH/m^2 and whole building CMH/m^2 • Overall air distribution kW/RT e. Overall – Provide unmet hours (Should not exceed 300 unmet hours) 5) Lighting 6) Receptacle load 7) MV fans 8) Schedule and diversity (including non-A/C areas like car park) 9) Energy saving items, eg heat recovery 10) Non-modelled items by alternative calculation
C. Output checks	1) Indoor thermal parameters for three typical indoor spaces 2) Daily, weekly, and monthly building cooling load 3) Energy breakdown proportion
D. Consistency checks	1) Proposed model and reference model consistency 2) Input data and output data consistency 3) Assumption verification 4) Exception calculation method

Appendix D: Alternative Cooling Technologies (ACT)

General

Singapore has a hot and humid climate and the use of conventional air-conditioning methods in such a climate requires intense amount of energy. Since the inception of BCA Green Mark Scheme in 2005 and efforts of 3 Green Building Masterplans in 2006, 2009 and 2013, various Alternative Cooling Technologies (ACT) have been researched and developed to provide similar thermal comfort conditions and comparable Indoor Air Quality (IAQ) as conventional systems while using significantly lesser energy.

Acceptable Solutions as Alternative Cooling Technologies

Examples of Alterative Cooling Technologies are:

a) Passive Displacement Cooling (PDC) Systems
b) Hybrid Cooling Systems
c) Decoupling of Latent and Sensible Cooling Systems

The adoption of above technologies in projects will be able to gain credits based on size of adoption under Part 5 Advanced Green Efforts as well as credits under Part 2 Building Energy Performance through direct and indirect improvement in performance and reduction in energy consumption. The use of ACT should not compromise thermal comfort and IAQ. The ACT are expected to have energy savings from 10% to 40% depending on degree of applications, building functions and application scenarios. The above list is non-exhaustive and other Alternate Cooling Technologies that intend to gain similar credit will require review by BCA Green Mark team.

Passive Displacement Cooling (PDC) Systems

Description

Uses natural convection of heat transfer to move the cooled air without mechanical fans and thus reduced energy uses.

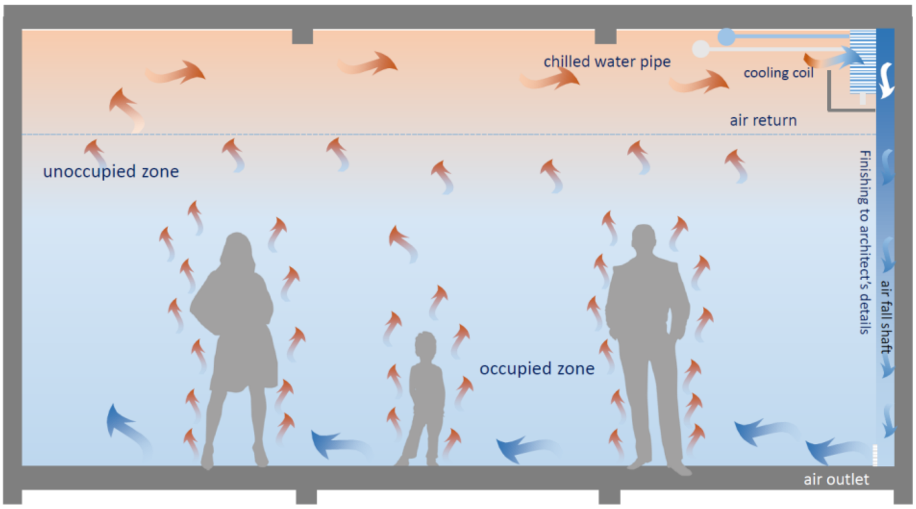


Figure D1: Schematic for Passive Displacement Cooling (PDC) Systems [Copyright ©. Used with permission.]

Hybrid cooling Systems

Description

Other than cooling through lower air temperature and lower humidity, cooling effect can be achieved through convection and evaporation processes from occupants' bodies with increased air speed. Within threshold limit, occupants feel cooler with higher air movement without the need to cool the air further. There are various ways to increase air movement such as desk, pedestal, wall-mounted, and ceiling fans. Electrical fans can be effectively used to increase air movement indoors and effectively cool down occupants to ensure that occupants are in thermal neutrality with the indoor environment even at higher set-point temperatures.

Elevating air speed compliments with air conditioning systems and it only requires a fraction of the energy needed to cool down the air temperature for achieving an equivalent thermal comfort condition. The higher the cooling temperature setpoint, the higher the energy saving. Every 1 °C increase in the cooling temperature set-point is estimated to reduce ACMV energy consumption by roughly 10%.

The air movement generated by specific fans, at different speed settings, can be obtained from the manufacturer's documentation. For ceiling fans, the data should comply with ASHRAE Standard 216. Project teams would need to ensure thermal comfort is achieved, by checking design with comfort tool with reference to ASHRAE Standard 55.

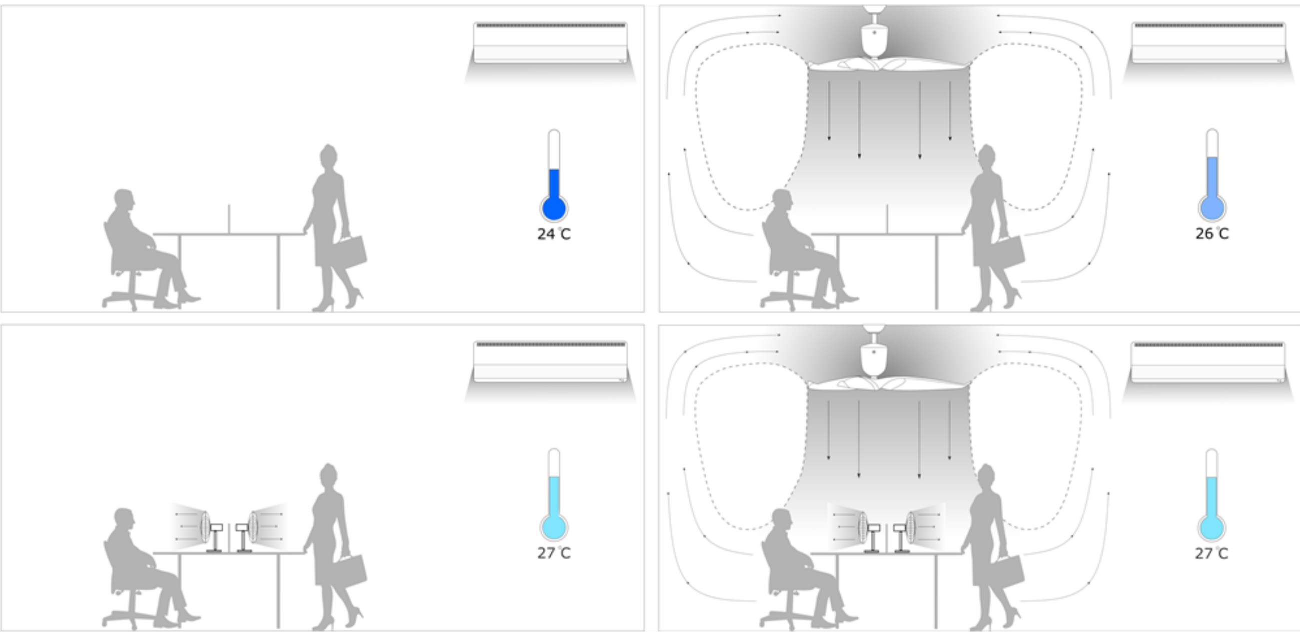


Figure D2: Schematic for Hybrid Cooling Systems (for illustration purpose only) [Copyright ©. Used with permission.]
Comparison of equivalent thermal comfort conditions.
For occupants involved in sedentary activities and wearing standard office attire, the same thermal comfort conditions can be achieved either by having lower space temperature, or by increasing air speed with elevated space temperature.

Decoupling of Latent and Sensible Cooling Systems

Description

Separate system to handle sensible load (through the use of radiant ceiling panels, chilled beam, underfloor slab etc.) and latent load (through the use of dedicated outdoor air system). There are many variants to this concept which comprises of direct or indirect cooling of air with chilled water pipes in spaces. All or most of latent load are handled at fresh air supply to allow chilled water pipes to handle mostly or only sensible load in spaces.

Radiant cooling through use of ceiling panels, metal chilled ceiling or comparable

The system operates primarily on the radiation principle and handles sensible cooling of the space. It is operated in combination with a heat recovery mechanical ventilation system to supply fresh air, cover latent loads by maintaining space dew point and if required, the remaining sensible load.

Metal chilled ceilings ceiling system is characterised by a variety of application and design options. It is used primarily in office and administration buildings, retail outlets, in rooms for seminars and conferences, as well as in clean rooms and hospitals. Some common variants are closed ceilings, island design, canopies or peripheral zones.

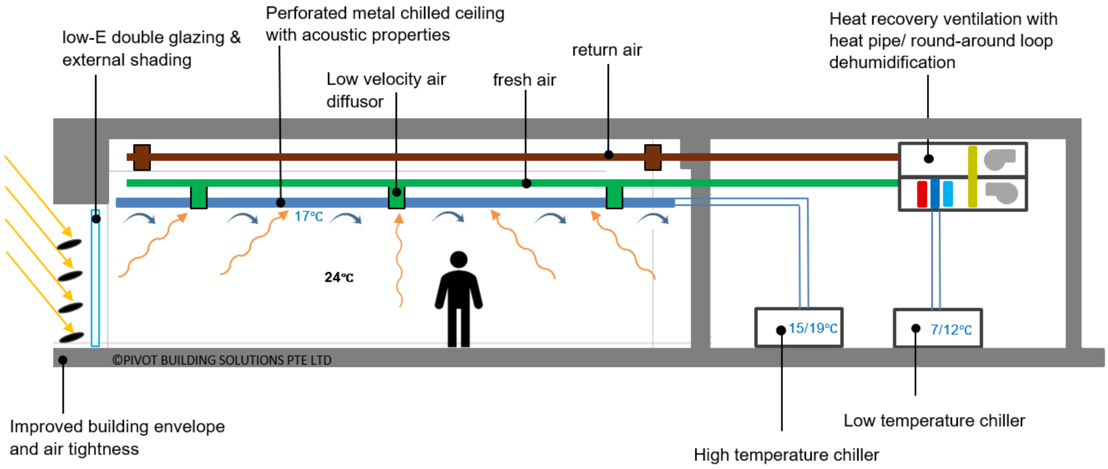


Figure D3: Schematic for perforated metal chilled ceilings with heat recovery ventilation with heat pipe dehumidification. [Copyright ©. Used with permission.]

Chilled beams

Chilled beams typically involves having metal chilled beams in occupant space and it is best suited for applications with high sensible heat ratio and low fresh air demand in hot and humid climate. Chilled beams are broadly classified as passive and active chilled beams. The former requires distinct load distribution with suitable space height to allow natural convection to bring hotter air to be cooled by chilled beams located near the ceiling. The latter makes use of small fan systems to bring about air movement toward the chilled beams. In applications where minor latent loads are involved, drain pans can be coupled into the system.

Underfloor cooling through the use of slab or comparable

A chilled slab system typically utilises the concrete's or screed's thermal mass by embedding pipes, such as polyethylene cross-linked pipes (PE-Xa), carrying chilled water to cool space's slab/wall. The embedded pipes activate the concrete or screed to temporary store and discharge thermal loads. In this way, activated ceilings, floors or walls contribute primarily to the sensible cooling of the building by removing convective, conductive, short and long wave radiation cooling loads.

Chilled slab systems in tropical climates are recommended to couple with heat recovery ventilation systems in fresh air supply, to remove latent loads before mixing with space air to control space's dew point. This application is recommended for base cooling, direct solar load removal and air stratification in building with high floor to ceiling height.

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