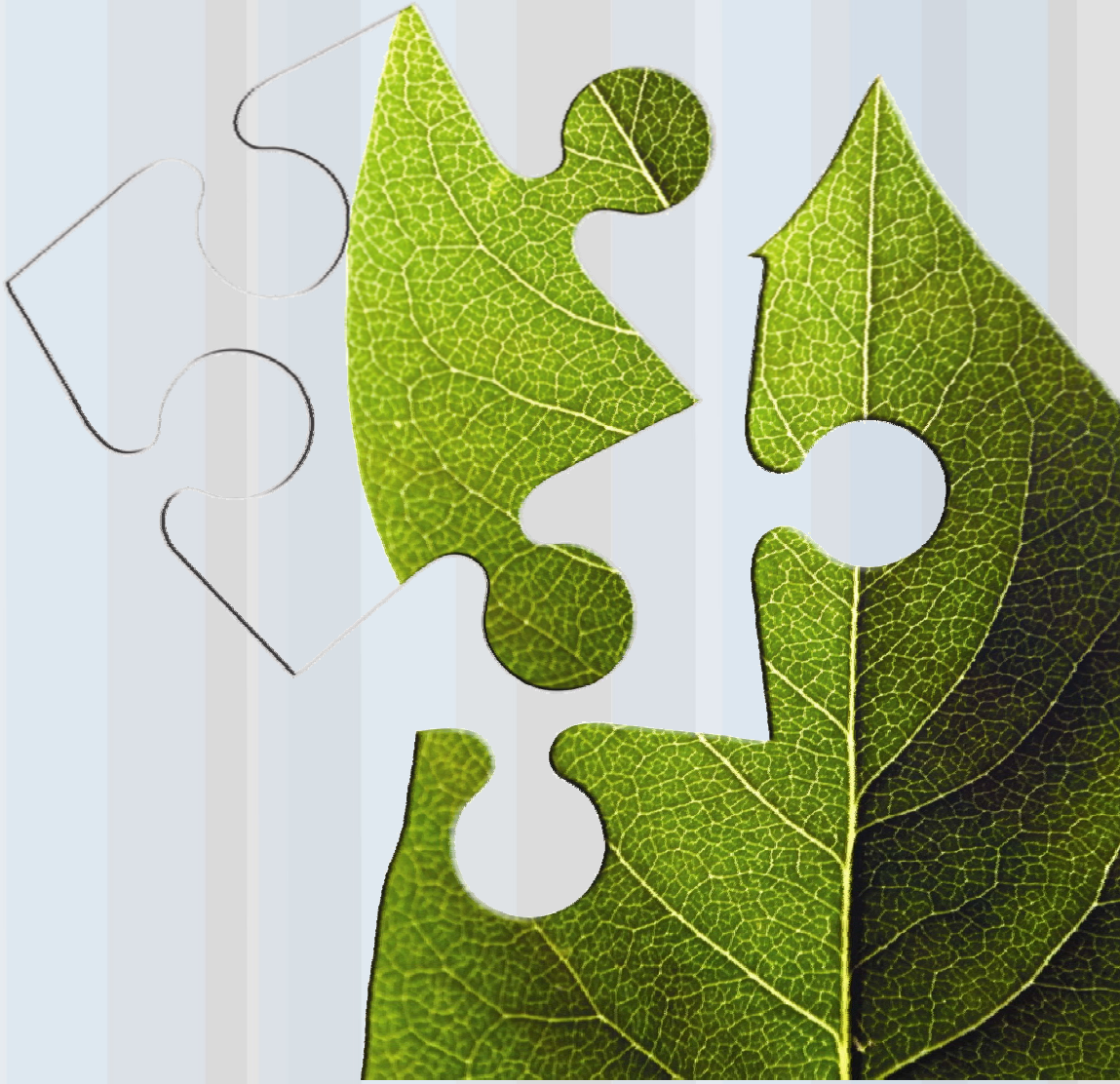
Building and Construction Authority

BCA GREEN MARK

BCA Green Mark

Certification Standard for New Buildings

GM Version 4.1



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October 2012

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BCA GREEN MARK CERTIFICATION STANDARD FOR NEW BUILDINGS

APPENDIXES

INTRODUCTION

The intent of this Certification Standard for New Buildings (referred to as “this Standard”) is to establish environmentally friendly practices for the planning, design and construction of buildings, which would help to mitigate the environmental impact of built structures.

This Standard sets out the requirement for assessing the environmental performance of a building development.

This Standard is not intended to abridge safety, health, environmental or related requirements contained in other applicable laws, codes or policies administered by relevant authorities. Where there is a conflict between a requirement of this Standard and such other laws affecting the design and construction of the building, precedence shall be determined by the relevant authorities.

If you need clarification on any aspect of this Standard, please contact the Building and Construction Authority, Singapore.

1 SCOPE

This Standard sets out the requirement for assessing the environmental performance of a building development. It provides the assessment criteria in determining the level of environmental performance of a building development.

The provisions of this Standard are applicable to :

a. New buildings and related building systems ; and

b. New building works and related building systems in existing buildings undergoing major retrofitting.

2 NORMATIVE REFERENCES

The following referenced codes, standards and other documents referred in this Standard shall be considered part of the requirements of this Standard to the extent as prescribed.

a. Code on Envelope Thermal Performance for Buildings

b. SS 530 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment

c. SS 531-1 - Code of Practice for Lighting of Work Places - Indoor

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

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

f. SS CP 38 - Code of Practice for Artificial Lighting in Buildings

g. AHRI Standard 550/590 - Performance Rating of Water Chilling Packages using the Vapour Compression Cycle

h. ANSI/ASHRAE Standard 140 - Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

i. ANSI/ASHRAE/IESNA 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings

j. ASHRAE Guideline 22 - Instrumentation for Monitoring Central Chilled Water Plant Efficiency

3 TERMS AND DEFINITIONS

For the purpose of this Standard, the following terms and definitions shall apply:

Dwelling Unit	A unit within residential development that provides complete, independent living facilities for one or more person.
Design System Efficiency (DSE)	The energy efficiency of building cooling system designed to meet the operating condition and requirement in providing an acceptable indoor thermal environment. It is a measure of how efficiently the cooling system would operate during building operation and its computation is to be based on the methodology spelled out in this Standard.

Green Mark Score	The score for environmental performance of buildings computed in accordance with the criteria and scoring methodology set out in this Standard.
Gross Floor Area (GFA)	The gross floor area (GFA) is calculated using the definition by the Urban Redevelopment Authority (URA).
Major Retrofitting	The provision, extension or substantial alteration of the building envelope and building services in or in connection with an existing building.

In instances where terms are not expressly stated in this Standard and are defined in other referenced documents, such terms shall have the meanings as determined in those documents.

4 CERTIFICATION PROCESS

The BCA Green Mark Certification Process is as follows :

- 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.

- A pre-assessment audit will be conducted to give the project team a better understanding of the criteria and evaluation of the certification level sought.

- Actual assessment to be conducted once the design and documentary evidences are ready.
- Assessment process includes design and documentary reviews to verify if the building project meets (i) the intents of the criteria and certification level; and (ii) the prerequisite requirements.
- For projects with potential BCA Green Mark Gold^{Plus} and Platinum rating, there is a requirement for projects to be presented and assessed by panel members.

- Site verification to be conducted upon project completion.
- Site verification process includes review of delivery records, updated documents on green features, building energy performance data and photographic evidences. Site inspection and measurement will be conducted.
- For projects with BCA Gold^{Plus} and Platinum rating, energy modeling based on the actual building operating data and parameters will be required to ascertain the energy savings over its reference model upon building completion.

5 ASSESSMENT FRAMEWORK

5.1 General

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 Standard. 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 four rating namely BCA Green Mark Certified, Gold, Gold^{Plus} or Platinum (see Table 5.2). The design of the building development shall also meet all the relevant mandatory requirements regulated under Part IV of the Building Control Regulations 2003.

5.2 Environmental Performance of Buildings for Certification

The Green Mark Score of the building design is the total of all the numerical scores (i.e. Green Mark points) assigned based on the degree of compliance with the applicable criteria. The following Table 5.2 states the corresponding Green Mark Score and prerequisite requirements to attain the respective Green Mark rating namely the BCA Green Mark Certified, Gold, Gold^{Plus} and Platinum.

Table 5.2 – BCA Green Mark Award Rating and Prerequisite Requirements

Green Mark Score	Green Mark Rating
90 and above	Green Mark Platinum
85 to < 90	Green Mark Gold^{Plus}
75 to < 85	Green Mark Gold
50 to <75	Green Mark Certified

Prerequisite Requirements for Residential Building Criteria	**Related Criteria**
(1) Building envelope design with Residential Envelope Transmittance Value (RETV) computed based on the methodology and guidelines stipulated in the Code on Envelope Thermal Performance for Buildings and this Standard. Green Mark Gold^{Plus} – RETV of 22 W/m^2 or lower Green Mark Platinum – RETV of 20 W/m^2 or lower	RB 1-1 – Thermal Performance of Building Envelope
(2) To be eligible for Green Mark Platinum rating, it is a requirement to use ventilation simulation modeling and analysis to identify the most effective building design and layout. The simulation results and the recommendations derived are to be implemented to ensure good natural ventilation. A minimum 70% of the selected typical dwelling units must have a weighted average wind velocity of 0.60 m/s. Details and submission requirements on ventilation simulation can be found in Appendix C of the Certification Standard. Other than dwelling units, common areas like staircases and lobbies (excluding those that are located in basement areas) must also be designed as naturally ventilated spaces with provision of openable windows or other openings with aggregate area of not less than 5% of the space required to be ventilated.	RB 1-2 Naturally Ventilated Design and Air-Conditioning System
(3) Prescribed system efficiency of air–conditioning system for all dwelling units to be as follows: Green Mark Gold^{Plus} Green Mark Platinum } Air-conditioners with 4-ticks that are certified under the Singapore Energy Labelling Scheme or equivalent COP	
(4) Minimum score under RB 3-1 Sustainable Construction Green Mark Gold^{Plus} ≥ 3 points Green Mark Platinum ≥ 5 points	RB 3-1 – Sustainable Construction
(5) Minimum score under RB 3-2 Sustainable Products Green Mark Gold^{Plus} ≥ 3 points Green Mark Platinum ≥ 4 points	RB 3-2 – Sustainable Products

Prerequisite Requirements for Non-Residential Building Criteria

Air-Conditioned Buildings

Related Criteria

(6) Building envelope design with Envelope Thermal Transfer Value (ETTV) computed based on the methodology and guidelines stipulated in the Code on Envelope Thermal Performance for Buildings and this Standard.

Green Mark Gold^{Plus} – ETTV of 42 W/m^2 or lower

Green Mark Platinum – ETTV of 40 W/m^2 or lower

NRB 1-1 – Thermal Performance of Building Envelope

(7) To demonstrate the stipulated energy savings over its reference model using the energy modeling framework set out in Appendix E of the Certification Standard. Details and submission requirements on energy modeling can be found in Appendix E.

Green Mark Gold^{Plus} – At least 25% energy savings based on energy efficiency measures and improvements that reduce cooling load requirements

Green Mark Platinum – At least 30% energy savings based on energy efficiency measures and improvements that reduce cooling load requirements

(8) Prescribed Design System Efficiency (DSE) of building cooling systems to be as follows :

NRB 1-2(a) – Air–Conditioning System

(i) For Buildings using Water-Cooled Chilled-Water Plant:

Green Mark Rating	**Peak Building Cooling Load (RT)**	
	< 500	**≥ 500**
	Minimum Design System Efficiency[(1)] DSE (kW/RT)	
Certified	0.80	0.70
Gold	0.80	0.70
Gold^{Plus}	0.70	0.65
Platinum	0.70	0.65

NRB 1-2(b) – Air–Conditioning System

(ii) For Buildings using Air Cooled Chilled-Water Plant or Unitary Air-Conditioners:

Green Mark Rating	**Peak Building Cooling Load (RT)**	
	< 500	**≥ 500**
	Minimum Design System Efficiency[(1)] DSE (kW/RT)	
Certified	0.90	0.80
Gold	0.90	Not applicable[(2)]
Gold^{Plus}	0.85	
Platinum	0.78	

Prerequisite Requirements for Non-Residential Building Criteria – *Cont'd*

	Related Criteria
Important notes : (a) The efficiency of the overall air-conditioning system shall meet its design system efficiency as well as the corresponding minimum DSE stipulated for the respective air-conditioning system and Green Mark rating during the building operating hours specified below: **Office Buildings:** Monday to Friday : 9 a.m. to 6 p.m. **Retail Malls :** Monday to Sunday :10 a.m. to 9 p.m. **Hotels:** Monday to Sunday : 24 Hours **Other Building Types:** To be determined based on operating hours (b) For building with peak building cooling load of more than 500 RT, the use of air cooled chilled-water plant or unitary air-conditioners are not applicable for Gold and higher ratings. In general, the system efficiency of the air cooled central chilled-water plant and other unitary air-conditioners are to be comparable with the stipulated efficiency for water-cooled central chilled-water plant. Buildings that are designed with air cooled systems and for higher Green Mark rating will be assessed on a case by case basis.	
(9) Instrumentation for monitoring the water cooled chilled-water plant efficiency is to be provided in accordance with the requirement set in the criteria.	NRB 1-2(d) – Air–Conditioning System
(10) Minimum score under NRB 3-1 Sustainable Construction Green Mark Gold^{Plus} ≥ 3 points Green Mark Platinum ≥ 5 points	NRB 3-1 – Sustainable Construction
(11) Minimum score under NRB 3-2 Sustainable Products Green Mark Gold^{Plus} ≥ 3 points Green Mark Platinum ≥ 4 points	NRB 3-2 – Sustainable Products
Non Air-Conditioned Buildings	**Related Criteria**
(12) To be eligible for Green Mark Platinum rating, it is a requirement to use ventilation simulation modeling and analysis to identify the most effective building design and layout. The simulation results and the recommendations derived are to be implemented to ensure good natural ventilation with minimum weighted average wind velocity of 0.6 m/s within the units. Details and submission requirements on ventilation simulation can be found in Appendix C of the Certification Standard.	NRB 1-4(a)(ii) – Natural Ventilation
(13) Minimum score under NRB 3-1 Sustainable Construction Green Mark Gold^{Plus} ≥ 3 points Green Mark Platinum ≥ 5 points	NRB 3-1 – Sustainable Construction
(14) Minimum score under NRB 3-2 Sustainable Products Green Mark Gold^{Plus} ≥ 3 points Green Mark Platinum ≥ 4 points	NRB 3-2 – Sustainable Products
Building Developments with more than 30% Non Air-Conditioned Spaces	
(15) Prerequisite requirement for building developments with a combination of ventilation mode and with aggregate non-air-conditioned spaces of more than 30% of the total constructed floor areas (excluding carparks and common areas) are as follows :	

Aggregate Non Air-Conditioned Spaces (m^2)	Aggregate Air-Conditioned Spaces (m^2)	Ventilation Simulation Requirement See Note (a)	Energy Modeling Requirement See Note (b)	Justification on Energy Savings See Note (c)
≥ 2000	≥ 5000	Yes	Yes	No
< 2000	≥ 5000	No	Yes	No
≥ 2000	< 5000	Yes	No	Yes
< 2000	< 5000	No	No	Yes

Important Notes :

(a) Ventilation requirement stated paragraph (12) is a pre-requisite requirement to attain Green Platinum rating.

(b) The stipulated energy savings and Design System Efficiency (DSE) of cooling system stated in paragraph (7) and (8) are pre-requisites to attain Green Mark Gold^{Plus} and Platinum rating.

(c) Detailed calculations to be provided to justify the savings in energy consumption from the use of salient energy efficient features /equipment. Energy savings will be based on the energy efficiency measures and improvements over the reference model established for similar building types. The reference ACMV system will be of the same type as the proposed system. The baseline used for the equipment will be in accordance with the minimum efficiency requirement stipulated in SS 530. For VRF system, the baseline COP of 3.37 shall be adopted. The stipulated energy savings stated in paragraph (7) are pre-requisites to attain Green Mark Gold^{Plus} and Platinum rating.

(d) Other pre-requisite stated paragraph (6),(9),(10),(11),(13)and (14) are applicable where relevant.

5.3 Assessment Criteria

5.3.1 There are basically two sets of criteria in this Standard namely, the Residential Building Criteria and Non-Residential Building Criteria. The framework and point allocations for the respective assessment criteria are as illustrated in Table 5.3.1(a) and (b).

5.3.2 The criteria consist of five(5) environmental impact categories namely :

(a) *Part 1 – Energy Efficiency :* This category focuses on the approach that can be used in the building design and system selection to optimise the energy performance of buildings.

(b) *Part 2 – Water Efficiency :* This category focuses on the adoption of water efficient fittings and features that would reduce the use of potable water during building operations.

(c) *Part 3 – Environmental Protection :* This category focuses on the design, practices and selection of materials and resources that would reduce the environmental impacts of built structures.

(d) *Part 4 – Indoor Environmental Quality* : This category focuses on the design strategies that would enhance the indoor environmental quality that includes air quality, thermal comfort, acoustic control and daylighting.

(e) *Part 5 – Other Green Features* : This category focuses on the adoption of green practices and new technologies that are innovative and have potential environmental benefits.

5.3.3 These environmental impact categories are broadly classified under two main groupings namely (I) Energy Related Requirements and (II) Other Green Requirements.

5.3.4 Energy Related Requirements consist of Part 1- Energy Efficiency where points are allocated for the various energy efficient designs, practices and features used. A minimum of 30 points must be obtained from this group to be eligible for certification.

5.3.5 Other Green Requirements consist of Part 2 – Water Efficiency, Part 3 – Environmental Protection, Part 4 – Indoor Environmental Quality and Part 5 – Other Green Features. Points are allocated for the water efficient features, environmentally friendly design

practices and innovative green features used. A minimum of 20 points must be obtained from this grouping to be eligible for certification.

5.3.6 Under the non-residential building criteria, the environmental impact category Part 1 – Energy Efficiency applies to both air-conditioned and non air-conditioned spaces. Points allocated are to be prorated in accordance with the respective floor areas if there is a combination of air-conditioned and non air-conditioned spaces. For simplicity, points applicable to air-conditioned areas are accounted only if the aggregate air-conditioned areas exceed 500 m^2. Similarly, points applicable to non air-conditioned areas are accounted only if the aggregate non air-conditioned areas are more than 10% of the total floor areas excluding carparks and common areas.

5.3.7 The Green Mark Score of the building design is the total of all the numerical scores (i.e. Green Mark points) assigned based on the degree of compliance with the applicable criteria listed in Table 5.3.7(a) and (b) and the scoring methodology stated in Appendix A and B. In addition to the Green Mark Score, the relevant pre-requisite requirements stated in Table 5.2 for the respective Green Mark criteria and ratings are to be complied with.

Table 5.3.1(a) : Framework and Point Allocations for Residential Building Criteria

	Category	Point Allocations
(I)	**Energy Related Requirements**	
Minimum 30 points	**Part 1 : Energy Efficiency**	
	RB 1-1 Thermal Performance of Building Envelope – RETV	15
	RB 1-2 Naturally Ventilated Design and Air-Conditioning System	22
	RB 1-3 Daylighting	6
	RB 1-4 Artificial Lighting	10
	RB 1-5 Ventilation in Carparks	6
	RB 1-6 Lifts	1
	RB 1-7 Energy Efficient Features	7
	RB 1-8 Renewable Energy	20
	Category Score for Part 1 – Energy Efficiency	**87 (Max)**
(II)	**Other Green Requirements**	
Minimum 20 points	**Part 2 : Water Efficiency**	
	RB 2-1 Water Efficient Fittings	10
	RB 2-2 Water Usage Monitoring	1
	RB 2-3 Irrigation System and Landscaping	3
	Category Score for Part 2 – Water Efficiency	**14**
	Part 3 : Environmental Protection	
	RB 3-1 Sustainable Construction	10
	RB 3-2 Sustainable Products	8
	RB 3-3 Greenery Provision	8
	RB 3-4 Environmental Management Practice	8
	RB 3-5 Green Transport	4
	RB 3-6 Stormwater Management	3
	Category Score for Part 3 – Environmental Protection	**41**
	Part 4 : Indoor Environmental Quality	
	RB 4-1 Noise Level	1
	RB 4-2 Indoor Air Pollutants	2
	RB 4-3 Waste Disposal	1
	RB 4-4 Indoor Air Quality in Wet Areas	2
	Category Score for Part 4 – Indoor Environmental Quality	**6**
	Part 5 : Other Green Features	
	RB 5-1 Green Features & Innovations	7
	Category Score for Part 5 – Other Green Features	**7**
	Green Mark Score :	**155**

Table 5.3.1(b) : Framework and Point Allocations for Non-Residential Building Criteria

	Category		Point Allocations
(I)	**Energy Related Requirements**		
Minimum 30 points	**Part 1 : Energy Efficiency**		
	NRB 1-1 Thermal Performance of Building Envelope - ETTV	Section (A) Applicable to air-con areas	12
	NRB 1-2 Air-Conditioning System		30
	Sub-Total (A) – NRB 1-1 to 1-2		42
	NRB 1-3 Building Envelope – Design/Thermal Parameters	Section (B) Applicable to non air-con areas excluding carparks and common areas	35
	NRB 1-4 Natural Ventilation / Mechanical Ventilation		20
	Sub-Total (B) – NRB 1-3 to 1-4		55
	NRB 1-5 Daylighting	Section (C) Generally applicable to all areas	6
	NRB 1-6 Artificial Lighting		12
	NRB 1-7 Ventilation in Carparks		4
	NRB 1-8 Ventilation in Common Areas		5
	NRB 1-9 Lifts and Escalators		2
	NRB 1-10 Energy Efficient Practices & Features		12
	NRB 1-11 Renewable Energy		20
	Sub-Total (C) – NRB 1-5 to 1-11		61
	Category Score for Part 1 – Energy Efficiency **Prorate Subtotal (A) + Prorate Subtotal (B) + Prorate Subtotal (C)**		**116 (Max)**
(II)	**Other Green Requirements**		
Minimum 20 points	**Part 2 : Water Efficiency**		
	NRB 2-1 Water Efficient Fittings		10
	NRB 2-2 Water Usage and Leak Detection		2
	NRB 2-3 Irrigation System and Landscaping		3
	NRB 2-4 Water Consumption of Cooling Towers		2
	Category Score for Part 2 – Water Efficiency		**17**
	Part 3 : Environmental Protection		
	NRB 3-1 Sustainable Construction		10
	NRB 3-2 Sustainable Products		8
	NRB 3-3 Greenery Provision		8
	NRB 3-4 Environmental Management Practice		7
	NRB 3-5 Green Transport		4
	NRB 3-6 Refrigerants		2
	NRB 3-7 Stormwater Management		3
	Category Score for Part 3 – Environmental Protection		**42**
	Part 4 : Indoor Environmental Quality		
	NRB 4-1 Thermal Comfort		1
	NRB 4-2 Noise Level		1
	NRB 4-3 Indoor Air Pollutants		2
	NRB 4-4 Indoor Air Quality (IAQ) Management		2
	NRB 4-5 High Frequency Ballasts		2
	Category Score for Part 4 – Indoor Environmental Quality		**8**
	Part 5 : Other Green Features		
	NRB 5-1 Green Features & Innovations		7
	Category Score for Part 5 – Other Green Features		**7**
		Green Mark Score :	**190 (Max)**

Table 5.3.7(a) : Residential Building Criteria

Part 1 – Energy Efficiency	Green Mark Points
RB 1-1 Thermal Performance of Building Envelope – Residential Envelope Transmittance Value (RETV) Enhance the overall thermal performance of building envelope to minimise heat gain thus reducing the overall cooling load when required. Baseline : Maximum Permissible RETV = 25 W/m^2 *Prerequisite Requirement :* *Green Mark Gold^{Plus} – RETV of 22 W/m^2 or less* *Green Mark Platinum – RETV of 20 W/m^2 or less*	3 points for every reduction of 1 W/m^2 in RETV from the baseline Points scored = 75 – [3 x (RETV)] where RETV $\leq$ 25 W/m^2 (Up to 15 points)
RB 1-2 Naturally Ventilated Design and Air-Conditioning System (a) Dwelling Unit Indoor Comfort Enhance dwelling unit indoor comfort through the provision of good natural ventilation design and energy efficient air-conditioners Option 1 – Ventilation Simulation Modeling Use of ventilation simulation modeling and analysis or wind tunnel testing to identify the most effective building design and layout to achieve good natural ventilation for all unit types. *Prerequisite Requirement :* *Green Mark Platinum – Minimum 70% of selected typical dwelling units with good natural ventilation. Common areas are to be designed as naturally ventilated spaces.* OR Option 2 – Ventilation Design (without the use of simulation modeling) and Efficient Use of Air-Conditioning System (i) Air flow within dwelling units • Building layout design: Proper design of building layout that utilizes prevailing wind conditions to achieve adequate cross ventilation. • Dwelling unit design: Good ventilation in indoor units through sufficient openings. (ii) Provision of air-conditioning system Use of energy efficient air-conditioners that are certified under the Singapore Energy Labelling Scheme. Note (1) : Option 2(ii) is not applicable for developments where air-conditioners are not provided. Points will be scored and prorated accordingly under Option 2(i) *Prerequisite Requirement :* *Green Mark Gold^{Plus}* *Green Mark Platinum* } *Air-Conditioners with 4 ticks under the Singapore Energy Labelling Scheme or equivalent COP*	0.2 point for every percentage of typical units with good natural ventilation Points scored = 0.2 x (% of typical units with good natural ventilation) (up to 20 points) OR 0.5 point for every 10 % of units with window openings facing north and south directions Points scored = 0.5 x (% of units /10) 0.5 point for every 10% of living rooms and bedrooms designed with true cross ventilation Points scored = 0.5 x (% rooms/10) (Up to 8 points) Extent of Coverage : At least 80% of the air-conditioners used in all dwelling units Air-conditioners labelled with : Three Ticks – 4 points Four Ticks – 8 points

<table>
<tr><th>Part 1 - Energy Efficiency</th><th>Green Mark Points</th></tr>
<tr><td><u>(b) Natural Ventilation in Common Areas</u>
Design for natural ventilation in following common areas :

(i) Lift lobbies and corridors

(ii) Staircases</td><td>Extent of Coverage : At least 80% of the applicable areas

1 point

1 point</td></tr>
<tr><td><u>RB 1-3 Daylighting</u>
Encourage design that optimises the use of effective daylighting to reduce energy use for artificial lighting.

(a) Use of daylight and glare simulation analysis to verify the adequacy of ambient lighting levels in all dwelling unit’s living and dining areas. The ambient lighting levels should meet the illuminance level and Unified Glare Rating (UGR) stated in SS CP 38 – Code of Practice for Artificial lighting in Buildings and SS 531 : Part 1:2006 – Code of Practice for Lighting of Work Places.

(b) Daylighting in the following common areas :
(i) Lift lobbies and corridors
(ii) Staircases
(iii) Car parks</td><td>Extent of coverage: At least 80% of the units with daylighting provisions meet the minimum illuminance level and are within the acceptable glare exposure.

Points scored based on the extent of perimeter daylight zones

<table><tr><th>Distance from the Façade Perimeters (m)</th><th>Points Allocation</th></tr><tr><td>≥ 3.0</td><td>1</td></tr><tr><td>4.0 – 5.0</td><td>2</td></tr><tr><td>> 5.0</td><td>3</td></tr></table>
(Up to 3 points)

Extent of Coverage : At least 80% of the applicable areas
1 point
1 point
1 point</td></tr>
<tr><td><u>RB 1-4 Artificial Lighting</u>
Encourage the use of energy efficient lighting in common areas to minimise energy consumption from lighting usage while maintaining proper lighting level.

<u>Baseline</u> = Maximum lighting power budget stated in SS 530</td><td>0.25 point for every percentage improvement in the lighting power budget

Points scored = 0.25 x (% improvement)
(Up to 10 points)</td></tr>
<tr><td><u>RB 1-5 Ventilation in Carparks</u>
Encourage the use of energy efficient design and control of ventilation systems in car parks.

(a) Carparks are designed with natural ventilation.

(b) CO sensors are used to regulate the demand for mechanical ventilation (MV).

Note (2): Where there is a combination of different ventilation mode adopted for carpark design, the points obtained under RB 1-5 will be prorated accordingly.</td><td>Naturally ventilated carparks – 6 points

Points scored based on the mode of mechanical ventilation provided

Fume extract – 4 points
MV with or without supply - 3 points

(Up to 6 points)</td></tr>
<tr><td><u>RB 1-6 Lifts</u>
Encourage the use of lifts with AC variable voltage and variable frequency (VVVF) motor drive or equivalent and energy efficient features such as sleep mode features or equivalent.</td><td>1 point</td></tr>
</table>

Part 1 – Energy Efficiency	Green Mark Points
RB 1-7 Energy Efficient Features Encourage the use of energy efficient features that are innovative and have positive environmental impact. (a) Use of energy efficient equipment or products that are certified by approved local certification body. (b) Use of the energy efficient features Examples : ▪ Heat recovery devices ▪ Regenerative lifts ▪ Cool paints ▪ Gas water heaters ▪ Calculation of Energy Efficiency Index (EEI) ▪ Provision of vertical greenery system that helps to reduce heat gain to buildings	Extent of Coverage : 90% of the applicable equipment type or product 0.5 point for each eligible certified equipment or product (Up to 2 points) 2 points for high impact item 1 point for medium impact item 0.5 point for low impact item (Up to 5 points)
RB 1-8 Renewable Energy Encourage the application of renewable energy sources such as solar energy in buildings.	3 points for every 1% replacement of electricity (exclude household's usage) by renewable energy (Up to 20 points) *Condition : The points scored for renewable energy provision shall not result in a double grade jump in the GM rating (i.e. from GM Certified to Gold^{Plus} or Gold to Platinum rating).*
PART 1 – ENERGY EFFICIENCY CATEGORY SCORE :	Sum of Green Mark Points obtained from RB 1-1 to 1-8

<table>
<tr><th>Part 2 – Water Efficiency</th><th colspan="3">Green Mark Points</th></tr>
<tr><td rowspan="4"><u>RB 2-1 Water Efficient Fittings</u>
Encourage the use of water efficient fittings that are certified under the Water Efficiency Labeling Scheme (WELS).

(a) Basin taps and mixers
(b) Flushing cistern
(c) Shower taps, mixers or showerheads
(d) Sink/Bib taps and mixers
(e) All other water fittings</td><td colspan="2">Rating based on Water Efficiency Labeling Scheme (WELS)</td><td rowspan="4">Points scored based on the number and water efficiency rating of the fitting type used

(Up to 10 points)</td></tr>
<tr><td>Very Good</td><td>Excellent</td></tr>
<tr><td colspan="2">Weightage</td></tr>
<tr><td>8</td><td>10</td></tr>
<tr><td><u>RB 2-2 Water Usage Monitoring</u>
Provision of private meters to monitor the major water usage such as irrigation, swimming pools and other water features.</td><td colspan="3">1 point</td></tr>
<tr><td><u>RB 2-3 Irrigation System and Landscaping</u>
Provision of suitable systems that utilise rainwater or recycled water for landscape irrigation and use of plants that require minimal irrigation to reduce potable water consumption.

(a) Use of non potable water including rainwater for landscape irrigation.

(b) Use of automatic water efficient irrigation system with rain sensor.

(c) Use of drought tolerant plants that require minimal irrigation.</td><td colspan="3">1 point

Extent of Coverage : At least 50% of the landscape areas are served by the system
1 point

Extent of Coverage : At least 80% of the landscape areas
1 point</td></tr>
<tr><td>PART 2 – WATER EFFICIENCY CATEGORY SCORE :</td><td colspan="3">Sum of Green Mark Points obtained from RB 2-1 to 2-3</td></tr>
</table>

Part 3 – Environmental Protection	Green Mark Points
RB 3-1 Sustainable Construction Encourage recycling and the adoption of building designs, construction practices and materials that are environmentally friendly and sustainable. (a) Use of Sustainable and Recycled Materials (i) Green Cements with approved industrial by product (such as Ground Granulated Blastfurnace Slag (GGBS), silica fume, fly ash) to replace Ordinary Portland Cement (OPC) by at least 10% by mass for superstructural works. (ii) Recycled Concrete Aggregates (RCA) and Washed Copper Slag (WCS) from approved sources to replace coarse and fine aggregates for concrete production of main building elements. Note (3) : For structural building elements, the use of RCA and WCS shall be limited to maximum 10% replacement by mass of coarse/fine aggregates respectively or as approved by the relevant authorities. (b) Concrete Usage Index (CUI) Encourage designs with efficient use of concrete for building components. *Prerequisite Requirement:* *Minimum score under this criterion:* *Green Mark Gold^{Plus} ≥ 3 points* *Green Mark Platinum ≥ 5 points*	1 point 1 point for every incremental of 0.5 times (0.5x) of the usage requirement (Up to 2x) **Quantity of RCA /WCS (tons)** / **Points Allocation** ≥ 0.5 x usage requirement — 1 ≥ 1.0 x usage requirement — 2 ≥ 1.5 x usage requirement — 3 ≥ 2.0 x usage requirement — 4 where usage requirement = 0.03 x (GFA in m^2) (Up to 5 points for RB 3-1(a)(i) and (a)(ii)) **Project CUI (m^3/m^2)** / **Points Allocation** ≤ 0.70 — 1 ≤ 0.60 — 2 ≤ 0.50 — 3 ≤ 0.40 — 4 ≤ 0.35 — 5
RB 3-2 Sustainable Products Promote use of environmentally friendly products that are certified by approved local certification body and are applicable to non-structural and architectural related building components. *Prerequisite Requirement:* *Minimum score under this criterion:* *Green Mark Gold^{Plus} ≥ 3 points* *Green Mark Platinum ≥ 4 points*	**Weightage based on the extent of environmental friendliness of products** **Good**: 0.5 **Very Good**: 1.5 **Excellent**: 2 Points scored based on the weightage and the extent of coverage & impact 1 point for high impact item 0.5 point for low impact item (Up to 8 points)

Part 3 – Environmental Protection	Green Mark Points
RB 3-3 Greenery Provision Encourage greater use of greenery, restoration of trees to reduce heat island effect. (a) Green Plot Ratio (GnPR) is calculated by considering the 3D volume covered by plants using the prescribed Leaf Area Index (LAI). (b) Restoration, conservation or relocation of existing trees on site. (c) Use of compost recycled from horticulture waste.	<table><tr><th>GnPR</th><th>Points Allocation</th></tr><tr><td>1.0 to < 2.0</td><td>1</td></tr><tr><td>2.0 to < 3.0</td><td>2</td></tr><tr><td>3.0 to < 4.0</td><td>3</td></tr><tr><td>4.0 to < 5.0</td><td>4</td></tr><tr><td>5.0 to < 6.0</td><td>5</td></tr><tr><td>≥ 6.0</td><td>6</td></tr></table> 1 point 1 point
RB 3-4 Environmental Management Practice Encourage the adoption of environmental friendly practices during construction and building operation. (a) Implement effective environmental management programmes including monitoring and setting of targets to minimise energy use, water use and construction waste. (b) Main builder that has good track records in the adoption of sustainable, environmentally friendly and considerate practices during construction such as the Green and Gracious Builder Award. (c) Building quality assessed under the Construction Quality Assessment System (CONQUAS) and Quality Mark Scheme. (d) Developer, main builder, M & E consultant and architect that are ISO 14000 certified. (e) Project team comprises Certified Green Mark Manager (GMM), Certified Green Mark Facilities Manager (GMFM) and Certified Green Mark Professional (GMP). (f) Provision of building users' guide with details of the environmental friendly facilities and features within the building and their functionalities in achieving the intended environmental performance during building operation. (g) Provision of facilities or recycling bins at each block of development for collection and storage of different recyclable waste such as paper, glass, plastic etc.	1 point 1 point 1 point each (Up to 2 points) 0.25 point for each firm (Up to 1 point) 0.5 point for certified GMM 0.5 point for certified GMFM 1 point for certified GMP (Up to 1 point) 1 point 1 point

Part 3 – Environmental Protection	Green Mark Points
RB 3-5 Green Transport Promote environmental friendly transport options and facilities to reduce pollution from individual car use.	
(a) Good access to nearest MRT/LRT or bus stops.	1 point
(b) Provision of covered walkway to facilitate connectivity and use of public transport.	1 point
(c) Provision of electric vehicle charging stations within the development.	Extent of Coverage : Minimum 1 number of electric vehicle charging station for every 100 carpark lots. *(Cap at 5)* 1 point
(d) Provision of covered/sheltered bicycle parking lots.	Points scored based on the number of bicycle parking lots provided 1 point if the provision ≥ 10% x number of dwelling units 0.5 point if the provision ≥ 5% x number of dwelling units
RB 3-6 Stormwater Management Encourage the treatment of stormwater run-off before discharge to public drains. Provision of infiltration features or design features as recommended in PUB's ABC Waters Design Guidelines : ▪ Bioretention swales/ other bioretention ▪ systems ▪ Rain gardens ▪ Constructed wetlands ▪ Cleansing biotopes ▪ Retention ponds	Points scored based on the extent of the stormwater treatment. 3 points for treatment of run-off from more than 35% of total site area or paved area 2 points for treatment of run-off from 10% to 35% of total site area 1 point for treatment of run-off from up to 10% of total site area (Up to 3 points)
PART 3 – ENVIRONMENTAL PROTECTION CATEGORY SCORE :	Sum of Green Mark Points obtained from RB 3-1 to 3-6

Part 4 – Indoor Environmental Quality	Green Mark Points
RB 4-1 Noise Level Building design to achieve ambient internal noise level as specified : 55 dB (6am-10pm) LeqA 45 dB (10pm-6 am) LeqA	1 point
RB 4-2 Indoor Air Pollutants Minimise airborne contaminants, mainly from inside sources to promote a healthy indoor environment. (a) Use of low volatile organic compounds (VOC) paints certified by approved local certification body. (b) Use of environmentally friendly adhesives that are certified by approved local certification body.	Extent of Coverage : At least 90% of the total internal wall areas 1 point Extent of Coverage : At least 90% of the applicable areas 1 point
RB 4-3 Waste Disposal Minimise airborne contaminants from waste by locating refuse chutes or waste disposal area at open ventilation areas such as service balconies or common corridors.	1 point
RB 4-4 Indoor Air Quality in Wet Areas Provision of adequate natural ventilation and daylighting in wet areas such as kitchens, bathrooms and toilets.	Points scored based on the % of applicable areas with such provision. 1 point for 50% to 90% of applicable areas 2 points for more than 90% of applicable areas
PART 4 – INDOOR ENVIRONMENTAL QUALITY CATEGORY SCORE :	Sum of Green Mark Points obtained from RB 4-1 to 4-4

Part 5 – Other Green Features	Green Mark Points
RB 5-1 Green Features and Innovations Encourage the use of other green features that are innovative and have positive environmental impact. Examples : ▪ Pneumatic waste collection system ▪ Carbon footprint of development ▪ Calculation of Concrete Usage Index (CUI) ▪ Dual chute system ▪ Self cleaning façade system ▪ Conservation of existing building structure ▪ Water efficient washing machines with Good rating and above.	2 points for high impact item 1 point for medium impact item 0.5 point for low impact item (Up to 7 points)
PART 5 – OTHER GREEN FEATURES CATEGORY SCORE :	Sum of Green Mark Points obtained from RB 5-1

Green Mark Score (Residential)

Green Mark Score (Res) = ∑Category Score [(Part 1 – Energy Efficiency) +
(Part 2 – Water Efficiency) +
(Part 3 – Environmental Protection) +
(Part 4 – Indoor Environmental Quality) +
(Part 5 – Other Green Features)]

where Category Score for Part 1 ≥ 30 points and
∑Category Score for Part 2, 3, 4 & 5 ≥ 20 points

Table 5.3.7(b) : Non-Residential Building Criteria

<table>
<tr><th>Part 1 – Energy Efficiency</th><th>Green Mark Points</th></tr>
<tr><td colspan="2">(A) Applicable to Air-Conditioned Building Areas (with an aggregate air-conditioned areas > 500 m^2)</td></tr>
<tr><td><u>NRB 1-1 Thermal Performance of Building Envelope – Envelope Thermal Transfer Value (ETTV)</u>

Enhance the overall thermal performance of building envelope to minimise heat gain thus reducing the overall cooling load requirement.

<u>Baseline</u> : Maximum Permissible ETTV = 50 W/m^2

<u>Prerequisite Requirement :</u>
Green Mark Gold^{Plus} – ETTV of 42 W/m^2 or less
Green Mark Platinum – ETTV of 40 W/m^2 or less</td><td>1.2 points for every reduction of 1 W/m^2 in ETTV from the baseline

Points scored = 1.2 x (50 - ETTV)
where ETTV ≤ 50 W/m^2

(Up to 12 points)</td></tr>
<tr><td><u>NRB 1-2 Air-Conditioning System</u>

Encourage the use of better energy efficient air-conditioned equipment to minimise energy consumption.

(a) Water-Cooled Chilled-Water Plant :
• Water-Cooled Chiller
• Chilled-Water Pump
• Condenser Water Pump
• Cooling Tower

<table><tr><th rowspan="2">Baseline</th><th colspan="2">Peak Building Cooling Load</th></tr><tr><th>≥ 500 RT</th><th>< 500 RT</th></tr><tr><td><u>Prerequisite Requirements</u>
Minimum Design System Efficiency (DSE) for central chilled-water plant</td><td>0.70 kW/RT</td><td>0.80 kW/RT</td></tr></table>
<u>Prerequisite Requirements for Higher Green Mark Rating :</u>
Green Mark Gold^{Plus} & Platinum : Minimum Design System Efficiency (DSE) of 0.65 kW/RT for peak building cooling load ≥ 500 RT and 0.7 kW/RT for peak building cooling load < 500 RT

(b) Air Cooled Chilled-Water Plant / Unitary Air-Conditioners

Air Cooled Chilled-Water Plant :
• Air-Cooled Chiller
• Chilled-Water Pump

Unitary Air-Conditioners :
• Variable Refrigerant Flow (VRF) system
• Single-Spilt Unit
• Multi-Spilt Unit</td><td><u>(a) Water-Cooled Chilled-Water Plant</u>

Peak building cooling load ≥ 500 RT

15 points for meeting the prescribed chilled-water plant efficiency of 0.70 kW/RT

0.25 point for every percentage improvement in the chilled-water plant efficiency over the baseline

Points scored = 0.25 x (% improvement)

Peak building cooling load < 500 RT

12 points for meeting the prescribed chilled-water plant efficiency of 0.80 kW/RT

0.45 point for every percentage improvement in the chilled-water plant efficiency over the baseline

Points scored = 0.45 x (% improvement)

(Up to 20 points)

<u>(b) Air Cooled Chilled-Water Plant/ Unitary Air-Conditioners</u>

Peak building cooling load ≥ 500 RT

12 points for meeting the prescribed air-conditioning system efficiency of 0.80 kW/RT

1.3 points for every percentage improvement in the air-conditioning system efficiency over the baseline

Points scored = 1.3 x (% improvement)</td></tr>
</table>

Part 1 – Energy Efficiency	Green Mark Points
(A) Applicable to Air-Conditioned Building Areas (with an aggregate air-conditioned areas > 500 m^2)	
(b) Air Cooled Chilled-Water Plant / Unitary Air-Conditioners – *Cont'd*	**Peak building cooling load < 500 RT**

Baseline	Peak Building Cooling Load	
	≥ 500 RT	< 500 RT
Prerequisite Requirements Minimum Design System Efficiency (DSE) for air cooled chilled-water plant or unitary conditioners	0.80 kW/RT	0.90 kW/RT

Prerequisite Requirements for Higher Green Mark Rating :
Green Mark Gold^{Plus} : Minimum Design System Efficiency (DSE) of 0.85kW/RT for peak building cooling load < 500 RT
Green Mark Platinum: Minimum DSE of 0.78kW/RT for peak building cooling load < 500 RT

Note (1) : Where there is a combination of central chilled water plant with unitary conditioners, the points scored will only be based on the air-conditioning system with a larger aggregate capacity.

10 points for meeting the prescribed air-conditioning system efficiency of 0.90 kW/RT

0.6 point for every percentage improvement in the air-conditioning system efficiency over the baseline

Points scored = 0.6 x (% improvement)

(Up to 20 points)

(c) Air Distribution System :
- Air Handling Units (AHUs)
- Fan Coil Units (FCUs)

(c) Air Distribution System

0.2 point for every percentage improvement in the air distribution system efficiency over the baseline

Points scored = 0.2 x (% improvement)

(Up to 6 points)

Option 1 – Fan System Motor Nameplate Power

Baseline : SS553:2009 Table 2 – Fan power limitation and as prescribed below :

Baseline Air Distribution System Type	Allowable Motor Nameplate Power	
	($kW/m^3/s$)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.7	0.47
AHUs ≥ 4kW (Variable Volume)	2.4	0.67
Fan systems with nameplate motor power < 4 kW	No baseline	

Option 2 – Fan System Input Power

Baseline : ASHRAE 90.1:2010 Clause 6.5.3.1 and as prescribed below :

Baseline Air Distribution System Type	Allowable Fan System Input Power*	
	($kW/m^3/s$)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.5	0.42
AHUs ≥ 4kW (Variable Volume)	2.1	0.58
Fan systems with nameplate motor power < 4 kW	0.6	0.17

* Applicable pressure drop adjustments can be considered based on ASHRAE 90.1 Table 6.5.3.1.1B and are subject to BCA's evaluation

Note (2) : For buildings with cooling provision from a licensed District Cooling System (DCS) supplier where the plant efficiency data is not available, the point scored for NRB 1-2(a) and (b) will be pro-rated based on the air distribution system efficiency under NRB 1-2(c).

Part 1 – Energy Efficiency	Green Mark Points
(A) Applicable to Air-Conditioned Building Areas (with an aggregate air-conditioned areas > 500 m^2)	
(d) *Prerequisite Requirements :* Provision of permanent measuring instruments for monitoring of water-cooled chilled-water plant efficiency. The installed instrumentation shall have the capability to calculate a resultant plant efficiency (i.e. kW/RT) within 5 % of its true value and in accordance with ASHRAE Guide 22 and AHRI Standard 550/590. The following instrumentation and installation are also required to be complied with : (i) Location and installation of the measuring devices to meet the manufacturer's recommendation. (ii) Data acquisition system with a minimum resolution of 16 bit. (iii) All data logging with capability to trend at 1 minute sampling time interval. (iv) Flow meters are to be provided for chilled-water and condenser water loop and shall be of ultrasonic / full bore magnetic type or equivalent. (v) 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 or calibration range. All thermo-wells shall be installed in a manner that ensures that the sensors can be in direct contact with fluid flow. Provisions shall be made for each temperature measurement location to have two spare thermo-wells located at both side of the temperature sensor for verification of measurement accuracy. (vi) Dedicated power meters are to be provided for each of the following groups of equipment : chillers, chilled water pumps, condenser water pumps and cooling towers.	Applicable only to buildings with provision of water cooled chilled-water plant 1 point
(e) Verification of central water cooled chilled-water plant instrumentation : Heat balance – substantiating test for water cooled chilled-water plant to be computed in accordance with AHRI 550/590	1 point
(f) Provision of variable speed controls for chiller plant equipment such as chilled-water pumps and cooling tower fans to ensure better part-load plant efficiency.	1 point
(g) Sensors or similar automatic control devices are used to regulate outdoor air flow rate to maintain the concentration of carbon dioxide in accordance with Table 1 – Recommended IAQ Parameters of SS 554. Carbon dioxide acceptable range: ≤ 700 ppm above outdoor.	1 point
Exception: For buildings that are underground, NRB 1-1 may be excluded in the computation. The score under NRB 1-2 will be pro-rated accordingly.	
Sub-Total (A) :	Sum of Green Mark Points obtained from NRB 1-1 to 1-2

Part 1 – Energy Efficiency	Green Mark Points
(B) Applicable to Non Air-Conditioned Building Areas (with an aggregate non air-conditioned areas > 10 % of total floor area excluding carparks and common areas)	
NRB 1-3 Building Envelope – Design / Thermal Parameters Enhance the overall thermal performance of building envelope to minimise heat gain that would improve indoor thermal comfort and encourage natural ventilation or mechanical ventilation.	
(a) Minimum direct west facing façade through building design orientation. Note (3) : Orientation of façade that falls within the range of 22.5° N of W and 22.5° S of W will be defined as west facing facade. Core walls for lifts or staircases and toilets that are located within this range are exempted in computation.	Points scored = 15 – 0.3 x (% of west facing facade areas over total façade areas) (Up to 15 points) Where there is no west facing façade, the total points scored for this item will be 30 points; the NRB 1-3 b(i), b(ii) and (c) as listed below will not be applicable.
(b)(i) Minimum west facing window openings.	Points scored = 10 - 0.1 x (% of west facing window areas over total west facing façade areas)
(b)(ii) Effective sunshading provision for windows on the west façade with minimum shading of 30%.	Points scored = 0.1 x (% of west facing window areas with sunshading devices over total west facing façade areas) (Up to 10 points for NRB 1-3 b(i) & b(ii))
(c) Better thermal transmittance (U-value) of external west facing walls. The U-value of external west facing walls should be equal or less than 2 W/m^{2}K.	Points scored = 0.05 x (% of the external west facing walls areas with U value of 2 W/m^{2}K or less over total west facing facades areas) (up to 5 points)
(d) Better thermal transmittance (U-value) of roof. Baseline: U-value for roof stated below depending on the weight range of roof structure: Weight Group / Weight range (kg/m^2) / Maximum Thermal Transmittance (W/m^{2}K) Light / Under 50 / 0.8 Medium / 50 to 230 / 1.1 Heavy / Over 230 / 1.5	1 point for every 0.1 W/m^{2}K reduction from the baseline roof U-value (Up to 5 points)
Exception : For existing buildings, NRB 1-3(a) may be excluded in computation, the total score obtained under NRB 1-3 (b), (c) and (d) will be prorated accordingly.	

Part 1 – Energy Efficiency	Green Mark Points
(B) Applicable to Non Air-Conditioned Building Areas (with an aggregate non air-conditioned areas > 10 % of total floor area excluding carparks and common areas)	
NRB 1-4 Natural Ventilation / Mechanical Ventilation (a) Natural Ventilation Encourage building design that facilitates good natural ventilation. (i) Proper design of building layout that utilises prevailing wind conditions to achieve adequate cross ventilation. (ii) Use of ventilation simulation modeling and analysis or wind tunnel testing to identify the most effective building design and layout to ensure good natural ventilation. *Prerequisite Requirement :* *Green Mark Platinum : Ventilation simulation modeling and analysis are to be carried out to ensure good natural ventilation with minimum weighted average wind velocity of 0.6 m/s within the functional spaces or units.* (b) Mechanical Ventilation Encourage energy efficient mechanical ventilation system design as the preferred ventilation mode to minimise air-conditioned spaces. Option 1 – Fan System Motor Nameplate Power Baseline : SS553:2009 Table 8 – Fan power limitation and as prescribed below :	1 point for every 10% of units/rooms with window openings facing north and south directions Points scored = 1 x (% of units/10) (Up to 10 points) 5 points Additional 5 points if the recommendations are implemented and meet the air-flow requirement (Up to 10 points) 0.6 point for every percentage improvement in the mechanical ventilation system efficiency over the baseline Points scored = 0.6 x (% improvement) (Up to 15 points)

Baseline Air Distribution System Type	Allowable Motor Nameplate Power	
	($kW/m^3/s$)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.7	0.47
Fan systems with nameplate motor power < 4 kW	No baseline	

Option 2 – Fan System Input Power

Baseline : ASHRAE 90.1 : 2010 Clause 6.5.3.1 and as prescribed below :

Baseline Air Distribution System Type	Allowable Fan System Input Power *	
	($kW/m^3/s$)	(W/CMH)
AHUs/FCUs ≥ 4kW (Constant Volume)	1.5	0.42
Fan systems with nameplate motor power < 4 kW	0.6	0.17

* Applicable pressure drop adjustments can be considered based on ASHRAE 90.1 Table 6.5.3.1.1B and are subject to BCA's evaluation

Note (4) : Where there is a combination of naturally ventilated and mechanical ventilated spaces, points scored will be based on the predominant ventilation modes of normally occupied spaces.

Sub-Total (B) :	Sum of Green Mark Points obtained from NRB 1-3 to 1-4

<table>
<tr><th>Part 1 - Energy Efficiency</th><th>Green Mark Points</th></tr>
<tr><td colspan="2">(C) General</td></tr>
<tr><td><u>NRB 1-5 Daylighting</u>

Encourage design that optimises the use of effective daylighting to reduce energy use for artificial lighting.

(a) Use of daylighting and glare simulation analysis to verify the adequacy of ambient lighting levels in meeting the illuminance level and Unified Glare Rating (UGR) stated in SS 531:Part 1:2006 – Code of Practice for Lighting of Work Places.

(b) Daylighting for the following common areas:
(i) Toilets
(ii) Staircases
(iii) Corridors
(iv) Lift Lobbies
(v) Atriums
(vi) Carparks

Note (5) : All daylit areas must be integrated with automatic electric lighting control system.</td><td>Extent of coverage: At least 75% of the units with daylighting provisions meet the minimum illuminance level and are within the acceptable glare exposure.

Points scored based on the extent of perimeter daylight zones

<table><tr><th>Distance from the Façade Perimeters (m)</th><th>Points Allocation</th></tr><tr><td>≥ 3.0</td><td>1</td></tr><tr><td>4.0 – 5.0</td><td>2</td></tr><tr><td>> 5.0</td><td>3</td></tr></table>
(Up to 3 points)

Extent of Coverage : At least 80 % of each applicable area

0.5 point each

(Up to 3 points)</td></tr>
<tr><td><u>NRB 1-6 Artificial Lighting</u>

Encourage the use of energy efficient lighting to minimise energy consumption from lighting usage while maintaining proper lighting level.

<u>Baseline</u> : Maximum lighting power budget stated in SS 530</td><td>0.3 point for every percentage improvement in lighting power budget

Points scored = 0.3 x (% improvement)
(Including tenant lighting provision)
(Up to 12 points)

(Excluding tenant lighting provision)

(Up to 5 points)</td></tr>
<tr><td><u>NRB 1-7 Ventilation in Carparks</u>

Encourage the use of energy efficient design and control of ventilation systems in carparks.

(a) Carparks are designed with natural ventilation.

(b) CO sensors are used to regulate the demand for mechanical ventilation (MV).

Note (6) : Where there is a combination of different ventilation mode adopted for carpark design, the points obtained under NRB 1-7 will be prorated accordingly.</td><td>Naturally ventilated carparks – 4 points

Points scored based on the mode of mechanical ventilation provided

Fume extract – 2.5 points

MV with or without supply - 2 points

(Up to 4 points)</td></tr>
</table>

Part 1 - Energy Efficiency	Green Mark Points
(C) General	
NRB 1-8 Ventilation in Common Areas Encourage the use of energy efficient design and control of ventilation systems in the following common areas : (a) Toilets (b) Staircases (c) Corridors (d) Lift lobbies (e) Atrium	Extent of Coverage : At least 90 % of each applicable area Points scored based on the mode of ventilation provided in applicable areas Natural ventilation – 1.5 points for each area Mechanical ventilation – 0.5 point for each area (Up to 5 points)
NRB 1-9 Lifts and Escalators Encourage the use of energy efficient lifts and escalators. Lifts and/or escalators with AC variable voltage and variable frequency (VVVF) motor drive and sleep mode features.	Extent of Coverage : All lifts and escalators Lifts – 1 point Escalators – 1 point
NRB 1-10 Energy Efficient Practices & Features Encourage the use of energy efficient practices and features that are innovative and/or have positive environmental impact. (a) Computation of energy consumption based on design load in the form of energy efficiency index (EEI). (b) Use of vertical greenery system on east and west façade to reduce heat gain through building envelope (c) Use of energy efficient equipment or product that are certified by approved local certification body (d) Use of energy efficient features. Examples: ▪ Heat recovery system ▪ Sun pipes ▪ Regenerative lifts ▪ Light shelves ▪ Photocell sensors to maximise the use of daylighting	1 point 1 point for high impact 0.5 point for low impact Extent of Coverage : 90% of the applicable equipment type or product 0.5 point for each eligible certified equipment or products (Up to 2 points) 3 points for every 1% energy saving over total building energy consumption (Up to 8 points)

<table>
<tr><th>Part 1 – Energy Efficiency</th><th>Green Mark Points</th></tr>
<tr><td colspan="2">(C) General</td></tr>
<tr><td><u>NRB 1-11 Renewable Energy</u>

Encourage the application of renewable energy sources in buildings.</td><td>Point scored based on the expected energy efficiency index (EEI) and % replacement of electricity by renewable energy source

<table>
<tr><th rowspan="2">Expected Energy Efficiency Index (EEI)</th><td colspan="2">Every 1% replacement of electricity (based on total building electricity consumption) by renewable energy source</td></tr>
<tr><th>Include tenant's usage</th><th>Exclude tenant's usage</th></tr>
<tr><td>≥ 30 kWh/m^2/yr</td><td>5 points</td><td>3 points</td></tr>
<tr><td>< 30 kWh/m^2/yr</td><td>3 points</td><td>1.5 points</td></tr>
</table>

(Up to 20 Points)

Condition : The points scored for renewable energy provision shall not result in a double grade jump in the GM rating (i.e. from GM Certified to Gold^{Plus} or Gold to Platinum rating).</td></tr>
<tr><td>Sub-Total (C) :</td><td>Sum of Green Mark Points obtained
from NRB 1-5 to 1-11</td></tr>
<tr><td>PART 1 – ENERGY EFFICIENCY CATEGORY SCORE :</td><td>Sub-Total (A) X <u>Air-Conditioned Building Floor Area</u>
Total Floor Area
+
Sub-Total (B) X <u>Non Air-Conditioned Building Floor Area</u>
Total Floor Area
+
Sub-Total (C)

where Sub-Total (A) = Sum of Green Mark Points obtained under Section (A) NRB 1-1 to 1-2
Sub-Total (B) = Sum of Green Mark Points obtained under Section (B) NRB 1-3 to 1-4
Sub-Total (C) = Sum of Green Mark Points obtained under Section (C) NRB 1-5 to 1-11</td></tr>
</table>

<table>
<tr><th>Part 2 – Water Efficiency</th><th colspan="3">Green Mark Points</th></tr>
<tr><td><u>NRB 2-1 Water Efficient Fittings</u>
Encourage the use of water efficient fittings covered under the Water Efficiency Labelling Scheme (WELS).

(a) Basin taps and mixers
(b) Flushing cistern
(c) Shower taps, mixers or showerheads
(d) Sink/Bib taps and mixers
(e) Urinals and urinal flush valve</td><td colspan="2">Rating based on Water Efficiency Labelling Scheme (WELS)
Very Good | Excellent
Weightage
8 | 10</td><td>Points scored based on the number and water efficiency rating of the fitting type used

(Up to 10 points)</td></tr>
<tr><td><u>NRB 2-2 Water Usage and Leak Detection</u>
Promote the use of sub-metering and leak detection system for better control and monitoring.

(a) Provision of private meters to monitor the major water usage such as irrigation, cooling tower and tenants' usage.

(b) Linking all private meters to the Building Management System (BMS) for leak detection.</td><td colspan="3">1 point

1 point</td></tr>
<tr><td><u>NRB 2-3 Irrigation System and Landscaping</u>
Provision of suitable systems that utilise rainwater or recycled water and use of plants that require minimal irrigation to reduce potable water consumption.

(a) Use of non potable water including rainwater for landscape irrigation.

(b) Use of automatic water efficient irrigation system with rain sensor.

(c) Use of drought tolerant plants that require minimal irrigation.</td><td colspan="3">1 point

Extent of Coverage : At least 50% of the landscape areas are served by the system
1 point

Extent of Coverage : At least 80% of the landscape areas
1 point</td></tr>
<tr><td><u>NRB 2-4 Water Consumption of Cooling Tower</u>
Reduce potable water use for cooling purpose.

(a) Use of cooling tower water treatment system that can achieve 7 or better cycles of concentration at acceptable water quality.

(b) Use of NEWater or on-site recycled water from approved sources.</td><td colspan="3">1 point

1 point</td></tr>
<tr><td>PART 2 – WATER EFFICIENCY
CATEGORY SCORE :</td><td colspan="3">Sum of Green Mark Points obtained from NRB 2-1 to 2-4</td></tr>
</table>

Part 3 – Environmental Protection	Green Mark Points
NRB 3-1 Sustainable Construction Encourage recycling and the adoption of building designs, construction practices and materials that are environmentally friendly and sustainable (a) Use of Sustainable and Recycled Materials (i) Green Cements with approved industrial by-product (such as Ground Granulated Blastfurnace Slag (GGBS), silica fume, fly ash) to replace Ordinary Portland Cement (OPC) by at least 10% by mass for superstructural works.	1 point
(ii) Recycled Concrete Aggregates (RCA) and Washed Copper Slag (WCS) from approved sources to replace coarse and fine aggregates for concrete production of main building elements. Note (7) : For structural building elements, the use of RCA and WCS shall be limited to maximum 10% replacement by mass of coarse/fine aggregates respectively or as approved by the relevant authorities.	1 point for every incremental of 0.5 times (0.5x) of the usage requirement (Up to 2x) **Quantity of RCA /WCS (tons)** / **Points Allocation** ≥ 0.5 x usage requirement — 1 point ≥ 1.0 x usage requirement — 2 points ≥ 1.5 x usage requirement — 3 points ≥ 2.0 x usage requirement — 4 points where usage requirement = 0.03 x (GFA in m^2) (Up to 5 points for NRB 3-1(a)(i) and (a)(ii))
(b) Concrete Usage Index (CUI) Encourage designs with efficient use of concrete for building components. *Prerequisite Requirement:* *Minimum points to be scored under this criterion:* *Green Mark Gold^{Plus} ≥ 3 points* *Green Mark Platinum ≥ 5 points*	**Project CUI (m^3/m^2)** / **Points Allocation** ≤ 0.70 — 1 point ≤ 0.60 — 2 points ≤ 0.50 — 3 points ≤ 0.40 — 4 points ≤ 0.35 — 5 points
NRB 3-2 Sustainable Products Promote use of environmentally friendly products that are certified by approved local certification body and are applicable to non-structural and architectural related building components. *Prerequisite Requirement:* *Minimum score under this criterion:* *Green Mark Gold^{Plus} ≥ 3 points* *Green Mark Platinum ≥ 4 points*	**Weightage based on the extent of environmental friendliness of products** **Good** / **Very Good** / **Excellent** 0.5 / 1.5 / 2 Points scored based on the weightage and the extent of coverage & impact 1 point for high impact item 0.5 point for low impact item (Up to 8 points)

<table>
<tr><th>Part 3 – Environmental Protection</th><th>Green Mark Points</th></tr>
<tr><td><u>NRB 3-3 Greenery Provision</u>

Encourage greater use of greenery, restoration of trees to reduce heat island effect.

(a) Green Plot Ratio (GnPR) is calculated by considering the 3D volume covered by plants using the prescribed Leaf Area Index (LAI).

(b) Restoration, conservation or relocation of existing trees on site.

(c) Use of compost recycled from horticulture waste.</td><td><table><tr><th>GnPR</th><th>Points Allocation</th></tr><tr><td>0.5 to < 1.0</td><td>1</td></tr><tr><td>1.0 to < 1.5</td><td>2</td></tr><tr><td>1.5 to < 3.0</td><td>3</td></tr><tr><td>3.0 to < 3.5</td><td>4</td></tr><tr><td>3.5 to < 4.0</td><td>5</td></tr><tr><td>≥ 4.0</td><td>6</td></tr></table>
1 point

1 point</td></tr>
<tr><td><u>NRB 3-4 Environmental Management Practice</u>

Encourage the adoption of environmental friendly practices during construction and building operation.

(a) Implement effective environmental friendly programmes including monitoring and setting targets to minimise energy use, water use and construction waste.

(b) Main builder that has good track records in the adoption of sustainable, environmentally friendly and considerate practices during construction such as the Green and Gracious Builder Award.

(c) Building quality assessed under the Construction Quality Assessment System (CONQUAS).

(d) Developer, main builder, M & E consultant and architect that are ISO 14000 certified.

(e) Project team comprises Certified Green Mark Manager (GMM), Green Mark Facilities Manager (GMFM) and Green Mark Professional (GMP).

(f) Provision of building users' guide that should include details of the environmental friendly facilities and features within the building and their functionalities in achieving the intended environmental performance during building operation.

(g) Provision of facilities or recycling bins for collection and storage of different recyclable waste such as paper, glass, plastic etc.</td><td>1 point

1 point

1 point

0.25 point for each firm
(Up to 1 point)

0.5 point for certified GMM
0.5 point for certified GMFM
1 point for certified GMP
(Up to 1 point)

1 point

1 point</td></tr>
</table>

Part 3 – Environmental Protection	Green Mark Points
NRB 3-5 Green Transport Promote environmental friendly transport options and facilities to reduce pollution from individual car use.	
(a) Good access to nearest MRT/LRT or bus stops.	1 point
(b) Provision of covered walkway to facilitate connectivity and the use of public transport.	1 point
(c) Provision of electric vehicle charging stations and priority parking lots within the development.	Extent of Coverage : Minimum one(1) electric vehicle charging station and priority parking lot for every 100 carpark lots *(Cap at 5)* 1 point
(d) Provision of sheltered bicycle parking lots with adequate shower and changing facilities.	Extent of Coverage : Minimum ten (10) bicycle parking lots *(Cap at 50)* Points scored based on the number of bicycle parking lots provided *(with adequate shower and changing facilities)* 1 point if the number provided ≥ 3% x Gross Floor Area (GFA)/10 0.5 point if the number provided ≥ 1.5% x Gross Floor Area (GFA)/10
NRB 3-6 Refrigerants Reduce the potential damage to the ozone layer and the increase in global warming caused by the release of ozone depleting substances and greenhouse gases.	
(a) Refrigerants with ozone depletion potential (ODP) of zero or with global warming potential (GWP) of less than 100.	1 point
(b) Use of refrigerant leak detection system in critical areas of plant rooms containing chillers and other equipments with refrigerants.	1 point
NRB 3-7 Stormwater Management Encourage treatment of stormwater run-off before discharge to the public drains. Provision of infiltration or design features as recommended in PUB's ABC Waters Design Guidelines : ▪ Bioretention swales/ other bioretention systems ▪ Rain gardens ▪ Constructed wetlands ▪ Cleansing biotopes ▪ Retention ponds	Points scored based on the extent of stormwater treatment. 3 points for treatment of run-off from more than 35% of total site area or paved area 2 points for treatment of run-off from 10% to 35% of total site area 1 point for treatment of run-off from up to 10% of total site area
PART 3 – ENVIRONMENTAL PROTECTION CATEGORY SCORE :	Sum of Green Mark Points obtained from NRB 3-1 to 3-7

Part 4 – Indoor Environmental Quality	Green Mark Points
NRB 4-1 Thermal Comfort Air-conditioning system is designed to allow for cooling load variation due to fluctuations in ambient air temperature and to maintain consistent indoor conditions for thermal comfort. Indoor operative temperature between 24 °C to 26 °C Relative humidity < 65%	1 point
NRB 4-2 Noise Level Occupied spaces in buildings are designed with good ambient sound levels as recommended in SS 553 Table 4 – Recommended ambient sound level.	1 point
NRB 4-3 Indoor Air Pollutants Minimise airborne contaminants, mainly from inside sources to promote a healthy indoor environment. (a) Use of low volatile organic compounds (VOC) paints certified by approved local certification body. (b) Use of environmental friendly adhesives certified by approved local certification body.	Extent of Coverage : At least 90% of the total internal wall areas 1 point Extent of Coverage : At least 90% of the applicable areas 1 point
NRB 4-4 Indoor Air Quality (IAQ) Management Ensure that building ventilation systems are designed and installed to provide acceptable IAQ under normal operating conditions. (a) Provision of filtration media and differential pressure monitoring equipment in Air Handling Units (AHUs) in accordance with SS 554: Clause 4.3.4.5 and its Annex E. (b) Implement effective IAQ management plan to ensure that building ventilation systems are clean and free from residuals left over from construction activities. Internal surface condition tests for ACMV systems are to be included.	1 point 1 point
NRB 4-5 High Frequency Ballasts *Applicable to offices, classrooms and the like* Improve workplace lighting quality by avoiding low frequency flicker associated with fluorescent lighting with the use of high frequency ballasts in the fluorescent luminaries.	Extent of Coverage : At least 90% of all applicable areas that are served by fluorescent luminaries 2 points
PART 4 – INDOOR ENVIRONMENTAL QUALITY CATEGORY SCORE :	Sum of Green Mark Points obtained from NRB 4-1 to 4-5

Part 5 – Other Green Features	Green Mark Points
NRB 5-1 Green Features and Innovations Encourage the use of other green features that are innovative and/or have positive environmental impact. Examples : ▪ Pneumatic waste collection system ▪ Carbon footprint of development ▪ Calculation of Concrete Usage Index (CUI) ▪ Dual chute system ▪ Self cleaning façade system ▪ Conservation of existing building structure	2 points for high impact item 1 point for medium impact item 0.5 point for low impact item (Up to 7 points)
PART 5 – OTHER GREEN FEATURES CATEGORY SCORE :	Sum of Green Mark Points obtained from NRB 5-1

Green Mark Score (Non-Residential)

Green Mark Score (Non-Res) = ∑Category Score [(Part 1 – Energy Efficiency) +
(Part 2 – Water Efficiency) +
(Part 3 – Environmental Protection) +
(Part 4 – Indoor Environmental Quality) +
(Part 5 – Other Green Features)]

where Category Score for Part 1 ≥ 30 points and
∑Category Score for Part 2, 3, 4 & 5 ≥ 20 points

6 DOCUMENTATION REQUIREMENTS

6.1 General

All documents submitted for the BCA Green Mark Assessment should be duly verified and signed by the Qualified Person (QP) and appropriate practitioners where applicable (see Table 6.1(a) and (b)). The detailed documentation requirements can be found in Appendix A and B.

The documentation required for ventilation simulation, daylighting simulation and energy modeling should also be endorsed by the QP and appropriate practitioners as part of the documentary evidences for certification.

Table 6.1 (a) : Summary Checklist and the Corresponding Signatories *for Residential Building Criteria*

Residential Building Criteria	Required Signatories
Part 1 - Energy Efficiency	
RB 1-1 Thermal Performance of Building Envelope - RETV	QP (BP)[1]
RB 1-2 Naturally Ventilated Design and Air-Conditioning System • Dwelling Unit Comfort - Ventilation Simulation / Design - Air-Conditioning System • Natural Ventilation in Common Areas	 QP (BP) PE (Mechanical)[2] QP (BP)
RB 1-3 Daylighting	QP(BP)
RB 1-4 Artificial Lighting	PE (Electrical)
RB 1-5 Ventilation in Carparks	PE (Mechanical)
RB 1-6 Lifts	PE (Electrical)
RB 1-7 Energy Efficient Features • Heat Recovery Devices • Occupancy Sensors /Photo Sensors • Others	 PE (Mechanical) PE (Electrical) Appropriate Practitioners[3]
RB 1-8 Renewable Energy	PE (Electrical)
Part 2 – Water Efficiency	
RB 2-1 Water Efficient Fittings	QP(BP)
RB 2-2 Water Usage Monitoring	PE (Mechanical)
RB 2-3 Irrigation System and Landscaping	QP(BP)
Part 3 – Environmental Protection	

[1] QP(BP) refers to Qualified Person who submits building plan.

[2] PE(Mechanical) or PE(Electrical) refers to a professional engineer registered under the Professional Engineers Act (Cap 253) in the branch of mechanical engineering or electrical engineering.

[3] Appropriate Practitioners refer to QP(BP), PE(Mechanical) or PE(Electrical).

Residential Building Criteria	Required Signatories
RB 3-1 Sustainable Construction	Appropriate Practitioners
RB 3-2 Sustainable Products	Appropriate Practitioners
RB 3-3 Greenery Provision	QP(BP)
RB 3-4 Environmental Management Practice	QP(BP)
RB 3-5 Green Transport	QP(BP)
RB 3-6 Stormwater Management	QP(BP)
Part 4 – Indoor Environmental Quality	
RB 4-1 Noise Level	QP(BP)
RB 4-2 Indoor Air Pollutants	QP(BP)
RB 4-3 Waste Disposal	QP(BP)
RB 4-4 Indoor Air Quality in Wet Areas	QP(BP)
Part 5 – Other Green Features	
RB 5-1 Green Features and Innovations	Appropriate Practitioners

Note : *Documentary evidences prepared by the domain experts or specialists such as acoustic consultant, landscape architect etc may be used to demonstrate compliance with the criteria where applicable.*

Table 6.1 (b) : Summary Checklist and the Corresponding Signatories
for Non-Residential Building Criteria

Non-Residential Building Criteria	Required Signatories
Part 1 - Energy Efficiency	
NRB 1-1 Thermal Performance of Building Envelope - ETTV	QP (BP)
NRB 1-2 Air-Conditioning System	PE (Mechanical)
NRB 1-3 Building Envelope – Design/ Thermal Parameters	QP (BP)
NRB 1-4 Natural Ventilation/ Mechanical Ventilation	QP (BP) PE (Mechanical)
NRB 1-5 Daylighting	QP (BP)
NRB 1-6 Artificial Lighting	PE (Electrical)
NRB 1-7 Ventilation in Carparks	PE (Mechanical)
NRB 1-8 Ventilation in Common Areas	PE (Mechanical)
NRB 1-9 Lifts and Escalators	PE (Electrical)
NRB 1-10 Energy Efficient Practices / Features • Heat Recovery System • Auto Condenser Tube Cleaning System • Energy Efficiency Index Computation • Occupancy Sensors /Photo Sensors • Others	 PE (Mechanical) PE (Mechanical) PE (Electrical) PE (Electrical) Appropriate Practitioners
NRB 1-11 Renewable Energy	PE (Electrical)
Part 2 – Water Efficiency	
NRB 2-1 Water Efficient Fittings	QP (BP)
NRB 2-2 Water Usage and Leak Detection	PE (Mechanical)
NRB 2-3 Irrigation System and Landscaping	QP (BP)
NRB 2-4 Water Consumption of Cooling Towers	PE (Mechanical)
Part 3 – Environmental Protection	
NRB 3-1 Sustainable Construction	Appropriate Practitioners
NRB 3-2 Sustainable Products	Appropriate Practitioners
NRB 3-3 Greenery Provision	QP (BP)
NRB 3-4 Environmental Management Practice	QP (BP)

Non-Residential Building Criteria	Required Signatories
Part 3 – Environmental Protection – Cont'd	
NRB 3-5 Green Transport	QP (BP)
NRB 3-6 Refrigerants	PE (Mechanical)
NRB 3-7 Stormwater Management	QP (BP)
Part 4 – Indoor Environmental Quality	
NRB 4-1 Thermal Comfort	PE (Mechanical)
NRB 4-2 Noise Level	QP (BP)
NRB 4-3 Indoor Air Pollutants	QP (BP)
NRB 4-4 Indoor Air Quality (IAQ) Management	PE (Mechanical)
NRB 4-5 High Frequency Ballasts	PE (Electrical)
Part 5 – Other Green Features	
NRB 5-1 Green Features and Innovations	Appropriate Practitioners

Note : *Documentary evidences prepared by the domain experts or specialists such as acoustic consultant, landscape architect etc may be used to demonstrate compliance with the criteria where applicable.*

Appendix A

SCORING METHODOLOGY & DOCUMENTATION

Residential Building Criteria

(I) Energy Related Requirements

Part 1 – Energy Efficiency

RB 1-1 THERMAL PERFORMANCE OF BUILDING ENVELOPE - RETV

Objectives	Enhance overall thermal performance of building envelope to minimise heat gain thus reducing the overall cooling load requirement.
Applicability	Applicable to residential buildings with GFA of 2000 m^2.
Baseline Standard	Maximum permissible RETV = 25 W/m^2 RETV stands for Residential Envelope Transmittance Value. The computation of RETV shall be based on the methodology specified in the Code on Envelope Thermal Performance for Buildings issued by BCA.
Requirements	Up to 15 points can be scored for building envelope with better thermal performance than the baseline standard : 3 points for every reduction of 1 W/m^2 in RETV from the baseline. Points scored = 75 – [3 x (RETV)] where RETV ≤ 25 W/m^2 For developments consisting of more than one residential building, the weighted average of the RETVs based on the façade areas of these buildings shall be used as the basis for point allocation. That is $RETV_{\text{Weighted average}} = \sum (RETV_{bldg} \times A_{bldg}) / A_{devt}$ where $RETV_{bldg}$ = RETV for a residential building (W/m^2) A_{bldg} = Summation of all facade areas that enclose all living rooms, dining rooms, study rooms and bedrooms of a residential building (m^2) A_{devt} = Summation of total applicable facade areas of all residential buildings within the development (m^2) (i.e. $\sum A_{bldg}$)
Prerequisites	Green Mark Gold^{Plus} – RETV of 22 W/m^2 or lower Green Mark Platinum – RETV of 20 W/m^2 or lower
Documentary Evidences	• Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant for the computation of RETV; • Architectural plan layouts and elevations showing the living rooms, dining rooms, study rooms and bedrooms; • Extracts of the tender specification or material schedules showing the salient data of the material properties that are to be used for the façade or external wall system; and • RETV calculation.

References	Code on Envelope Thermal Performance for Buildings issued by BCA.
Worked Example 1-1	Example 1 RETV = 22 W/m^2 Points scored = 75 – [3 x (RETV)] = 75 – [3x (22)] = 9 points Example 2 RETV = 19 W/m^2 Points scored = 75 – [3 x (RETV)] = 75 – [3 x (19)] = 18 points > 15 points (max) Therefore, points scored should be 15 points (Max) Example 3 A proposed building development comprises three residential building blocks. The individual RETV of the each residential building computed are as follows : $RETV_{bldg1}$ = 20 W/m^2 A_{bldg} = 4000 m^2 $RETV_{bldg2}$ = 25 W/m^2 A_{bldg} = 3600 m^2 $RETV_{bldg3}$ = 19 W/m^2 A_{bldg} = 5000 m^2 A_{devt} = 4000 +3600 +5000 = 12600 m^2 Therefore $RETV_{\text{Weighted average}} = \sum (RETV_{bldg} \times A_{bldg}) / A_{devt}$ $= \frac{(RETV_{bldg1} \times A_{bldg1}) + (RETV_{bldg2} \times A_{bldg2}) + (RETV_{bldg3} \times A_{bldg3})}{(A_{devt})}$ $= \frac{(20 \times 4000) + (25 \times 3600) + (19 \times 5000)}{12600}$ = 21.03 W/m^2 Points scored = 75 – [3 x (RETV)] = 75 – [3 x (21.03)] = 11.91 points Note : Refer to the Code on Envelope Thermal Performance for Buildings for more detailed examples on how to compute the RETV.

RB 1-2 NATURALLY VENTILATED DESIGN AND AIR-CONDITIONING SYSTEM

Objectives	Enhance building design to achieve good natural ventilation for better indoor comfort or through the use of better efficient air-conditioners if needed.
Applicability	Applicable to all dwelling units within the development.
Baseline Standard	1-2(a) Option 1 - Ventilation simulation modeling and analysis shall be based on the methodology specified in Appendix C – Ventilation Simulation Methodology and Requirements. 1-2(a) Option 2(ii) - As specified under the Singapore Energy Labeling Scheme for air-conditioners.
Requirements	1-2 (a) Dwelling Unit Indoor Comfort For Option 1- Ventilation Simulation Modeling and Analysis Up to 20 points can be scored for the use of ventilation simulation modeling & analysis or wind tunnel testing to identify the most effective building design and layout to achieve good natural ventilation for all unit types. All typical dwelling unit types should be included in the ventilation simulation (up to maximum of 5 types). If there are more than 5 typical dwelling unit types, the selection of the units for simulation will be based on extent of coverage that is the five typical dwelling units with the most number of units. The unit is deemed to have good natural ventilation if the area-weighted average wind velocity within the unit is not less than 0.60 m/s based on the ventilation simulation analysis. The percentage of units achieving good natural ventilation is given by: $\frac{\Sigma(\text{No. of Selected Units for Each Layout} \times \text{Area-Weighted Average Wind Velocity})}{\text{Total Number of Selected Units} \times 0.60\ \text{m/s}} \times 100\%$ 0.2 point for every percentage of typical units with good natural ventilation Points scored = 0.2 x (% of typical units with good natural ventilation) For Option 2 – Ventilation Design (without the use of ventilation simulation modeling) and Efficient Use of Air-Conditioning System Up to 16 points can be scored for the following design Option 2(i) Air Flow within Dwelling Units ▪ Building layout design that utilises prevailing wind conditions to achieve adequate cross ventilation. 0.5 point for every 10% of units with window openings facing north and south directions Points scored = 0.5 x(% of units/10) ▪ Dwelling unit design that allows for true cross ventilation in the living rooms and bedrooms of the dwelling units 0.5 point for every 10% of living rooms and bedrooms design with true cross ventilation Points scored = 0.5 x (% of rooms/10)

Note: In Singapore, 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, buildings designed 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 as illustrated below.

Illustrations on building layout design that facilitate cross ventilation

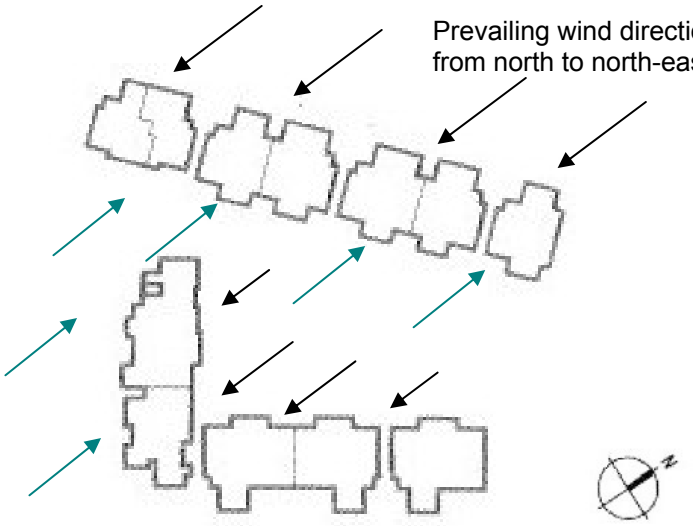


Illustration 1 – Building layout showing all dwelling units with window openings facing the north and south direction. In this instance, all units can be considered meeting the requirement 1-2(a) Option 2(i)

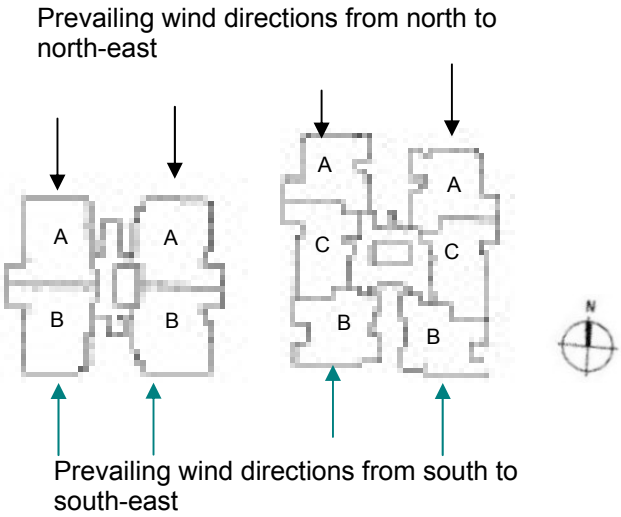
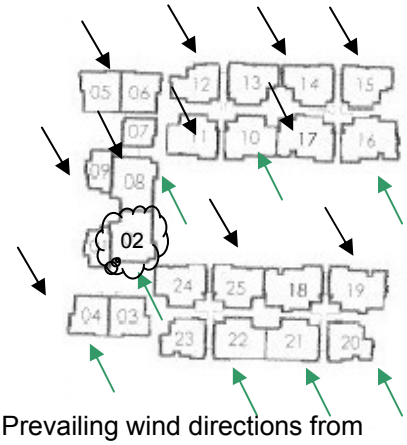


Illustration 2 – Building layout showing all dwelling unit Type A and B with window openings facing either the north or south direction. The dwelling unit Type C has no window openings in the north and south directions. In this instance, no unit can be considered meeting the requirement 1-2(a) Option 2(i)

Prevailing wind directions from north to north-east

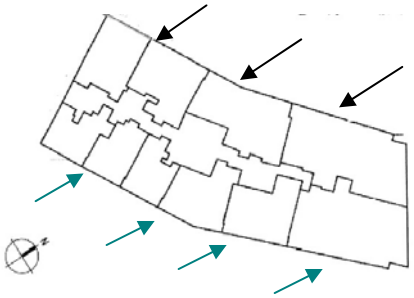


Prevailing wind directions from south to south-east

Illustration 3 – Building layout showing the window openings of all dwelling units facing the north and south direction except dwelling unit 02. Dwelling 02 has window openings facing only the south direction and hence it is not considered meeting the requirement 1-2(a) Option 2(i)

Illustration 4 – Building layout showing the window openings of all dwelling units facing either the north or south direction and hence they are not considered meeting the requirement 1-2(a) Option 2(i)

Prevailing wind directions from north to north-east



Prevailing wind directions from south to south-east

Illustrations on dwelling unit design that facilitates true cross ventilation

Dwelling unit design is considered to have true cross ventilation when there is a reasonably unobstructed air flow path between the windows or vents on opposite sides of the building. For this requirement, the main entrance of the dwelling units is assumed to be closed and all the windows / internal doors are assumed to be open.

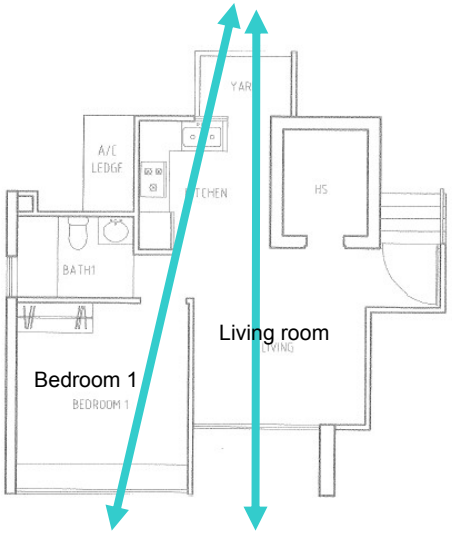


Illustration 5 – Dwelling unit layout showing that both living room and bedroom 1 are considered to have true cross ventilation and meet the requirement 1-2(a) Option 2(i)

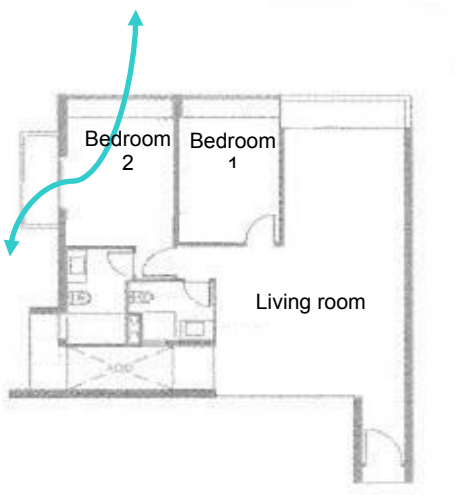


Illustration 6 – Dwelling unit layout showing only bedroom 2 is considered to have true cross ventilation. Living room and bedroom 1 are not considered meeting the requirement 1-2(a) Option 2(i)

<table>
<tr><td></td><td>
<u>Option 2(ii) Provision of energy efficient air-conditioning system</u>
Up to 8 points can be scored for the use of the air-conditioners that are certified under the Singapore Energy Labelling Scheme based on the following rating.

<table>
<tr><th>Energy Efficiency Rating</th><th>Point Allocation</th></tr>
<tr><td>✓✓✓</td><td>4</td></tr>
<tr><td>✓✓✓✓</td><td>8</td></tr>
</table>

Extent of coverage : At least 80% of air-conditioners used in all dwelling units are energy labeled

Note: Option 2(ii) is not applicable for developments where air-conditioners are not provided. Points can be scored and prorated accordingly under Option 2(i).

<u>1-2 (b) Natural Ventilation in Common Areas</u>

1-2(b)(i) 1 point can be scored if at least 80% of the lift lobbies (including private lift lobbies) and corridors areas are designed to be naturally ventilated

1-2(b)(ii) 1 point can be scored if at least 80% of the staircases areas are designed to be naturally ventilated
</td></tr>
<tr><td>Prerequisites</td><td>
(A) To be eligible for Green Mark Platinum, it is a requirement to use ventilation simulation modeling and analysis to identify the most effective building design and layout. The simulation results and the recommendations derived are to be implemented. A minimum 70% of the selected typical dwelling units must have a weighted average wind velocity of 0.60 m/s. Other than the dwelling units, common areas like staircases and lobbies (excluding those that are located in the basement areas) must also be designed as naturally ventilated spaces with provision of openable windows or other openings with aggregate area of not less than 5% of the space required to be ventilated.

(B) Prescribed system efficiency of air-conditioning system for all dwelling units to be as follows :

Green Mark Gold^{Plus}
Green Mark Platinum
} Air-conditioners with 4-ticks that are certified under the Singapore Energy Labelling Scheme or equivalent COP
</td></tr>
<tr><td>Documentary Evidences</td><td>
<u>For 1-2(a) Option 1 – Ventilation Simulation Modeling</u>
• Ventilation simulation or wind tunnel testing reports summarising the analysis and modeling results for each typical space as well as the recommendations for design. Refer to Appendix C for details
• Calculation showing the percentage of units achieving good natural ventilation in the prescribed tabulated format as shown in worked example 1-2(a) Option 1.

<u>For 1-2(a) Option 2(i) Air Flow within Dwelling Units</u>
• Floor plan of all the unit types with highlights of those with window openings facing the north and south directions and/or with true cross ventilation;
• Schedules showing the total number of units in the development and those with window openings facing the north and south direction.
• Schedules showing the total number of living rooms and bedrooms in the development and those with true cross ventilation.
• Calculation showing the percentage of living rooms and bedrooms of dwelling units with true cross ventilation in the prescribed tabulated format as shown in the worked example 1-2(a) Option 2.
</td></tr>
</table>

<table>
<tr><td></td><td>
<u>For 1-2(a) Option 2(ii) – Provision of Air-Conditioning Systems</u>
• Extracts of the tender specification showing the provision of the types of air-conditioners for the dwelling units of the development;
• Schedule of air-conditioners showing the numbers, types and the approved rating from the Singapore Energy Labelling Scheme; and
• Technical product information of the air-conditioners and approved rating.

<u>For 1-2(b) – Natural Ventilation in Common Areas</u>
• Plan layouts showing the applicable common areas and confirmation that they are designed to be naturally ventilated.
</td></tr>
<tr><td>References</td><td>-</td></tr>
<tr><td>Worked Example 1-2(a) Option 1</td><td>
A residential development with one block of 20-storey apartments comprises 200 units and with 7 typical dwelling unit layouts or types.

1. Select the five typical dwelling unit types with the most number of units for ventilation simulation.
2. Based on the ventilation simulation results, list down the total number of units for each typical dwelling unit type and its corresponding area-weighted average wind velocity as tabulated below.

<table>
<tr><th colspan="2">Dwelling Unit Layouts /Types</th><th>No. of Units</th><th>Area Weighted Average Wind Velocity</th></tr>
<tr><td>1</td><td>Typical Layout A</td><td>80</td><td>0.60</td></tr>
<tr><td>2</td><td>Typical Layout B</td><td>30</td><td>0.60</td></tr>
<tr><td>3</td><td>Typical Layout C</td><td>20</td><td>0.70</td></tr>
<tr><td>4</td><td>Typical Layout D</td><td>20</td><td>0.50</td></tr>
<tr><td>5</td><td>Typical Layout E</td><td>20</td><td>0.40</td></tr>
<tr><td colspan="3">Total Number of Selected Units : 170</td><td></td></tr>
<tr><td>6</td><td>Typical Layout F*</td><td>15</td><td>Not included</td></tr>
<tr><td>7</td><td>Typical Layout G*</td><td>15</td><td>Not included</td></tr>
</table>
* Dwelling Unit Layout not selected for simulation

Percentage of units achieving good natural ventilation is given by:

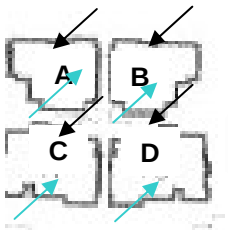
$$\frac{\Sigma(\text{No. of Selected Units for Each Layout} \times \text{Area-Weighted Average Wind Velocity})}{\text{Total Number of Selected Units} \times 0.60 \text{ m/s}} \times 100\%$$
$$= \frac{80\times0.60+30\times0.60+20\times0.70+20\times 0.5 +20\times0.40}{170\times0.60} \times 100\%$$
$$= 96\%$$

Points scored for 1-2(a) Option 1 = 0.2 x 96% = 19.2 points
</td></tr>
</table>

Worked Example 1-2(a)

Option 2

Proposed residential development with one block of 10 storey apartment comprises 40 units. Each dwelling comes with a living room and two bedrooms. There are four different unit types for this development as illustrated below.



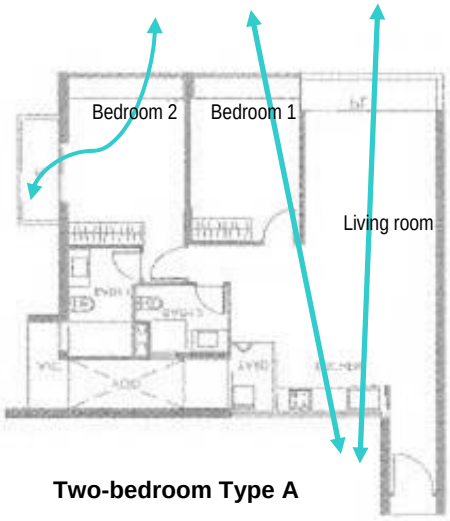
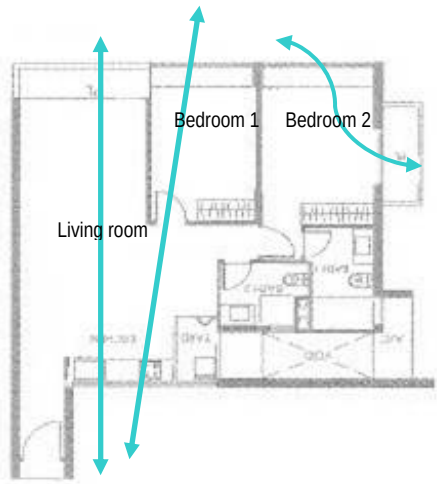
Building Layout Design

Total no. of units in the developments = 40

Total units with all window openings facing north and south directions = 40

% of units with window openings facing north and south directions = 40/40 x 100 = 100%

Points scored = 0.5 x (% unit/10)
= 0.5 x (100/10) = 5 points

 **Two-bedroom Type A**	 **Two-bedroom Type B**
The living room, bedroom 1 and bedroom 2 are considered to have true cross ventilation.	The living room, bedroom 1 and bedroom 2 are considered to have true cross ventilation.
 **Two-bedroom Type C**	 **Two-bedroom Type D**
Only living room is considered to have true cross ventilation. Both bedroom 1 & 2 do not meet the requirement.	Only living room is considered to have true cross ventilation. Both bedroom 1 & 2 do not meet the requirement.

Dwelling Unit Design

Table 1-2(a)(ii) : Percentage of rooms with true cross ventilation

Type of dwelling unit	No. of units (a)	For each unit		Total living rooms and bedrooms with true cross ventilation (b + c) x (a)
		Living room with true cross ventilation (b)	Bedrooms with true cross ventilation (c)	
2-bedroom Type A	10	1	2	30
2-bedroom Type B	10	1	2	30
2-bedroom Type C	10	1	0	10
2-bedroom Type D	10	1	0	10
			Total :	80

Total no. of living rooms and bedrooms = 3 x 40 units = 120

Total no. of living rooms and bedrooms with true cross ventilation = 80

Percentage of living rooms and bedrooms with true cross ventilation = 80/120 x 100%
= 66.7%

Points scored = 0.5 x (% rooms/10) = 0.5 x (66.7/10) = 3.3 points

All dwelling units are provided with 4 ticks air-conditioners

Points scored for 1-2(a) Option 2(ii) = 8 points

Total points scored for 1-2(a) Option 2 = 5 +3.3 +8 = 16.3 points

Worked Example 1-2(b)

Proposed development has the following provision :

All lift lobbies and corridors are designed to be naturally ventilated except for two private lobbies of the penthouses units that are designed with air-conditioning system. All staircases are designed to be naturally ventilated

No point for 1-2(b)(i) if less than 80% of lift lobbies are naturally ventilated.

1 point for 1-2(b)(ii) for staircases that are all designed to be naturally ventilated.

Therefore, points scored for 1-2(b) = 1 point

RB 1-3 DAYLIGHTING

<table>
<tr><td>Objectives</td><td>Encourage design that optimises the use of effective daylighting to reduce energy use for artificial lighting</td></tr>
<tr><td>Applicability</td><td>1-3(a) Applicable to all dwelling units' living and dining areas within the development.

1-3(b) Applicable to all common areas within the development.</td></tr>
<tr><td>Baseline Standard</td><td>1-3(a) The daylighting and glare simulation shall be based on the methodology specified in Appendix D – Daylighting and Glare Simulation Methodology and Requirements.

Minimum illuminance level shall be in accordance with CP 38 –Code of Practice for Artificial Lighting in Buildings and design intent.

The acceptable Unified Glared Rating (UGR) shall be in accordance with SS 531: Part 1 – Code of Practice for Lighting of Work Places – Indoor.</td></tr>
<tr><td>Requirements</td><td>1-3(a) Up to 3 points can be scored for the use of daylight and glare simulation software to identify dwelling units' living and dining areas with acceptable glare exposure and effective daylighting.

The daylighting provision is deemed to be effective if the areas within the prescribed distances from building perimeters (that is the perimeter daylight zones) meet the minimum illuminance level and acceptable Unified Glared Rating.

Points can be scored if at least 80% of the units are designed with effective daylighting provision. The scoring will be based on the extent of the perimeter daylight zones that is expressed as in term of the distances from façade perimeters as shown in the table below.

<table>
<tr><th>Distance from Façade Perimeters (m)</th><th>Points Allocation</th></tr>
<tr><td>≥ 3.0</td><td>1</td></tr>
<tr><td>4.0 - 5.0</td><td>2</td></tr>
<tr><td>> 5.0</td><td>3</td></tr>
</table>

1-3(b)(i) 1 point for provision of daylighting for lift lobbies and corridors.

1-3(b)(ii) 1 point for provision of daylighting for staircases.

1-3(b)(iii) 1 point for provision of daylighting for carparks.</td></tr>
<tr><td>Documentary Evidences</td><td><u>For 1-3(a)</u>
• Schedules showing the total number of living and dining areas in the development and those with acceptable glare exposure and effective daylighting; and
• Daylight and glare simulation report summarizing the analysis and modeling results for each living and dining area that meets the requirement, as specified in Appendix D.</td></tr>
</table>

<table>
<tr><td></td><td>For 1-3(b)
• Extracts of the tender specification or drawings showing the use of daylighting for lift lobbies and corridors, staircases and carparks where applicable.</td></tr>
<tr><td>References</td><td>SS CP 38 – Code of Practice for Artificial Lighting in Buildings

SS 531: Part 1 – Code of Practice for Lighting of Work Places – Indoor</td></tr>
<tr><td>Worked Example 1-3(a)</td><td>Proposed development comprises a 20 storey apartments comprises 250 units. Daylight and glare simulation has been conducted for the development. Based on simulation, 80% of all units (i.e. 200 units) can achieve effective daylighting at a distance of 6 m from building façade perimeters and meet the acceptable Unified Glared Rating .

<table>
<tr><th>Unit type</th><th>No. of Units</th><th>Average Distance from Façade Perimeter (m)</th></tr>
<tr><td>1</td><td>50</td><td>7.1</td></tr>
<tr><td>2</td><td>50</td><td>6.6</td></tr>
<tr><td>3</td><td>40</td><td>6.4</td></tr>
<tr><td>4</td><td>85</td><td>5.8</td></tr>
<tr><td>5</td><td>25</td><td>2.7</td></tr>
</table>

Percentage of units meeting the minimum requirement = $\frac{(50+50+40+85)}{250} \times 100 = 90\%$

Weighted average distance = $\frac{(50)(7.1)+50(6.6)+(40)(6.4)+(85)(5.8)+(25)(2.7)}{250}$
= 6 m

Distance for 6 m from building perimeters ⇨
<table>
<tr><th>Distance from Façade Perimeters (m)</th><th>Points Allocation</th></tr>
<tr><td>≥ 3.0</td><td>1</td></tr>
<tr><td>4.0 - 5.0</td><td>2</td></tr>
<tr><td>> 5.0</td><td>3</td></tr>
</table>

Points scored for 1-3(a) = 3 points</td></tr>
<tr><td>Worked Example 1-3(b)</td><td>Proposed residential development with the following provision :

All lift lobbies (including private lift lobbies), corridors and staircases are designed to have adequate daylighting that would eliminate the need for artificial lightings during daytime.

75% of of the carpark areas have daylighting provision while the other 25% of the carpark areas would need to employ the use of artificial lightings during daytime to maintain proper lighting level.

1 point for lift lobbies and corridors

1 point for staircases

No point for carparks as it does not meet the minimum 80% of the applicable areas

Therefore, points scored for 1-3(b) = 2 points</td></tr>
</table>

RB 1-4 ARTIFICIAL LIGHTING

Objectives	Encourage the use of energy efficient lighting to minimise energy consumption from lighting usage
Applicability	Applicable to lighting provisions for the type of usage specified in the SS 530 Clause 7 – Lighting power budget pertaining to common areas and facilities within the residential developments such as staircases, lobbies, corridors, indoor carparks and landscape areas . It is not applicable to lighting provisions for dwelling units.
Baseline Standard	Maximum lighting power budget stated in SS 530 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
Requirements	Up to 10 points can be scored for the improvement in the lighting power budget in common areas : 0.25 point for every percentage improvement in the lighting provisions over the baseline standard. That is Points scored = 0.25 x (% improvement) Display lighting and specialised lighting are to be included in the calculation of lighting power budget. The design service illuminance, lamp efficacies and the light output ratios of luminaries shall be in accordance with SS CP 38 – Code of Practice for Artificial Lighting in Buildings where applicable.
Documentary Evidences	• Lighting layout plan; • Lighting schedules showing the numbers, locations and types of luminaries used; • Calculation of the proposed lighting power budget and the percentage; improvement in the prescribed tabulated format as shown in the worked example 1-4; • Tabulation showing the designed lux level and the minimum lux level based on code requirement for the respective areas; and • Technical product information of the lighting luminaries used.
References	SS 530 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment.

Worked Example 1-4

(1) Determine the total power consumption based on the lighting layout design for each area and light fitting types used

(2) Calculate the total power consumption based on the maximum lighting power budget stated in SS 530.

(3) Calculate the percentage improvement in the total power consumption.

Table 1-4-1 : Total power consumption based on each fitting type

Description	Areas (m^2) (A)	Light Fitting Type (B)	Power Consumption per fitting (W) (C)	Ballast Loss (W) (D)	No. of Fittings (E)	Total power consumption based on fitting type [(C+D) x (E)]
Corridors	580	T5	1x28	3	70	2170
Staircase	420	T5	1x28	3	35	1085
Carparks	1500	T5	1x28	3	130	4030
Exterior Lighting	200	LED bollard	4x 1	1	28	140
		Floodlight CDM-TC	1x 35	4	15	585
					Total :	8010

Table 1-4-2 : Total power consumption based on design and SS 530 requirements

Description	Areas (m^2) (A)	Design Data		SS 530 Requirements	
		Total Power Consumption (by area)(W) (F)	Design Lighting Power Budget (W/m^2) (F/A)	Reference Lighting Power Budget (W/m^2) (H)	Reference Total Power Consumption (by area) (W) (H x A)
Corridors	580	2170	3.74	10	5800
Staircase	420	1085	2.85	6	2520
Carparks	1500	4030	2.69	5	7500
Exterior Lighting	200	725	3.63	5	1000
Total :		8010			16820

% improvement in the lighting power budget = $[\Sigma(HxA) - \Sigma(F)] / \Sigma(HxA) \times 100$

= (16820 - 8010)/16820 x 100

= 52.38%

Points scored = 0.25 x 52.38% = 13 points > 10 points (max)

Therefore, points scored for 1-4 should be 10 points

RB 1-5 VENTILATION IN CARPARKS

Objectives	Encourage the use of energy efficient design and control of ventilation systems in carparks.
Applicability	Applicable to all carpark spaces in the development.
Baseline Standard	-
Requirements	1-5(a) 6 points can be scored for carpark spaces that are fully naturally ventilated. 1-5(b) For carparks that have to be mechanically ventilated, points can be scored for the use of carbon monoxide (CO) sensors in regulating such demand based on the mode of mechanical ventilation (MV) used; 4 points for carparks using fume extract system and 3 points for those with MV with or without supply. Note : Where there is a combination of different ventilation modes adopted for carpark design, the points scored under this requirement will be prorated accordingly.
Documentary Evidences	For 1-5 (a) and (b) • Plan layouts showing all carpark provisions for the development with highlights of the carpark spaces that are designed to be naturally ventilated and/or mechanical ventilated; • Plan layouts indicating the locations of CO sensors and the mode of ventilation adopted for the design; and • Calculation showing the points allocation if there is a combination of different ventilation mode adopted for the carpark design.
References	SS CP 553- Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.
Worked Example 1-5	Proposed development has two levels of basement carparks. Level 1 basement carpark (B1) is designed with more than 20% openings for natural ventilation and fume extract system. Level 2 basement carpark (B2) is fully mechancially ventilated. CO sensors are installed to control the ventilation system for both carpark levels. Areas of basement capark – B1 = 700 m^2 Areas of basement carpark– B2 = 500 m^2 Total areas = 1200 m^2 Points scored for 1-5 = (700/1200) x 4 + (500/1200) x 3 = 3.58 points

RB 1-6 LIFTS

Objectives	Encourage the use of energy efficient lifts.
Applicability	Applicable to all lifts in the development.
Baseline Standard	-
Requirements	1 point can be scored for the use of lifts with energy efficient features such as AC variable voltage and variable frequency (VVVF) motor drive and energy efficient features such as sleep mode.
Documentary Evidences	• Extracts of the tender specification indicating the types of lifts and related features used; and • Technical information of the lifts.
References	-
Worked Example 1-6	Proposed development has the following provision: All lifts are VVVF motor drive with sleep mode features 1 point for the use of VVVF motor drive with sleep mode features. Therefore, points scored for 1-6 = 1 point

RB 1-7 ENERGY EFFICIENT FEATURES

Objectives	Encourage the use of energy efficient features that are innovative and have positive environmental impact in terms of energy saving.
Applicability	Applicable to practices and features that are not listed in the requirements under Part 1 – Energy Efficiency.
Baseline Standard	-
Requirements	(a) 0.5 point for the use of energy efficient equipment or products that are certified by approved local certification body for at least 90% of the applicable equipment type or products.(Up to 2 points) (b) Up to 5 points can be scored for the use of the following energy efficient features based on their potential environmental benefits and the extent of coverage. (i) Use of heat recovery devices • 2 points for more than 50% of all dwelling units • 1 point for at least 25% of all dwelling units • 0.5 point for club house or other common facilities (ii) Use of thermal insulation or cool paints on the east and west facing external walls • 2 points for window to wall ratio (WWR) of less than 0.5 • 1 point for WWR that is between 0.5 to 0.75 • 0.5 point for WWR of more than 0.75 (iii) Use of occupancy sensors for private lift lobbies, staircases, common toilets • 1 point for at least 50 occupancy sensors installed • 0.5 point for less than 50 occupancy sensors installed (iv) Provision of vertical greenery system on building facades abutting the living, dining and bedrooms areas of dwelling units and club house • 2 points for more than 50% of building facades • 1 point for at least 25% of building facades • 0.5 point for clubhouse (v) Provision of gas water heater • 1 point for more than 90% of all dwelling units • 0.5 point for between 50% to 90% of all dwelling units (vi) Provision of clothes drying facilities and open spaces • 1 point for more than 90% of all dwelling units • 0.5 point for between 50% to 90% of all dwelling units (vii) Provision of lifts with better energy efficient features (Up to 2 points) • 2 points for the use of regenerative drive system for at least 90% of lifts installed • 1 point for the use of gearless drive system for at least 90% of lifts installed (viii)Use of sun pipes for natural lighting. • 1 point for more than 10 sun pipes • 0.5 point for at least 5 sun pipes

Requirements

- Cont'd

(ix) 0.5 point for the provision of ductless fans for basement ventilation.

(x) 0.5 point for the computation of Energy Efficiency Index (EEI) for common facilities of the development.

Calculation of EEI for Common Facilities :

EEI = (TEC / GFA) x 365 days

where:

(a) TEC : Total electricity consumption for common facilities (kWh/day)
(b) GFA : Gross floor area of development (m^2)

The common facilities and the daily usage hours of these facilities are pre-determined for consistency as shown in Table 1-7. They are to be used in the computation for EEI. Other common facilities that are not listed should be included under 'Others' and the operation hours can be estimated based on the likely usage pattern.

Table 1-7 : Common Facilities and Daily Usage Pattern

	Description	Daily Usage (hr)
A)	**Mechanical Load**	
	MV fan (plant room)	9
	Car park fan	4
	A/C for club house	12
	A/C for lobbies	12
	A/C for guard house	24
	Domestic pump	2
	Ejector pump	2
	Booster pump	3
	Sump pumps	0.5
B)	**Lift Load**	
	Passenger lifts	2
	Service lift	2
C)	**General lighting**	
	Car park lighting - 24 hours operation	24
	Car park lighting - 5 hours operation	5
	Guard house lighting	12
	Facade lighting	5
	Landscape lighting - 12 hours operation	12
	Landscape lighting - 5 hours operation	5
	Lift lobbies, corridors & staircase lighting - 12 hours operation	12
	Lift lobbies, corridors & staircase lighting - 5 hours operation	5
D)	**Club Facilities**	
	Club house interior lighting	12
	Power to Gym equipment, SPA, etc	6
	Swimming pool filtration	12
	Water features	8
E)	**Others**	
	Facilities A	To estimate
	Facilities B	To estimate

Important notes : *For features that are not listed in RB 1-7(i) to (x) above, the QP is required to submit the details showing the positive environmental impacts and potential energy savings of the proposed features to BCA for assessment.*

Documentary Evidences

- Extracts of the tender specification showing the provision of the proposed energy efficient features and the extent of implementation where applicable;
- Technical product information on the energy efficient features used; and
- Calculation of the potential energy savings that could be reaped from the use of these features.
- Calculation of the Energy Efficiency Index (EEI) using the pre-determined daily usage pattern as in Table 1-7 and in the prescribed tabulated format as shown in the worked example 1-7(x).

References

-

Worked Example 1-7(x)

Background info :

Proposed residential development with the following estimated electricity consumption for common facilities.

Table 1-7(xi) : Estimated electricity consumption for common facilities

	Description	Estimated Load (KW)	Daily Usage (hr)	Load per day (KWh)
A)	**Mechanical Load**			
	MV fan (plant room)	9	9	81
	Carpark fan	320	4	1280
	A/C for club house	8	12	96
	A/C for lobbies (1st sty & Basement)	0	12	0
	A/C for guard house	2	24	48
	Domestic pump	70	2	140
	Ejector pump	13	2	26
	Booster pump	28	3	84
	Sump Pumps	12	0.5	6
B)	**Lift Load**			
	Passenger Lifts	470	2	940
	Service Lifts	0	2	0
C)	**General lighting**			
	Carpark lighting – 24 hours operation	23	24	552
	Carpark lighting - 5 hours operation	23	5	115
	Guard house lighting	0.3	12	3.6
	Facade lighting	0	5	0
	Landscape lighting - 12 hours operation	30	12	360
	Landscape lighting - 5 hours operation	28	5	140
	Lift lobbies, corridor& staircase Lighting - 12 hours operation	20	12	240
	Lift lobbies, corridor& staircase lighting - 5 hours operation	19	5	95
D)	**Club Facilities**			
	Club house interior lighting	12	12	144
	Power to Gym equipment, SPA, etc	85	6	510
	Swimming Pool Filtration	50	12	600
	Water Feature	25	8	200
	Total kWh per day			**5660.60**

Calculation of EEI for Common Facilities :

Total electricity consumption per day = 5660.60 kWh/day

EEI = (TEC / GFA) x 365 days
= (5660.60 / 40 000) x 365
= 51.65 kWh/m^2/yr

Points scored for 1-7(x) = 0.5 point

RB 1-8 RENEWABLE ENERGY

Objectives	Encourage the use of renewable energy sources in buildings.
Applicability	Includes all renewable energy sources
Baseline Standard	-
Requirements	Up to 20 points can be scored based on the percentage replacement of electricity by the renewable energy source 3 points for every 1% replacement of electricity (based on annual electricity consumption exclude household's usage) by renewable energy *Condition : The points scored for renewable energy provision shall not result in a double grade jump in the GM rating (i.e. from GM Certified to Gold^{Plus} or Gold to Platinum).*
Documentary Evidences	• Extracts of the tender specification and plans showing the location of the renewable energy system and the extent of implementation; • Technical product information on the salient features of the renewable energy system and the expected renewable energy generated; and • Calculation of the percentage replacement of electricity and the total annual electricity consumption of the development.
References	-
Worked Example 1-8	A residential development with GFA of 15,000m^2. The Energy Efficiency Index for its common facilities is 50 kWh/m^2/year The installation of solar array on the roof of its open car park was estimated to generate 7,500 kWh annually Total electricity consumption of the development's common areas = 50 x 15,000 = 750,000 kWh/year Percentage of replacement of electricity by renewable energy = 7,500 / 750,000 x 100% = 1% Points scored for 1-8 for 1% replacement of electricity = 3 points

(II) Other Green Requirements

Part 2 – Water Efficiency

RB2-1 Water Efficient Fittings
RB2-2 Water Usage Monitoring
RB2-3 Irrigation System and Landscaping

RB 2-1 WATER EFFICIENT FITTINGS

<table>
<tr><td>Objectives</td><td>Reduce the use of potable water by using water efficient fittings covered under the Water Efficiency Labelling Scheme (WELS).</td></tr>
<tr><td>Applicability</td><td>Applicable to the water fittings covered by the WELS :
Basin taps and mixers
Flushing cistern
Sink/bib taps and mixers
Shower taps and mixers or showerheads
All other water fittings</td></tr>
<tr><td>Baseline Standard</td><td>As specified under Water Efficiency Labelling Scheme (WELS).</td></tr>
<tr><td>Requirements</td><td>Up to 10 points can be scored based on the number and water efficiency rating of the fitting type used.<table><tr><th>WELS Rating</th><th>Water Efficiency</th><th>Weightage for Point Allocation</th></tr><tr><td>✓✓</td><td>Very Good</td><td>8</td></tr><tr><td>✓✓✓</td><td>Excellent</td><td>10</td></tr></table></td></tr>
<tr><td>Documentary Evidences</td><td>Extracts of the tender specification showing all the water fitting provisions for the development;
Water fitting schedules showing the numbers, types and the approved rating of the proposed fittings in the prescribed tabulated format shown in the worked example; and
Calculation showing the percentage of proposed water fittings that are approved under WELS.</td></tr>
<tr><td>References</td><td>For more information about WELS, refer to
http://www.pub.gov.sg/wels/Pages /default.aspx</td></tr>
</table>

Worked Example 2-1

Example of a water fitting schedule showing the numbers, types and the approved rating of the proposed fitting for a residential development (including common facilities such as clubhouse toilets).

Ref.	Water Fitting Type	WELS rating		Mandatory requirement MWELS	Total no. based on fitting type
		Excellent	Very Good	Good	
1	Shower taps and mixers	0	45	0	45
2	Basin taps and mixers	10	150	0	160
3	Sink/bib taps and mixers	5	0	50	55
4	Flushing cisterns	10	50	0	60
5	Urinals and urinal flush valves for club house	10	0	0	10
Total no. based on rating (A)		35	245	50	∑A =330
Weightage (B)		10	8	0	0
Total (AXB)		350	1960	0	∑(AxB) =2310

Points scored = ∑(AxB) / ∑A

=2310/330

= 7 points

RB 2-2 WATER USAGE MONITORING

Objectives	Promote the use of private meters for better control and monitoring of major water usage.
Applicability	Applicable to sub-metering provisions for major water uses of the building developments.
Baseline Standard	-
Requirements	1 point can be scored if private meters are provided for all major water uses i.e. irrigation system, swimming pools and other water features where applicable.
Documentary Evidences	• Extracts from the tender specification stating the locations and provision of private meters for all major water uses. • Schematic drawings of cold water distribution system showing the location of the private meters provided.
References	-

RB 2-3 IRRIGATION SYSTEM AND LANDSCAPING

Objectives	Reduce potable water consumption by provision of suitable systems that utilise rainwater or recycled water for landscape irrigation and use of plants that require minimal irrigation to reduce potable water consumption.
Applicability	Applicable to residential development with landscaping provision.
Baseline Standard	-
Requirements	2-3(a) 1 point can be scored for the use of non-potable water including rainwater for landscape irrigation. 2-3(b) 1 point can be scored if more than 50% of the landscape areas are served by water efficient irrigation system with features such as automatic sub-soil drip irrigation system with rain sensor control. 2-3(c) 1 point can be scored if at least 80% of the landscape areas consist of drought tolerant plants or plants that require minimal irrigation.
Documentary Evidences	<u>For 2-3(a)</u> • Extracts of the tender specification showing how the non-potable water source is to be provided; • Relevant drawings showing the location and design of the non-potable water source; and • For rainwater harvesting and storage system, approval letter from PUB is to be provided. <u>For 2-3(b)</u> • Extracts of the tender specification showing the provision and details of water efficient irrigation system; • Relevant layout plans showing the overall landscape areas and the areas that would be served using the system; and • Calculation showing the percentage of the landscape areas that would be served using the system. <u>For 2-3(c)</u> • Relevant layout plans showing the overall landscape areas and the areas that use drought tolerant plants or plants that require minimal irrigation. • Calculation showing the percentage of the landscape areas that use drought tolerant plants or plants that require minimal irrigation.
References	The list of drought tolerant or resistant plant species may be obtained from the online website: http://florafaunaweb.nparks.gov.sg/

(II) Other Green Requirements

Part 3 – Environmental Protection

RB 3-1 SUSTAINABLE CONSTRUCTION

<table>
<tr><td>Objectives</td><td>Encourage the adoption of building designs, construction practices and materials that are environmentally friendly and sustainable.</td></tr>
<tr><td>Applicability</td><td>Generally applicable to all building developments.</td></tr>
<tr><td>Baseline Standard</td><td>-</td></tr>
<tr><td>Requirements</td><td>
3-1(a) Up to 5 points can be scored with the use of (i) Green Cements and (ii) Recycled Concrete Aggregates (RCA) and Washed Copper Slag (WCS) as detailed in the following para 3-1(a)(i) and 3-1(a)(ii) :

3-1(a)(i) 1 point can be scored for use of Green Cements with approved industrial by-product (such as Ground Granulated Blastfurnace Slag (GGBS), silica fume, fly ash) to replace Ordinary Portland Cement (OPC) by at least 10% by mass for superstructural works.

3-1(a)(ii) Up to 4 points can be scored for use of Recycled Concrete Aggregates (RCA) or Washed Copper Slag (WCS) from approved sources to replace coarse or fine aggregates for concrete production of main building elements.

1 point for every incremental of 0.5 times (0.5x) of the usage requirement (Up to 2x)

<table>
<tr><th>Quantity of RCA /WCS</th><th>Points Allocation</th></tr>
<tr><td>≥ 0.5 x usage requirement</td><td>1</td></tr>
<tr><td>≥ 1.0 x usage requirement</td><td>2</td></tr>
<tr><td>≥ 1.5 x usage requirement</td><td>3</td></tr>
<tr><td>≥ 2.0 x usage requirement</td><td>4</td></tr>
</table>

where usage requirement = 0.03 x Gross Floor Area (GFA in m^2)

The RCA/WCS quantity (in tons) used for the concrete production of main building elements can be derived from the concrete volume comprising these recycled materials and based on the following conversion factor:

RCA (tons)= 1.0 (tons/m^3) X (concrete vol in m^3) X (RCA replacement rate)%

WCS (tons)= 0.7(tons/m^3) X (concrete vol in m^3) X (WCS replacement rate)%

Important notes :
For structural building elements, the use of RCA and WCS shall be limited to maximum 10% replacement by mass of coarse/fine aggregates or as approved by the relevant authorities.
</td></tr>
</table>

Requirements

Cont'd

3-1(b) Up to 5 points are allocated to encourage more efficient concrete usage for building components based on the percentage reduction in the prescribed Concrete Usage Index (CUI) limit.

Table 3-1 (b) Points allocation for project CUI

Project CUI (m^3/m^2)	Points Allocation
≤ 0.70	1
≤ 0.60	2
≤ 0.50	3
≤ 0.40	4
≤ 0.35	5

Note : *Concrete Usage Index* (CUI) is 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-structural works such as basements and foundations. CUI is defined as the volume of concrete in cubic metres needed to cast a square metre of constructed floor area. It is expressed as:

$$\text{Concrete Usage Index} = \frac{\text{Concrete Volume in } m^3}{\text{Constructed Floor Area in } m^2}$$

Prerequisites

Minimum score under RB 3-1 Sustainable Construction

Green Mark Gold^{Plus} ≥ 3 points
Green Mark Platinum ≥ 5 points

Documentary Evidences

For 3-1(a)(i) & a(ii)

- Extract of tender specification and concrete mix design showing the detailed usage of Green Cements
- Extract of tender specification and concrete mix design showing the detailed usage of RCA and WCS.
- Evidence of site delivery of these materials where applicable.

For 3-1(b)

- Architectural and structural plan layout, elevation and sectional plans showing the type of wall system used, the dimensions and sizes of all the building and structural elements; and
- Summary showing the quantity of concrete for each floor level in the prescribed tabulated format shown in worked example 3-1(b). The calculation should include all the building elements as listed in the worked example and the derivation of the concrete volume should be detailed and made available for evaluation.

Worked Example 3-1(a)

Proposed development comprises a 15 storey residential block with a basement carpark and the following details :

Gross Floor Area (GFA) = 10,000 m^2

Total Concrete Usage with replacement of coarse and fine aggregate with recycled concrete aggregate and washed copper slag = 6 000 m^3

(i) Use of Green Cements to replace 10% of OPC for superstructural works

Points scored = 1 point

(ii) Use of recycled concrete aggregates (RCA) to replace coarse aggregate and the use of washed copper slag (WCS) to replace fine aggregate for main building elements with a replacement rate of 10%.

Usage requirement = 0.03 x 10000 = 0.03 x 10000 = 300 tons

RCA (tons) = 1.0 (tons/m^3) X (concrete vol in m^3) X (RCA replacement rate)%

= 1.0 (6 000)(10%) = 600 tons

As the total quantity used (i.e. 600 tons) for replacement of coarse aggregate is 2 x usage requirement :

Therefore, points scored for RCA under 3-1(a)(ii) = 4 points

WCS (tons)= 0.7(tons/m^3) X (concrete vol in m^3) X (WCS replacement rate)%

= 0.7 (6 000)(10%) = 420 tons

Points scored for WCS under 3-1(a)(ii) = 2 points

Points scored for 3-1(a)(i) &(a)(ii) = 1(for green cement) +4 (for RCA) +2 (for WCS) = 7 points > 5 points(max)

Hence, total points scored for 3-1(a)(i) & (a)(ii) should be 5 points

Worked Example 3-1(b)

Proposed development comprises a 15 storey residential block with a basement carpark and the following details :

Concrete usage for the superstructure	**Constructed floor areas**
For 1st storey = 587 m^3 From 2nd to 15th storey = 5400 m^3 (including roof level)	For 1st storey = 1000 m^2 From 2nd to 15th storey = 14000 m^2 (including roof level)
Therefore, Total concrete usage = 5987 m^3	Therefore, Total constructed floor area = 15000 m^2

Note : The concrete usage for foundation and two basements are not required to be included.

Concrete Usage Index CUI = $\frac{5987}{15000}$ = 0.4 m^3/m^2

Refer to the following Table 3-1(b) for more details

Based on the point allocation shown in Table 3-1(b)

CUI of 0.4 m^3/m^2 ≤ 0.4 m^3/m^2

Therefore, point scored = 4 points

Worked Example 3-1(b) – Cont'd

Table 3-1(b) – Concrete Usage Index

COMPUTATION OF CONCRETE USAGE INDEX				**RESIDENTIAL BLDG**
Project Reference No.: AXXXX-00001-2007			**Total no. of storey for the project: 15**	
Block No : A				
	Structural System	**Thickness (mm) or size (mm x mm)**	**Volume of concrete (m^3)**	**Remark ***
1	**1st storey**			
	1.1 Columns	200x400, 200x200	72	Precast
	1.2 Beams	200x400, 200x500	145	Precast
	1.3 Slabs	150,200	265	Post – tensioned
	1.4 Staircases	150	30	Precast
	1.5 Suspended structures like planter boxes, bay windows, ledges etc	150	10	Precast
	1.6 Parapets	150	5	RC
	1.7 External walls - loadbearing walls	Nil	0	–
	1.8 External walls – non-loadbearing walls	125	15	RC
	1.9 Internal walls – loadbearing walls	200	40	RC
	1.10 Internal walls – non-loadbearing walls	Nil	0	Light weight concrete
	1.11 Others (kerbs, ramps, services risers, etc)	Not required	5	RC
	Total volume of concrete for this storey (m^3)		587	
	Total constructed floor area for this storey (m^2)		1000	
2	**Typical floor layout**			
	2.1 Columns	200x400, 200x200	55	Precast
	2.2 Beams	200x400, 200x500	45	Precast
	2.3 Slabs	150,200	160	Post – tensioned
	2.4 Staircases	150	30	Precast
	2.5 Suspended structures like planter boxes, bay windows, ledges etc	150	10	Precast
	2.6 Parapets	150	5	RC
	2.7 External walls - loadbearing walls	Nil	0	–
	2.8 External walls – non-loadbearing walls	125	15	RC

Worked Example 3-1(b) – Cont'd

COMPUTATION OF CONCRETE USAGE INDEX RESIDENTIAL BLDG

Project Reference No.: AXXXX-00001-2007 **Total no. of storey for the project: 15**

Block No : A

	Structural System	Thickness (mm) or size (mm x mm)	Volume of concrete (m^3)	Remark *
2	**2nd storey to 30th storey (Typical floor layout)**			
	2.9 Internal walls – loadbearing walls	200	40	RC
	2.10.Internal walls – non-loadbearing walls	Nil	0	–
	2.11 Others (kerbs, ramps, services risers etc)	Nil	0	–
	Volume of concrete for one storey (m^3)		360	
	Constructed floor area for one storey		933.3	
	Total volume of concrete for 2nd to 15th storey (including roof level)		360 X 15 = 5400	
	Total constructed floor area for 2nd to 15th storey (m^2) (including roof level)		933.3 x 15 = 14000	
	Total volume of concrete for this project (m^3)		5987	
	Total constructed floor area for this project (m^2)		15000	
	Concrete Usage Index (CUI in m^3/m^2)		0.4	

* 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

Important notes : *The quantities of the concrete for all the structural and non-structural elements for each floor level are computed. All the elements listed in the table such as columns, beams, slabs, suspended structures (like planter boxes, bay windows and ledges etc) , parapets, walls and others (service risers, kerbs, ramps etc) are to be included. The concrete usages for foundation and basement works are excluded in CUI computation.*

RB 3-2 SUSTAINABLE PRODUCTS

<table>
<tr><td>Objectives</td><td>Encourage the use of products that are environmentally friendly and sustainable.</td></tr>
<tr><td>Applicability</td><td>Applicable to non-structural and architectural building components.</td></tr>
<tr><td>Baseline Standard</td><td>-</td></tr>
<tr><td>Requirements</td><td>Up to 8 points are allocated to encourage the use of appropriate environmentally friendly products that are certified by approved local certification body. The products used should have considerably contributions in the overall environmental sustainability standard of the development. Points scored will be based on the weightage, extent of coverage and impact.

The weightage given will be based on the extent of environmental friendliness as determined by the approved local certification body and are subject to BCA's evaluation.

<table>
<tr><th>Extent of Environmental Friendliness of Products</th><th>Weightage for Point Allocation</th></tr>
<tr><td>Good</td><td>0.5</td></tr>
<tr><td>Very Good</td><td>1.5</td></tr>
<tr><td>Excellent</td><td>2</td></tr>
</table>

The use of environmental friendly products or recycled materials used for all dwelling units of the development will be considered as high impact (1 point). Items that are used for all common areas, external works and communal facilities are considered as low impact (0.5 point).

Note : The point allocated for low volatile organic compound (VOC) paints and adhesives certified by approved local certification body can be found in RB 4-2 and hence shall not be included in the scoring for RB 3-2.</td></tr>
<tr><td>Prerequisites</td><td>Minimum score under RB 3-2 Sustainable Products

Green Mark Gold^{Plus} ≥ 3 points
Green Mark Platinum ≥ 4 points</td></tr>
<tr><td>Documentary Evidences</td><td>• Extracts from the tender specification and drawings showing the requirements to incorporate the environmental friendly products that are certified with approved local certification body;

• Certification details from approved local certification body such as the material certification standards, rating and product reference; and

• Technical product information and delivery records.</td></tr>
<tr><td>References</td><td>For more info on product certification, refer to

http://www.sgbc.sg/green-certifications/product-certifications/

http://www.greenlabel.sg/</td></tr>
</table>

Worked Example 3-2 (i)

1. Determine if the environmental friendly products selected are certified with approved local certification body.
2. Check if the products used are meant for all dwelling units of the development and can be considered as high impact. Products that are meant for common areas and external works such as toilets, lobbies and landscaping areas are considered as low impact.
3. Check on the extent of environmental friendliness of the products and the rating granted by the approved certification body.

   Example of a proposed residential development using the following products that are rated as 'Good' by approved local certification body.

Products and Extent of coverage		With approved certification	Points allocated based on impact (A)	Weightage based on rating (B)	Points scored (AxB)
1	Waterproofing for all units' toilets	Yes	1	0.5	0.5
2	Timber doors for all dwelling units	Yes	1	0.5	0.5
3	Bamboo Flooring for all units' bedrooms	Yes	1	0.5	0.5
4	Roof waterproofing	No	NA	NA	0

Points scored for 3-2 (i) = 0.5+0.5+0.5 = 1.5 points

Worked Example 3-2 (ii)

Note : Certain products can have more environmentally friendly features than others. Other than recycled materials, they may have features like low VOC assembly or manufactured with resource efficient processes, durability etc that will render the products more environmental friendly than others. If the certified products selected are more environmental friendly and are given a better rating by the approved local certification body, a higher weightage can be considered in point scoring.

Example of a proposed development with the following provisions :

(a) Use of certified wooden doors for all dwelling units. Product is rated as 'Very Good' by approved local certification body.

(b) Use of certified bamboo flooring for all units' bedrooms. Product is rated as 'Excellent' by approved local certification body.

(c) Use of certified roof waterproofing coating. Product is rated as 'Excellent' rating by approved local certification body.

Products and Extent of coverage		With approved certification	Points allocated based on impact (A)	Weightage based on rating (B)	Points scored (AxB)
(a)	Wooden doors for all dwelling units	Yes	1	1.5	1.5
(b)	Bamboo flooring for all units' bedrooms	Yes	1	2	2
(c)	Roof waterproofing	Yes	0.5	2	1

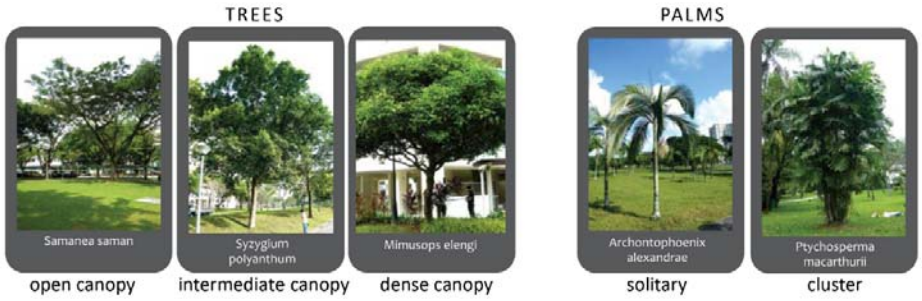
Therefore, points scored for 3-2 (ii) = 1.5 +2 +1 = 4.5 points

RB 3-3 GREENERY PROVISION

<table>
<tr><td>Objectives</td><td>Encourage greater use of greenery and restoration of existing trees to reduce heat island effect.</td></tr>
<tr><td>Applicability</td><td>Applicable to building developments with landscaping areas.</td></tr>
<tr><td>Baseline Standard</td><td>-</td></tr>
<tr><td>Requirements</td><td>3-3(a) Up to 6 points can be scored for the provision of greenery within the developments including roof top/ sky garden and green roof.

Green Plot Ratio (GnPR) is calculated by considering the 3D volume covered by plants using the following Leaf Area Index (LAI)

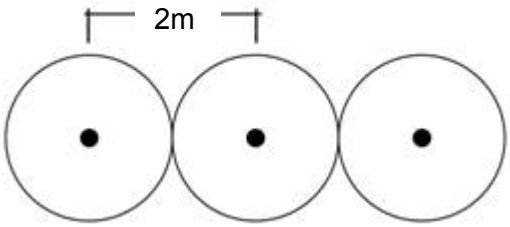
<table>
<tr><th>Plant group</th><th>Trees</th><th>Palms</th><th>Shrubs & Groundcover</th><th>Turf</th></tr>
<tr><td>LAI</td><td>Open Canopy = 2.5
Intermediate Canopy = 3.0
Dense Canopy = 4.0</td><td>Solitary = 2.5
Cluster = 4.0</td><td>Monocot = 3.5
Dicot = 4.5</td><td>Turf = 2.0</td></tr>
<tr><td>Area</td><td>All = 60 m^2</td><td>Solitary = 20 m^2
Cluster = 17 m^2</td><td>Planted area</td><td>Planted area</td></tr>
</table>

Green Plot Ratio (GnPR) = Total Leaf Area / Site Area

<table>
<tr><th>GnPR</th><th>Points Allocation</th></tr>
<tr><td>1.0 to < 2.0</td><td>1</td></tr>
<tr><td>2.0 to < 3.0</td><td>2</td></tr>
<tr><td>3.0 to < 4.0</td><td>3</td></tr>
<tr><td>4.0 to < 5.0</td><td>4</td></tr>
<tr><td>5.0 to < 6.0</td><td>5</td></tr>
<tr><td>≥ 6.0</td><td>6</td></tr>
</table>
</td></tr>
</table>

	3-3(b) 1 point for restoration, conservation or relocation of existing trees on site. 3-3(c) 1 point for the use of compost recycled from horticulture waste.
Documentary Evidences	<u>For 3-3(a)</u> • Plan layouts 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); and • Calculation showing the extent of the greenery provision in the prescribed tabulated format as in worked example 3-3(a). <u>For 3-3(b)</u> • Site layouts showing the existing and final locations (where applicable) and number of the trees to be restored or conserved or relocated. <u>For 3-3(c)</u> • Extracts of the tender specification showing the requirements to use compost recycled from horticulture waste.
Exceptions	**TREES AND PALMS SPACING (CENTRE-TO-CENTRE)** (a) 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 (in m^2).  **COLUMNAR TREES** (b) 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 brachiata . Gnetum gnemon
References	The plant species, its sub categories and LAI values may be obtained from the online website: http://florafaunaweb.nparks.gov.sg

Worked Example 3-3(a)

(1) Determine the number of trees, palms and the areas for shrub and turfs and other greenery area

(2) The Leaf Area Index (LAI) of the individual plant species and its canopy area are predetermined design parameters applicable for all developments.

(3) The plant species sub categories and its LAI values can be obtained from the online website: http://florafaunaweb.nparks.gov.sg/ (see example below) by searching the common / scientific names of the plants.

(4) Compute the green areas as shown in the Table 3-3(a) below

Table 3-3(a) – Calculation of the Green Plot Ratio

Category	Sub category	(A)	(B)	(C)	(A) x (B) x (C)
		LAI value	Canopy Area	Qty/ Planted Area	Leaf Area
Trees (no.)	Open Canopy	2.5	60 m^2	0 no.	0
	Intermediate Canopy	3.0	60 m^2	8 no.	1440
	Dense Canopy	4.0	60 m^2	12 no.	2880
	Intermediate columnar canopy *	3.0	12 m^2	4 no.	144
Palms (no.or m^2)	Solitary	2.5	30 m^2	10 no.	750
	Solitary (trunk-to trunk ≤ 2m)	2.5	NA	20 m^2	50
	Cluster	4.0	17 m^2	10 no.	680
Shrubs (m^2)	Monocot	3.5	NA	0 m^2	0
	Dicot	4.5	NA	20 m^2	90
Turf (m^2)	Turf	2.0	NA	90 m^2	180
Vertical Greenery (m^2)	-	2.0	NA	10 m^2	20
*Note : * refer to the exceptions*				**Total Leaf Area :**	**6234**

Note: Green roof landscaping would be calculated as per illustrated above

Assume site area is 2000m^2

Green Plot Ratio (GnPR) = total leaf area / site area
= 6234 / 2000 = 3.117 < 4.0

where GnPR = 3.0 to < 4.0

Therefore, points scored for 3-3(a) = 3 points

RB 3-4 ENVIRONMENTAL MANAGEMENT PRACTICE

Objectives	Encourage the adoption of environmental friendly practices during construction and building operation.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	3-4(a) 1 point can be scored if effective implementation of environmental friendly programmes including monitoring and setting targets to minimise energy use, water use and construction waste are in place. 3-4(b) 1 point can be scored if main builder has good track records in the adoption of sustainable, environmentally friendly and considerate practices during construction such as the Green and Gracious Builder Award. 3-4(c) 1 point can be scored if the building quality is assessed under the Construction Quality Assessment System (CONQUAS) and an additional one (1) point can be scored if the project is assessed under Quality Mark. 3-4(d) Up to 1 point if the developer, main builder, M & E consultant and architect are ISO 14000 certified. 0.25 point is allocated for each firm that is certified. 3-4(e) Up to 1 point if the project team comprises one Certified Green Mark Manager (GMM)(0.5 point), one Certified Green Mark Facility Manager (GMFM)(0.5 point) or one Certified Green Mark Professional (GMP)(1 point). 3-4(f) 1 point can be scored for the provision of building users' guide with details of the environmental friendly facilities and features within the building and their uses in achieving the intended environment performance during building operation. 3-4(g) 1 point can be scored for the provision of facilities or recycling bins at each block of development for collection and storage of different recyclable waste such as paper, glass, plastic etc.
Documentary Evidences	<u>For 3-4(a)</u> • Extracts of the tender specification showing the requirements for builder to provide and implement environmental friendly programmes to minimise energy use, water use and construction waste; and • Details of the environmental friendly programmes implemented. <u>For 3-4(b)</u> • A certified true copy of the main builder's Green and Gracious Builder Award; or • Details of track records in the adoption of sustainable, environmentally friendly and considerate practices during construction. <u>For 3-4(c)</u> • Extracts of the tender specification showing the requirement to adopt CONQUAS and Quality Mark where applicable.

	For 3-4(d) • A certified true copy of the ISO 14000 certificate of developer, main contractor, M & E consultant and architect where applicable. For 3-4(e) • A certified true copy of the certificate of Green Mark Manager or Green Mark Facility Manager and Green Mark Professional where applicable and a confirmation of their involvement and contribution in the project. For 3-4(f) • A copy of the building users' guide containing the details of the environmental friendly facilities and features within the building and their uses in achieving the intended environment performance during building operation. For 3-4(g) • Plan layout showing the location of the recycling bins for collection and storage of different recyclable waste.
References	-

RB 3-5 GREEN TRANSPORT

Objectives	Promote environmental friendly transport options and facilities to reduce pollution from individual car use.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	3-5(a) 1 point can be scored for design that provides good access (< 500m walking distance) to public transport networks such as MRT/LRT stations and bus stops. 3-5(b) 1 point can be scored for provision of covered walkway to facilitate connectivity and the use of public transport. 3-5(c) 1 point can be scored for provision of electric vehicle charging stations within the development. (*Minimum provision : 1 charging station for every 100 carpark lots, round up to the nearest hundreds (Cap at 5 charging stations)* 3-5(d) Up to 1 point can be scored for the provision of covered/sheltered bicycles parking lots: o 1 point for at least 10% of total number of dwelling units o 0.5 point for at least 5% of total number of dwelling units
Documentary Evidences	For 3-5(a) • Site layout plan in the context of the surrounding area showing the location of the development site and the location of the MRT/LRT stations and bus stops. For 3-5(b) • Site layout plan showing the connection of covered walkway from the development to the MRT/LRT stations or bus stops; and • Extracts of the tender specification showing the requirement to provide covered walkway. For 3-5(c) • Extracts of the tender specification showing the requirement to provide electric vehicle charging stations. For 3-5(d) • Extracts of the tender specification showing the requirement to provide covered/sheltered bicycles parking lots for the development and the total quantity of bicycle lots provided.
References	-

RB 3-6 STORMWATER MANAGEMENT

Objectives	Encourage the treatment of stormwater runoff through provision of infiltration or design features before discharge to public drains.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	Up to 3 points can be scored for the treatment of stormwater runoff. • 3 points for treatment of run-off from more than 35% of total site area or paved area • 2 points for treatment of run-off from more than 10% to up to 35% of total site area • 1 point for treatment of run-off from up to 10% of total site area Note: (1) The treatment of stormwater runoff shall be through provision of infiltration or design features as recommended in PUB's ABC Waters design Guidelines. (2) Points can be scored if the treatment of run-off covers more than 35% of total paved area of the site. If the percentage of total paved area is less than 35%, points can only be scored based on total site area.
Documentary Evidences	• Site layout plans indicating the total site area, total paved area within the site as well as the total catchment areas where runoff are treated through the provision of ABC Waters design features. Other information such as the total paved areas within the catchment areas, treatment areas and the hydraulic retention time of the design features are to be included where applicable. • Drainage plan, schematic plan, location plan and section details of ABC Waters Design features such as the specification of filtration layer, transition layer and drainage layer, sub-soil drainage system, overflow arrangement, plant list etc. Relevant design calculations and simulation/ modeling results are to be provided where applicable.
References	Public Utilities Board (PUB), Singapore publication on - ABC Waters Design Guidelines - Engineering Procedure for ABC Waters Design Features For more information about ABC Waters Design Guidelines, refer to http://www.pub.gov.sg/abcwaters/abcwatersdesignguidelines/Pages/ABCDesignGuidelines.aspx

Worked Example 3-6	A development has a site area of 1000 m^2 that includes 500 m^2 paved area. It was planned that 300 m^2 of the site area would be treated through a bio-retention system designed according to PUB's ABC Waters design guidelines. <u>Based on total site area</u> Percentage of run-off being treated = 300/1000 x 100% = 30% Points scored = 2 points <u>Based on paved area</u> If 200 m^2 out of the 300m^2 catchment area treated, was paved Percentage of run-off being treated = 200/500 x 100% = 40% Points scored = 3 points Therefore, points scored for RB 3-6 = 3 points

(II) Other Green Requirements

Part 4 – Indoor Environmental Quality

RB4-1 Noise Level
RB4-2 Indoor Air Pollutants
RB4-3 Waste Disposal
RB4-4 Indoor Air Quality in Wet Areas

RB 4-1 NOISE LEVEL

Objectives	Recognise buildings that are designed to consider the potential noise levels within the dwelling units are maintained at an appropriate level.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	1 point can be scored if the building is designed to achieve ambient internal noise level as specified : • 55 dB (6am-10 pm) LeqA • 45 dB (10 pm-6 am) LeqA For developments that are in close proximity to road with heavy traffic, flyover or highway, it is necessary to have a detailed analysis conducted by the acoustic consultant. Points can only be scored if the recommendations from the acoustic consultant are implemented.
Documentary Evidences	• Extracts of the tender specification showing the requirement to design the occupied space with the ambient sound levels; and • A report of the detailed analysis and recommendations from acoustic consultant on how the designed ambient sound levels can be met where applicable.
References	-

RB 4-2 INDOOR AIR POLLUTANTS

Objectives	Minimise airborne contaminants, mainly from inside sources to promote a healthy indoor environment.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	4-2(a) 1 point can be scored for the use of low volatile organic compounds (VOC) paints certified by approved local certification body for at least 90% of the internal wall areas. 4-2(b) 1 point can be scored for the use of environmentally friendly adhesives certified by approved local certification body for at least 90% of the applicable building works or areas.
Documentary Evidences	<u>For 4-2(a)</u> • Extracts of the tender specification showing the requirement to use low VOC paints that are certified by approved local certification body or equivalent. <u>For 4-2(b)</u> • Extracts of the tender specification showing the requirement to use adhesive with low emission formaldehyde and are certified by approved local certification body or equivalent for all composite wood products used.
References	-

RB 4-3 WASTE DISPOSAL

Objectives	Minimise airborne contaminants from waste.
Applicability	Generally applicable to all developments.
Baseline Standard	-
Requirements	1 point can be scored if the refuse chutes are located at open ventilation areas such as service balconies or common corridors
Documentary Evidences	• Plan layouts showing the location of the refuse chutes for all typical dwelling units.
References	-

RB 4-4 INDOOR AIR QUALITY IN WET AREAS

Objectives	Encourage provision of adequate natural ventilation and daylighting in wet areas.
Applicability	Generally applicable to all wet areas such as kitchens, bathrooms and toilets of the developments.
Baseline Standard	-
Requirements	Up to 2 points can be scored if there is provision for adequate natural ventilation and daylighting in wet areas i.e. kitchens, bathrooms and toilets. • 2 points for more than 90% of all applicable areas • 1 point for at least 50% to 90% of all applicable areas
Documentary Evidences	• Plan layouts showing the location of the window openings of the kitchens, bathrooms and toilets for all typical dwelling units.
References	-

(II) Other Green Requirements

Part 5 – Other Green Features

RB5-1 Green Features and Innovations

RB 5-1 OTHER GREEN FEATURES

Objectives	Encourage the use of green features that are innovative and have positive environmental impact on water efficiency, environmental protection and indoor environmental quality of the buildings.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	Up to 7 points can be scored for the use of the following green features depending on their potential environmental benefits and the extent of coverage. <u>Water Efficiency</u> (i) Use of self cleaning façade system • 2 points for more than 75% of the applicable facades areas • 1 point for more than 50% of the applicable facades areas • 0.5 point for at least 25% of the applicable facades areas (ii) Use of integrated basin/cistern pedestal system • 2 points for more than 50% of all dwelling units' flushing cisterns • 1 point for more than 25% of all dwelling units' flushing cisterns • 0.5 point for at least 10% of all dwelling units' flushing cisterns (iii) Use of grey water recycling system • 2 points for all blocks of the development. • 1 point for at least one block of the development. (iv) Provision of system to recycle surface runoff from the vertical green wall and sky garden • 1 point for at least 25% of the green areas • 0.5 point for less than 25% of the green areas (v) Use of water efficient washing machine with WELS 'Good' rating and above • 1 point for more than 90% of all dwelling units. • 0.5 point for at least 50% of all dwelling units. <u>Environmental Protection</u> (i) Use of precast toilets • 2 points for more than 75% of all toilets • 1 point for more than 50% of all toilets • 0.5 point for at least 25% of all toilets (ii) Provision of green roof and roof top garden • 1 point for more than 50% of the roof areas • 0.5 point for at least 25% of the roof areas (iii) Provision of vertical greening in common areas • 2 points for more than 75% of the applicable wall areas • 1 point for more than 50% of the applicable wall areas • 0.5 point for at least 25% of the applicable wall areas (iv) 1 point for the provision of double refuse chutes for separating recyclable from non-recyclable waste. (v) 0.5 point for the use of non-chemical termite treatment system.

	(vi) 0.5 point for the provision of at least 5 nos. of compost bins to recycle organic waste. (vii) 0.5 point for the use of non-chemical water treatment system for swimming pools. (viii) Conservation of existing building structure or building envelopes (by areas). • 2 points for conserving more than 50% of the existing structure or building envelope • 1 point for conserving at least 25% of the existing structure or building envelope (ix) Buildable design with development's buildability scores (BScore) above the prevailing minimum requirement (Refer to COP on Buildable Design). • 1 point for BScore > 5 points above minimum requirement • 0.5 point for BScore > 3 to ≤ 5 points above minimum requirement (x) Computation of carbon footprint of the development comprising energy usage data of materials production and on-site construction of building materials listed in the prescribed form. • 1 point for the submission of complete carbon footprint calculation for all building materials listed and in the prescribed format or a complete carbon footprint report of the development prepared by an independent carbon consultant • 0.5 point for the submission of carbon footprint calculation for any four building materials listed and in the prescribed format (xi) 1 point for the computation of Concrete Usage Index (CUI) of the building development (xii) Adoption of demolition protocol to maximise resource recovery of demolition materials for reuse or recycling. • 2 points for recovery rate of more than 35% crushed concrete waste to be sent to the approved recyclers with proper facilities • 1 point for recovery rate of at least 20% crushed concrete waste to be sent to the approved recyclers with proper facilities *Refer to details at http://www.bca.gov.sg/SustainableConstruction/sc_demolition.html for compliance.* Indoor Air Quality 1 point for the use of pneumatic waste collection system. Others 0.5 point for the use of siphonic rainwater discharge system at roof. ***Important notes :*** *For features that are not listed above, the QP is required to submit the details showing the positive environmental impacts, possible savings and benefits of the proposed features to BCA for assessment.*
Documentary Evidences	• Extracts of the tender specification showing the provision of the specific green features used and the extent of implementation where applicable; • Technical product information (including drawings and supporting documents) of the green features; • A summary sheet listing the breakdown and the extent of implementation as well as the total requirements for the same intended purpose for the specific green features used; and

Documentary Evidences

Cont'd

- Quantified evidences on the potential environmental benefits that the features can bring to the development.
- The carbon footprint calculation to be submitted in the following prescribed form and format.

ENERGY USAGE OF MATERIALS PRODUCTION AND ON-SITE CONSTRUCTION

Project Title: _____

Project GFA: _____

Section A: Materials Production											
Material	Total Energy usage per month										
	Electricity		Diesel		Petrol		Gas		Others (Pls Specify)		
	kWh	$/kWh	Litres	$/litres	Litres	$/litres	KG	$/KG	Fuel	Units	$/unit
Cement											
Sand											
Concrete											
Aggregate											
Brick											
Steel											
Aluminium											
Glass											
Paint											
Tiles: Ceramic											
Tiles: Granite											

Section B1: Material Usage (On-Site)	
Material	Total Quantity Used
Cement	
Sand	
Concrete	
Aggregate	
Brick	
Steel	
Aluminium	
Glass	
Paint	
Tiles: Ceramic	
Tiles: Granite	

Section B2: Energy Usage (On-Site)		
	Units used	$/unit
Electricity (kWh and $)		
Diesel (litres and $)		
Petrol (litres and $)		
Gas (KG and $)		
Coal (ton)		
Crude Oil (KL)		

Section C: Operational Carbon (Post-Occupancy)		
	Units used	$/unit
Electricity (kWh and $)		
Renewable Energy Sources		

- Computation of Concrete Usage Index (CUI) and supporting documents as stated under Part 3 – RB 3-1 (b)
- Demolition audit form showing the summary of the total and actual quantity of concrete waste and delivery records or receipts from approved recycling firm.

References

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Appendix B

SCORING METHODOLOGY & DOCUMENTATION
Non-Residential Building Criteria

(I) Energy Related Requirements

Part 1 – Energy Efficiency

NRB 1-1 THERMAL PERFORMANCE OF BUILDING ENVELOPE - ETTV

Objectives	Enhance overall thermal performance of building envelope to minimise heat gain thus reducing the overall cooling load requirement.
Applicability	Applicable to air-conditioned building spaces with aggregate areas > 500 m^2.
Baseline Standard	Maximum permissible ETTV = 50 W/m^2 ETTV stands for Envelope Thermal Transfer Value. The computation of ETTV shall be based on the methodology specified in the Code on Envelope Thermal Performance for Buildings issued by BCA.
Requirements	Up to 12 points can be scored for building envelope with better thermal performance than the baseline standard : 1.2 points for every reduction of 1 W/m^2 in ETTV from the baseline. Points scored = 1.2 x (50 – ETTV) where ETTV ≤ 50 W/m^2 For developments consisting of more than one building, the weighted average of the ETTVs based on the façade areas of these buildings shall be used as the basis for point allocation. That is $ETTV_{\text{Weighted average}} = \sum (ETTV_{bldg} \times A_{bldg}) / A_{devt}$ where $ETTV_{bldg}$ = ETTV for a building (W/m^2) A_{bldg} = Summation of all facade areas that enclose all the air-conditioning areas (m^2) in a building A_{devt} = Summation of total applicable facade areas of all buildings within the development (m^2) (i.e. $\sum A_{bldg}$) *Exception: For buildings that are underground, NRB 1-1 may be excluded in the computation. The score obtained under NRB 1-2 will be pro-rated accordingly.*
Pre-requisite	Green Mark Gold^{Plus} – ETTV of 42 W/m^2 or lower Green Mark Platinum – ETTV of 40 W/m^2 or lower
Documentary Evidences	• Architectural elevation drawings showing the composition of the different façade or wall systems that are relevant for the computation of ETTV; • Architectural plan layouts and elevations showing all the air-conditioning areas; • Extracts of the tender specification or material schedules showing the salient data of the material properties that are to be used for the façade or external wall system; and • ETTV calculation.

References	Code on Envelope Thermal Performance for Buildings issued by BCA
Worked Example 1-1	Example 1 ETTV = 45 W/m^2 Points scored = 1.2 x (50 – ETTV)= 1.2 x (50 - 45) = 6 points Example 2 ETTV = 35 W/m^2 Points scored = 1.2 x (50 – ETTV) = 1.2 x (50 – 35) = 18 points > 12 points Therefore, points scored is 12 points (max) Example 3 A proposed building development comprises three building blocks. The individual ETTV of the each building computed are as follows : $ETTV_{bldg1}$ = 35 W/m^2 A_{bldg} = 5000 m^2 $ETTV_{bldg2}$ = 45 W/m^2 A_{bldg} = 6800 m^2 $ETTV_{bldg3}$ = 50 W/m^2 A_{bldg} = 7500 m^2 A_{devt} = 5000+6800+7500 = 19300 m^2 Therefore $ETTV_{\text{Weighted average}} = \sum (ETTV_{bldg} \times A_{bldg}) / A_{devt}$ $= \frac{(ETTV_{bldg1} \times A_{bldg1}) + (ETTV_{bldg2} \times A_{bldg2}) + (ETTV_{bldg3} \times A_{bldg3})}{(A_{devt})}$ $= \frac{(35 \times 5000) + (45 \times 6800) + (50 \times 7500)}{19300}$ = 44.35 W/m^2 Points scored = 1.2 x (50 – ETTV) = 1.2 x (50 – 44.35) = 6.78 points Note : Refer to the Code on Envelope Thermal Performance for Buildings for more detailed examples on how to compute the ETTV.

NRB 1-2 AIR-CONDITIONING SYSTEM

Objectives

Encourage the use of better energy efficient air-conditioned equipments and energy management to minimise energy consumption.

Applicability

Applicable to air-conditioned building areas where its aggregate air-conditioned areas > 500 m^2.

Scope covers all air-conditioned equipments for the buildings as listed:

- Chillers
- Chilled-Water Pumps
- Condenser Water Pumps
- Cooling Towers
- Air Handling Units (AHUs)
- Fan Coil Units (FCUs)
- Direct-Expansion (DX) Unitary Air-Conditioners/ Condensing Units for single-split units, multi-spilt units and variable refrigerant flow (VRF) system

Baseline Standard

1-2(a) Water Cooled Chilled-Water Plant

Baseline	Peak Building Cooling Load	
	≥ 500 RT	< 500 RT
Minimum Design System Efficiency (DSE) for Central Chilled Water Plant	0.70 kW/RT	0.80 kW/RT

- Chiller - Refer Table 2 of SS 530.
- Chilled and condenser water pump efficiency - Refer to Clause 10.5.1.1 in SS 553, which states that:
  The pump power limitation for chilled water systems shall be 349 kW/m^3/s.
  The pump power limitation for condensing water systems shall be 301 kW/m^3/s.

- Cooling tower performance at the rating condition stated in Table 3 of SS530.

  Rating condition is as follows : 35°C Entering water
  29°C Leaving water
  24°C Wet bulb outdoor air

  Propeller and axial fan cooling tower :
  With heat rejected from every 3.23 L/s of condenser water per 1 kW of fan power rating :

  Cooling tower performance ≤ 1kW / 3.23 L/s
  ≤ 0.310 kW/ L/s

  Centrifugal fan cooling tower :
  With heat rejected from every 1.7 L/s of condenser water per 1 kW of fan power rating :

  Cooling tower performance ≤ 1kW/ 1.7 L/s
  ≤ 0.588 kW/ L/s

Baseline Standard

Cont'd

1-2(b) Air Cooled Chilled-Water Plant/ Unitary Air-Conditioners

Baseline	Peak Building Cooling Load	
	≥ 500 RT	< 500 RT
Minimum Design System Efficiency (DSE) for Air Cooled Chilled-Water Plant or Unitary Air-Conditioners	0.80 kW/RT	0.90 kW/RT

For Air Cooled Chilled-Water Plant :

- Chiller - Refer Table 2 of SS 530.
- Chilled water pump efficiency - Refer to Clause 10.5.1.1 in SS 553, which states that the pump power limitation for chilled water systems shall be 349 kW/m^3/s.

For Unitary Air-Conditioners and Condensing Units:

- Refer to the minimum efficiency requirement as stated in Table 1 of SS 530.

1-2(c) Air Distribution System

Option 1 – Fan System Motor Nameplate Power

Baseline : SS553:2009 Table 2 – Fan power limitation and as prescribed below :

Baseline **Air Distribution System Type**	**Allowable Motor Nameplate Power**	
Fan systems with motor nameplate power ≥ 4kW	(kW/m^3/s)	(W/CMH)
• Air Handling Units (AHUs) /Fan Coil Units (FCUs) (Constant Volume)	1.7	0.47
• Air Handling Units (AHUs) /Fan Coil Units (FCUs) (Variable Volume)	2.4	0.67
Fan systems with nameplate motor power < 4 kW	No baseline	

Option 2 – Fan System Input Power

Baseline : ASHRAE 90.1 Clause 6.5.3.1 and as prescribed below :

Baseline **Air Distribution System Type**	**Allowable Fan System Input Power***	
Fan systems with motor nameplate power ≥ 4kW	(kW/m^3/s)	(W/CMH)
• Air Handling Units (AHUs) /Fan Coil Units (FCUs) (Constant Volume)	1.5	0.42
• Air Handling Units (AHUs) /Fan Coil Units (FCUs) (Variable Volume)	2.1	0.58
Fan systems with motor nameplate power < 4 kW	0.6	0.17

*Applicable pressure drop adjustments can be considered based on ASHRAE 90.1 Table 6.5.3.1.1B and are subject to BCA's evaluation.

Requirements

(1) In general, chiller systems should be designed and rightly sized based on an accurate peak building cooling load as well as the cooling load profile so as to meet the operating load conditions with optimal efficiency. Various combinations of chillers should be considered and designed to match the intended building cooling load profile during operation for better energy performance.

(2) In deriving the peak building cooling loads, the conditions of a design day where solar gains and temperatures are expected to be highest shall be used for consistency. The relevant baseline standard for the building cooling system under the criteria NRB 1-2 (a) and (b) will be based on the peak building cooling load occurring on the specified simulated design day.

(3) Water Cooled Chilled-Water Plant

For the purpose of determining the point scoring for NRB 1-2(a), the improvement in the water cooled chilled-water plant efficiency can be computed based on the following simplified methodology.

- Generate the simulated total building cooling load profile for a typical week for the following building operating hours specified :

Office Buildings: Monday to Friday : 9 a.m. to 6 p.m. **Retail Malls :** Monday to Sunday :10 a.m. to 9 p.m.	**Hotels:** Monday to Sunday : 24 Hours **Other Building Types:** To be determined based on operating hours

- Design for optimal air-conditioning plant configuration that would ensure that the chilled-water plants can operate within the best efficiency range during the building operating hours specified.
- Determine the power inputs of the various system components selected over the operating range of cooling load conditions.
- Derive the Design System Efficiency (DSE) of the proposed building cooling system based total average cooling load and total power input for point scoring.

Time	Average Cooling Load (CL)	Chillers Power Input	Chilled Water Pumps Power Input	Condensed Water Pumps Power Input	Cooling Towers Power Input	Total Power Input (TPI)
	(RT)	(kW)	(kW)	(kW)	(kW)	(kW)
0900	$CL_{@0900}$					$TPI_{@0900}$
1000	$CL_{@1000}$					$TPI_{@1000}$
1100	$CL_{@1100}$					$TPI_{@1100}$
1200	$CL_{@1200}$					$TPI_{@1200}$
1300	$CL_{@1300}$					$TPI_{@1300}$
1400	$CL_{@1400}$					$TPI_{@1400}$
1500	$CL_{@1500}$					$TPI_{@1500}$
1600	$CL_{@1600}$					$TPI_{@1600}$
1700	$CL_{@1700}$					$TPI_{@1700}$
1800	$CL_{@1800}$					$TPI_{@1800}$
1900	$CL_{@1900}$					$TPI_{@1900}$
Total Average Cooling Load (0900-1800 hrs)	$\sum CL_i$	**Total Power Input of air-conditioning plant (0900 -1900 hrs)**				$\sum TPL_i$

Design the air-conditioning plant configuration and determine the kW from the various system components

$$\textbf{Design System Efficiency (DSE)} = \frac{\textbf{Total Power Input}}{\textbf{Total Cooling Load}} = \frac{\sum TPL_i}{\sum CL_i}$$

Requirements

Cont'd

Important notes :

The minimum frequency set-point for the Variable Speed Drives (VSDs) used for regulating the speed of the chilled-water pumps, condenser water pumps or the cooling tower fans and their limitation are to be considered to ensure that the chilled-water flow can be effectively distributed.

Point scoring for 1-2 (a) Water Cooled Chilled-Water Plant (Up to 20 points)

Peak building cooling load ≥ 500 RT

15 points for meeting the prescribed Design System Efficiency of 0.70 kW/RT (refer to the chilled-water plant efficiency)

0.25 point for every percentage improvement in the chilled-water plant efficency over the baseline

Points scored = 0.25 x (% improvement)

Peak building cooling load < 500 RT

12 points for meeting the prescribed chilled-water plant efficiency of 0.80 kW/RT

0.45 point for every percentage improvement in the chilled-water plant efficiency over the baseline

Points scored = 0.45 x (% improvement)

(4) Air-Cooled Chilled- Water Plant or Unitary Conditioners

For the purpose of determining the point scoring for NRB 1-2(b), the improvement in the Design System Efficiency (DSE) of air-cooled chilled-water plant or unitary conditioners can be computed based on the efficiency at full installed capacity (excluding standby provision) or at the expected operating part-load condition as outlined below.

- Generate the simulated total building cooling load profile for a typical week for the following building operating hours specified :

Office Buildings: Monday to Friday : 9 a.m. to 6 p.m. **Retail Malls :** Monday to Sunday :10 a.m. to 9 p.m.	**Hotels:** Monday to Sunday : 24 Hours **Other Building Types:** To be determined based on operating hours

- Method A - Compute the required capacities of the building cooling systems based on full installed capacity for the different systems and zones. Derive the Design System Efficiency (DSE) of the proposed building cooling system based on total required cooling load and total power input for point scoring.
- Method B – Determine the most frequently occurring operating part load condition for the proposed building cooling system for all zones. Derive the Design System Efficiency (DSE) of the proposed building cooling system at the expected operating part load condition based on total required cooling load and total power input for point scoring.

Requirements **Cont'd**	Point Scoring for 1-2 (b)Air Cooled Chilled-Water Plant / Unitary Air Conditioners (Up to 20 points) **Peak building cooling load ≥ 500 RT** 12 points for meeting the prescribed Design System Efficiency of 0.80 kW/RT (refers to efficiency of air-conditioning system such as air-cooled chilled-water plant or unitary air-conditioners) 1.3 points for every percentage improvement in the air-conditioning system efficiency over the baseline Points awarded = 1.3 x (% improvement) **Peak building cooling load < 500 RT** 10 points for meeting the prescribed Design System Efficiency of 0.90 kW/RT 0.6 point for every percentage improvement in the air-conditioning system efficiency over the baseline Points awarded = 0.6 x (% improvement) ***Important notes :*** (i) 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 improvement in the system efficiency can be computed based on the efficiency of full installed capacity of outdoor condensing units or part-load efficiency of the system. (ii) Where there are more than one most frequent occurring part-load conditions for the building operation hours specified, the improvement in the building cooling system efficiency and the point scored shall be based on the worst case scenario. (5) Where there is a combination of central chilled water plants with unitary conditioners, the points scored will only be based on the building cooling system with a larger aggregate capacity. (6) The above simplified methodologies for point scoring under NRB 1-2(a) and (b) do not apply to projects with Green Mark Gold^{Plus} and Platinum as the target rating. For these projects, the point scoring will be based on the Design System Efficiency derived using the energy modeling framework set out in Appendix E of this Standard. (7) Air Distribution System Point Scoring for 1-2 (c) Air Distribution System (Up to 6 points) 0.2 point for every percentage improvement in the air distribution system efficiency above the baseline. Points scored = 0.2 x (% improvement) ***Important notes :*** For buildings with cooling provision from a district cooling system (DCS) supplier that is authorised by a licence to carry out all or any of the functions of providing district cooling services to the services areas, the point scoring will be pro-rated based on the air-distribution system efficiency under NRB 1-2(c). (8) Permanent Instrumentation Requirement The permanent instrumentation shall comprise the temperature, flow and power measurement system. Each measurement system shall include the sensor, any signal conditioning (where applicable), the data acquisition system and the wiring connecting them.

Requirements **Cont'd**	<u>Point Scoring for 1-2 (d) Instrumentation for Monitoring Central Water Cooled Chilled-Water Plant Efficiency</u> • 1 point for the provision of permanent measuring instruments for monitoring of water-cooled chilled-water plant efficiency. The installed instrumentation shall have the capability to calculate the resultant chilled-water plant efficiency within ± 5 % of the true value and in accordance with ASHRAE Guide 22 and AHRI 550/590. The methodology for determining the total uncertainty of measurement shall be computed using the root-sum square formula as follows: $Error_{rms} = \sqrt{(\sum (U_N)^2)}$ 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 instrumentation and installation are also required to be complied with : (i) Location and installation of the measuring devices to meet the manufacturer's recommendation. (ii) Data Acquisition system i.e. Analog-to-digital or A/D converter used shall have a minimum resolution of 16 bit. For example, ▪ The specification for the A/D converter of the BTU meter shall have a minimum resolution of 16-bit. This applies to direct data acquisition from the BTU meter. ▪ For data acquisition using Building Management System (BMS), the specification of the specific Digital Direct Controller (DDC) connecting the temperature sensors shall have a minimum resolution of 16-bit. (iii) All data logging with capability to trend at 1 minute sampling time interval. (iv) Flow meters for chilled-water and condenser water loop shall be ultrasonic / full bore magnetic type or equivalent. (v) Temperature sensors are to be provided for chilled water and condenser water loop and the measurement system shall have an end-to-end uncertainty from the temperature sensors to the read out devices not exceeding ± 0.05 °C over the entire measurement or calibration range. All thermo-wells shall be installed in a manner that ensures that the sensors can be in direct contact with fluid flow. Provisions shall be made for each temperature measurement location to have two spare thermo-wells located at both side of the temperature sensor for verification of measurement accuracy. (vi) Dedicated digital power meters are to be provided for each of the following groups of equipment: chillers, chilled water pumps, condenser water pumps and cooling towers.

Requirements

Cont'd

(9) Heat Balance-Substantiating Test

Point scoring for 1-2 (e) Verification of central chilled-water plant instrumentation : Heat balance – substantiating test

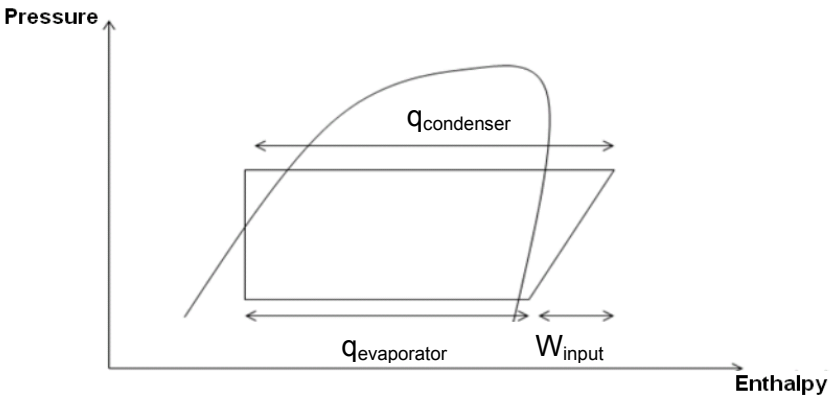
1 point for completing the verification of chilled-water plant instrument using the heat balance-substantiating test in accordance to AHRI 550/590. The heat balance shall be conducted over the entire specific operating hours with more than 80% of the computed heat balance within ± 5% over a one (1) week period.

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

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

where $q_{condenser}$ = heat rejected
$q_{evaporator}$ = cooling load
W_{input} = power input to compressor

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



Pressure Enthalpy Diagram

The system heat balance of the chilled water plant shall be computed using the following formula over the building operating hours as specified for the different building categories.

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

Note: For open drive chillers, the W_{input} shall take into account the motor efficiency provided by the manufacturer. For example :

Input power (measured) = 100 kW
Motor efficiency (η_m) = 90%
Adjusted W_{input} = 100 kW x 90%
= 90 kW

In the event where hydraulic losses of pumps constitute substantial heat gain, these losses should be accounted for as illustrated in the following examples. Note that the motor and pump efficiency values used in the computation should be based on the manufacturer's specification.

Requirements

Cont'd

(a) For chilled water pump(s) adjustment

Motor input power (measured)	= 30 kW	(A)
Motor efficiency (η_m)	= 90%	(B)
Pump efficiency (η_p)	= 80%	(C)
Hydraulic losses	= (A) x (B) x [(100% – (C)]	
	= 30 kW x 90% x (100% - 80%)	
	= 5.4 kW	
Adjusted W_{input}	= kW_i (chillers) + 5.4 kW	

where kW_i (chillers) = adjusted power input to compressor, kW

(b) For condenser water pump(s) adjustment

Motor input power (measured)	= 20 kW	(A)
Motor efficiency (η_m)	= 90%	(B)
Pump efficiency (η_p)	= 80%	(C)
Hydraulic losses	= (A) x (B) x [(100% – (C)]	
	= 20 kW x 90% x (100% - 80%)	
	= 3.6 kW	
Adjusted $q_{condenser}$	= $q_{condenser}$ - 3.6 kW	

(10) Control Devices

Point scoring for 1-2 (f) Variable speed control devices for chiller plant equipment (1 point)

1 point can be scored if there are provisions of variable speed controls for chilled water pumps and cooling tower fans to ensure better part-load efficiency of the plant.

Point scoring for 1-2 (g) Sensors or similar automatic control devices (1 point)

1 point can be scored if sensors or similar automatic control devices are used to regulate outdoor air flow rate to maintain the concentration of carbon dioxide (CO_2) in accordance with Table 1 – Recommended IAQ Parameters of SS 554.

Carbon dioxide acceptable range: ≤ 700 ppm above outdoor.

Prerequisites

(A) Prescribed Design System Efficiency (DSE) of building cooling system to be as follows:

(i) For Buildings using Water Cooled Chilled-Water Plant

Green Mark Rating	Peak Building Cooling Load (RT)	
	< 500	≥ 500
	Minimum Design System Efficiency (kW/RT)	
Certified	0.80	0.70
Gold	0.80	0.70
Gold^{Plus}	0.70	0.65
Platinum	0.70	0.65

Prerequisites

Cont'd

(ii) For Buildings using Air Cooled Chilled-Water Plant or Unitary Air-Conditioners

Green Mark Rating	Peak Building Cooling Load (RT)	
	< 500	≥ 500
	Minimum Design System Efficiency (kW/RT)	
Certified	0.90	0.80
Gold	0.90	Not applicable
Gold^{Plus}	0.85	
Platinum	0.78	

(B) Instrumentation for monitoring the water cooled chilled-water plant efficiency is to be provided in accordance with the requirement set in the criteria.

Documentary Evidences

For 1-2(a) and 1-2(b)

- Detailed calculations of the Design System Efficiency (DSE) of the air-conditioning system that include the cooling load profile in the prescribed formats as shown in the worked examples 1-2(a) & 1-2(b);
- Drawings showing the schematic and layout of the proposed building cooling system;
- Plan layouts showing the mode of ventilation for various floor and blocks as well as the location of the plant room and cooling towers;
- Air-conditioning system information in prescribed format;
- Pump Head Calculation; and
- Technical specification and performance data of the various components of the building cooling system designed and installed.

For 1-2(c)

- Detailed calculations of the overall improvement in equipment efficiency of the air distribution system in the prescribed tabulated formats as shown in the worked examples 1-2(c); and
- Technical specification and product information of the air-distribution system designed and installed.

For 1-2(d)

- Calculation of the overall uncertainty of measurement of the resultant chiller plant efficiency in kW/RT to be within ± 5 % of the true value as illustrated in the worked example 1-2(d);
- Instruments' calibration certificates from accredited laboratory and factory calibration certificates from manufacturers;
- Chiller plant room plan layouts showing the details of the instruments' locations;
- Plan layouts showing the locations and the types of instrumentation used;
- Summary of instruments, standards and measurement accuracy to be presented in the following format and example :

Documentary Evidences

Cont'd

ID	Description	Sensor Type	Measurement/ Calibration range	End-to End Measurement Uncertainty (%)	Last Calibration Date
TT01	CHWS Temperature	10K Ω Thermistor	0°C - 40°C	± 0.05°C	10/10/2012
TT02	CHWR Temperature	10K Ω Thermistor	0°C - 40°C	± 0.05°C	10/10/2012
TT03	CWS Temperature	10K Ω Thermistor	0°C - 40°C	± 0.05°C	10/10/2012
TT04	CWR Temperature	10K Ω Thermistor	0°C - 40°C	± 0.05°C	10/10/2012
FM01	CHW Flow	Magnetic Full Bore	30 l/s- 200 l/s	± 0.5%	10/10/2012
FM02	CW Flow	Magnetic Full Bore	30 l/s- 200 l/s	± 0.5%	10/10/2012
kW01	Chiller 1 Power	True RMS, 3 phase	60 – 600 kW	± 0.5%	10/10/2012
kW02	Chiller 2 Power	True RMS, 3 phase	60 – 600 kW	± 0.5%	10/10/2012
kW03	CHW Pump 1 & 2 Power	True RMS, 3 phase	20 – 200 kW	± 0.5%	10/10/2012
kW04	CW Pump 1 & 2 Power	True RMS, 3 phase	20 – 200 kW	± 0.5%	10/10/2012
kW05	CT 1 & 2 Power	True RMS, 3 phase	15 – 150 kW	± 0.5%	10/10/2012

For 1-2(d) – Cont'd

- Technical specification and product information of the flow meter proposed and installed;
- Technical specification and product information of the temperature sensors proposed and installed; and
- Technical specification and product information of the power meter proposed and installed.

For 1-2(e)

- Heat balance substantiating test result verifying the central chilled-water plant's instrumentation and in the prescribed format shown in the worked example 1-2(e).

For 1-2 (f)

- Technical specifications of control devices and a write up or schematic drawings on how these devices are to be used and installed; and
- Plan layouts showing the locations of variable speed control devices for the chiller plant equipment i.e. chilled water pump and cooling tower fans or schematic print-out from BMS.

For 1-2(g)

- Technical specifications of the control devices and a write up or schematic drawings on how these devices are used and installed; and
- Plan layouts showing the locations and the types of control devices used to regulate fresh air intake or schematic print-out from BMS.

References

SS 530 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment.

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

SS 554 - Code of Practice for Indoor Air Quality for Air-Conditioned Buildings

ASHRAE Guideline 22 – Instrumentation for Monitoring Central Chilled-Water Plant Efficiency

AHRI Standard 550/590 – Performance Rating of Water- Chilling Packages Using The Vapor Compression Cycle

Worked Example 1-2(a)

For Water Cooled Chilled-Water Plant

Computation of the Design System Efficiency (DSE)

<u>Calculation of System Efficiency of Water Cooled Central Chilled-Water Plant - Primary Variable Chilled-Water System</u>

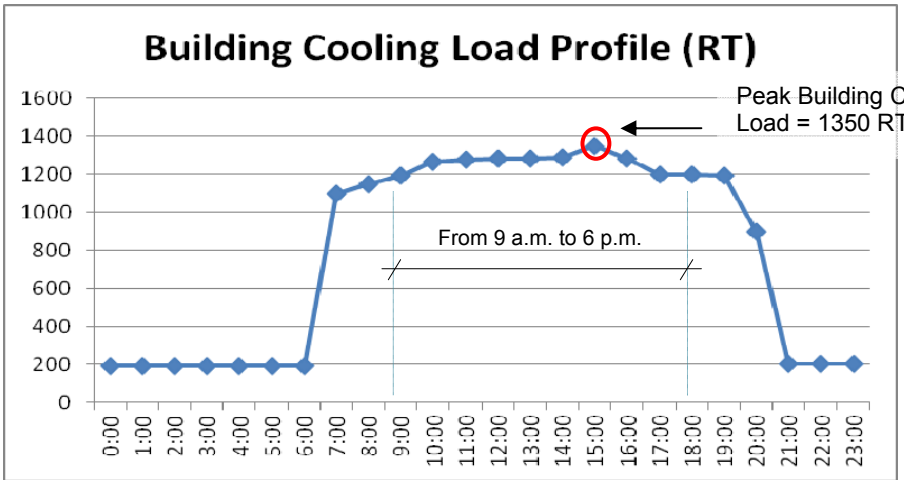
Background info

- Office building air-conditioned floor area = 67,500 m^2
- Variable-speed drives are designed to control the speed of the chilled-water pumps and cooling tower fans
- Building operating hours for office buildings as specified:

  Monday to Friday : 9 a.m. to 6 p.m.

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

Simulation analysis of the building cooling load profile based on design day to be carried out to determine the peak building cooling load and the relevant baseline standard.



From the simulated building cooling load profile, the peak building cooling load is 1,350 RT (> 500 RT) and the minimum Design System Efficiency for water cooled chilled water plant is **<u>0.70 kW/RT</u>**.

<u>Step 2 – Generate the simulated total building cooling load profile based on a typical week for the building operating hours specified.</u>

Time	Average Cooling Load (RT)
8:00	1150
9:00	1190
10:00	1260
11:00	1260
12:00	1260
13:00	1260
14:00	1260
15:00	1260
16:00	1190
17:00	1190
18:00	1190
19:00	980

Worked Example 1-2(a) – Cont'd

For Water Cooled Chilled-Water Plant

Computation of the Design System Efficiency (DSE)

Step 3 – Propose air-conditioning plant configuration and derive the respective power input of various components

Proposed air-conditioning plant configuration for the building operating hours specified to be as follows :

Chillers	3 nos. x 700 RT (2 in operation and 1 stand by)
Chilled Water Pumps	3 nos. x 45 kW (2 in operation and 1 stand-by)
Condenser Water Pumps	3 nos. x 55 kW (2 in operation and 1 stand-by)
Cooling Towers	3 nos. x 900 RT (2 in operation and 1 stand-by)

Important notes :

(1) 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 point scoring purpose.

(2) The estimated operating pump and motor power of the various components at part-load condition as illustrated in Step 3 are based on the affinity laws assuming that the system curve remains unchanged.

3(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 0900 to 1000 & 1500 to 1800	1190 RT	2x700RT @ 85%	0.521	620
From 1000 to 1500	1260 RT	2x700RT @ 90%	0.522	658

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

(i) 2 nos.x 45 kW primary chilled-water pump to be installed with Variable Speed Drive (VSD)

(ii) Water flow rate per pump at full load (Q) = 106 L/s

(iii) Operating static head (h)= 28 m

(iv) Pump efficiency (η_p) = 86.8 %

(v) Motor efficiency (η_m) = 94.2 %

Worked Example 1-2(a) – Cont'd

For Water Cooled Chilled-Water Plant

Computation of the Design System Efficiency (DSE)

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

where Q =water flow rate in L/s
ρ =density of water in kg/m^3
g =gravitational acceleration in m/s^2
h =static pressure head m
η_p =pump efficiency
η_m=motor efficiency

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

= 35.61 kW

For part-load operating condition,

$$\frac{\text{Pump Power}_{@\ 85\%}}{\text{Pump Power}_{@\ 100\%}} = \left(\frac{\text{Pump Speed}_{@\ 85\%}}{\text{Pump Speed}_{@\ 100\%}}\right)^3$$

Pump power at 85% part-load (kW) = 35.61 x $(0.85)^3$ = 21.87 kW

Total operating pump power (kW) = 21.87 kW x 2
= 43.74 kW

Similarly,

Pump power at 90% part-load (kW) = 35.61 x $(0.9)^3$ = 25.96 kW

Total operating pump power (kW) = 25.96 kW x 2
= 51.92 kW

Cooling Load (RT)	No. of Chilled-Water Pumps in operation	Total Operating Pump Power (kW)*
1190 RT	2 x 45 kW @ 85%	43.74
1260 RT	2 x 45 kW @ 90%	51.92

* Note that the change in the system curve as well as VSD losses (if substantial) should be considered.

3(c) Condenser water pumps :

(i) 2 nos.x 55 kW condenser water pumps to be installed with VSD

(ii) Water flow rate for the condenser water pump (Q) = 132.5 L/s

(iii) Operating static head (h) = 32m

(iv) Pump efficiency (η_p)= 88.5%

(v) Motor efficiency (η_m) = 94.7%

Power requirement of condenser water pump at full load (kW)

= $\frac{(132.5)(1000)(9.81)(32)}{(10^6)(0.885)(0.947)}$ = 49.63 kW

Worked Example 1-2(a) – Cont'd

For Water Cooled Chilled-Water Plant

Computation of the Design System Efficiency (DSE)

For part-load operating condition,

$$\frac{\text{Pump Power}_{@\ 85\%}}{\text{Pump Power}_{@\ 100\%}} = \left(\frac{\text{Pump Speed}_{@\ 85\%}}{\text{Pump Speed}_{@\ 100\%}} \right)^3$$

Pump power at 85% part-load (kW) = $49.63 \times (0.85)^3 = 30.48$ kW

Total operating pump power (kW) = 30.48 kW x 2

= 60.96 kW

Similarly,

Pump power at 90% part-load (kW) = $49.63 \times (0.9)^3 = 36.18$ kW

Total operating pump power (kW) = 36.18 kW x 2 = 72.36 kW

Cooling Load (RT)	No. of Condenser Water Pumps in operation	Total Operating Pump Power (kW)*
1190 RT	2 x 55 kW @ 85%	60.96
1260 RT	2 x 55 kW @ 90%	72.36

* Note that the reduced condenser water flow rate at part load condition and the VSD losses (if substantial) should be considered.

3(d) Cooling towers :

(i) 2 nos. of cooling towers to be installed with VSD

(ii) Heat rejection capacity per cooling tower = 900 RT

(iii) Total heat rejection for 2 x cooling towers = 1800 RT

(iv) Each cooling tower with 3 fan cells with fan motor = 7.5 kW

(v) Fan motor efficiency = 92%

(vi) Input power per cooling tower = (7.5 kW x 3 fans) x 92% = 24.4 kW

(vii) 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 to chiller compressor (kW)

$$\frac{\text{Fan Power}_{@\ \text{part load\%}}}{\text{Fan Power}_{@\ 100\%}} = \left(\frac{\text{Fan Speed}_{@\ \text{part load\%}}}{\text{Fan Speed}_{@\ 100\%}} \right)^3$$

Cooling Load (a)	Chiller Input Power (b)	Required Heat Rejection (c) = (a) + (b)	Total Heat Rejection capacity for 2 nos of Cooling Towers	Percentage Loading for Required and Available Heat Rejection	Total Fan Motor Power at required part-load condition*
(RT)	(kW)	(RT)	(RT)	%	(kW)
1190 RT	620	1366.28	1800	75.9%	21.39
1260 RT	658	1447.08	1800	80.4%	25.43

* Note that the same corresponding effect of higher condenser water supply temperature arising due to the reduced cooling tower fan speed should be considered.

Worked Example 1-2(a) – Cont'd

For Water Cooled Chilled-Water Plant

Computation of the Design System Efficiency (DSE)

Step 4 – Derive the Design System Efficiency (DSE)

Time	Average Cooling Load	Chillers Power Input	CHW Pumps Power	CW Pumps Power	CT power	Total Power Input
	(RT)	(kW)	(kW)	(kW)	(kW)	(kW)
9:00	1190	620	43.74	60.96	21.39	746.09
10:00	1260	658	51.92	72.36	25.43	807.71
11:00	1260	658	51.92	72.36	25.43	807.71
12:00	1260	658	51.92	72.36	25.43	807.71
13:00	1260	658	51.92	72.36	25.43	807.71
14:00	1260	658	51.92	72.36	25.43	807.71
15:00	1260	658	51.92	72.36	25.43	807.71
16:00	1190	620	43.74	60.96	21.39	746.09
17:00	1190	620	43.74	60.96	21.39	746.09
18:00	1190	620	43.74	60.96	21.39	746.09
Total (0900 to 1800)	$\sum CL_i$ = 12320	6428	486.48	678	238.14	$\sum TPL_i$ = 7830.62
Efficiency kW/RT		0.522	0.039	0.055	0.019	**0.64**

Design Efficiency of the various components of the proposed building cooling system

Design System Efficiency (DSE) of the proposed building cooling system

Total Power Input/Total Cooling Load

$$= \frac{\sum TPL_i}{\sum CL_i}$$

< 0.70 kW/RT Ok

15 points for meeting the prescribed Design System Efficiency of 0.70 kW/RT

0.25 point for every percentage improvement in the chilled-water plant efficiency over the baseline

Therefore, points scored = 15 + 0.25 x (% improvement)

= 15 + 0.25 x [(0.70 – 0.64)/0.70 x100%]

= 15 + 0.25 (8.57) = 17.14 points

Worked Example 1-2(b)

For VRF System

<u>Calculation of System Efficiency for Unitary Air-Conditioners/ Condensing Units - VRF System</u>

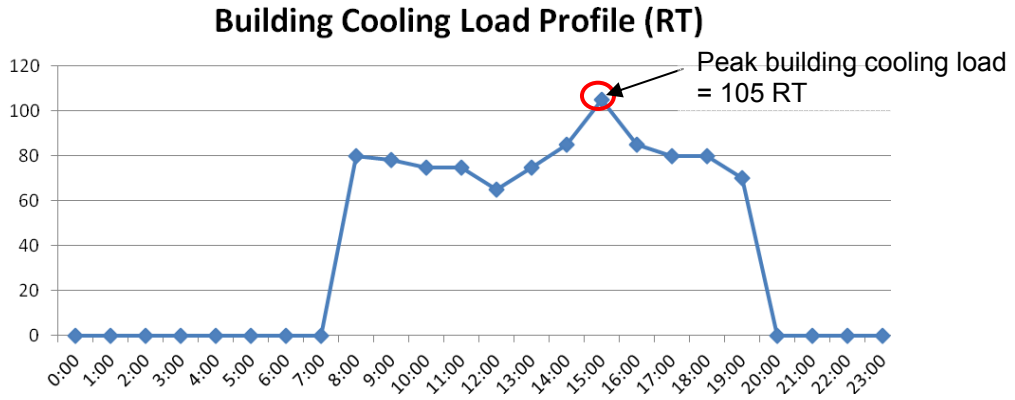
<u>Background info</u>

- Air-conditioned areas = 4250 m^2
- Building operation hours are defined as:

  Monday to Friday : 9 a.m. to 6 p.m.

Step1 – Determine the peak building cooling load and relevant baseline

Simulation analysis of the building cooling load profile based on design day to be carried out to determine the peak building cooling load and the relevant baseline standard.



From the simulated building cooling load profile, the peak building cooling load is 105 RT (< 500 RT) and therefore the minimum Design System Efficiency for VRF system is **<u>0.90 kW/RT</u>**.

The proposed Design System Efficiency of the VRF system and the improvement can be computed based on the efficiency at full load condition that is full installed capacity (excluding standby provision) or expected operating part-load condition. The following will illustrate these two simplified approaches in determining the point scoring based on the full load condition (as detailed in Method A) and expected operating part-load condition (as detailed in Method B) for clarity.

Worked Example 1-2(b) – Cont'd

For VRF System

Computation of Design System Efficiency (DSE) based on full load condition

Method (A) : Computation of the Design System Efficiency (DSE) based on full installed capacity

Step A-1 - Determine the required capacities of the VRF systems at full-load condition - Proposed VRF System Schedule

System	Floor	Location Served	Specification of VRF Outdoor Condensing Unit		
			Total Cooling Capacity (kW)	Power Input (kW)	COP
			Full Installed Capacity	Full Installed Capacity	Full Installed Capacity
1	1	FCC Room	22.4	5.24	4.2
	1	Lift Lobby + Internal Corridor			
	1	Reception			
System	**Floor**	**Location Served**	Full Installed Capacity	Full Installed Capacity	Full Installed Capacity
2 to 9	2 to 9	Office Office Office Office Office Lift lobby Lobby 2	44.8	10.5	4.29

Note : Typical VRF Systems are designed for Floor 2 to 9

Step A-2 - Determine the Design System Efficiency (DSE) of the VRF system at full load condition

Full load efficiency :

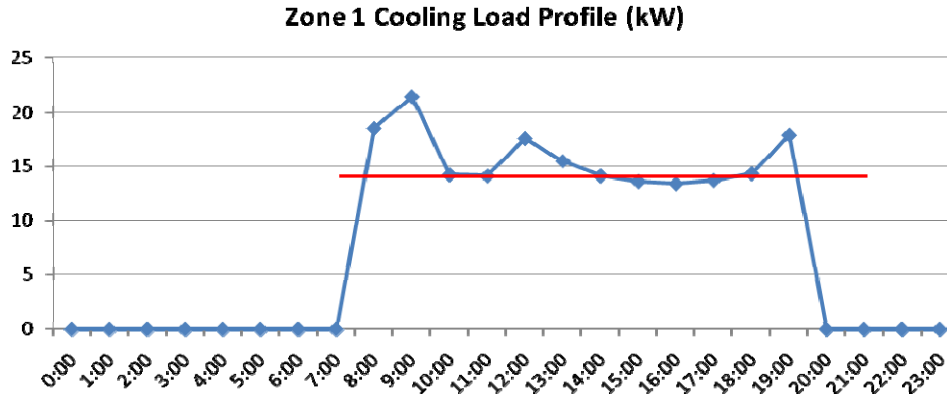
System	Floor	Total Power Input (kW) @ Full Load	Total Required Cooling (kW) @ Full Load	Total Required Cooling (RT)
1	1	5.24	22.4	6.37
2 to 9	2 to 9	84.0	358.4	102.0
Total:		**89.24**	380.8	**108.37**

Design System Efficiency (DSE) for the VRF system = 89.24/108.37
at full load condition = **0.82 kW/RT**

10 points for meeting the prescribed DSE of 0.90 kW/RT

0.6 point for every percentage improvement in the VRF system efficiency over the baseline

	Therefore, points scored = 10 + 0.6 x (% improvement) = 10 + 0.6 [(0.90 – 0.82)/0.90x 100%] = 10 + 0.6 (8.89) = 15.33 points
Worked Example 1-2(b) – Cont'd ***For VRF System*** ***Computation of Design System Efficiency (DSE) based on expected operating part - load condition***	**Method (B) : Computation of the Design System Efficiency (DSE) based on the expected operating part load condition** <u>Step B-1 Determine the most frequent occurring operating part load condition of the installed outdoor condensing unit capacity for all zones</u> (Most frequent occurring operating part-load conditions can be determined by the operating load points that form a horizontal straight line; the points can either fall on the line or very close to the line) B-1(a) Zone 1 design day cooling load profile:



Time	Cooling Load (kW)
0:00 – 7.00	0
8:00	18.5
9:00	21.5
10:00	14.2
11:00	14.1
12:00	17.6
13:00	15.5
14:00	14.1
15:00	13.6
16:00	13.4
17:00	13.7
18:00	14.3
19:00	17.9
20:00–23:00	0

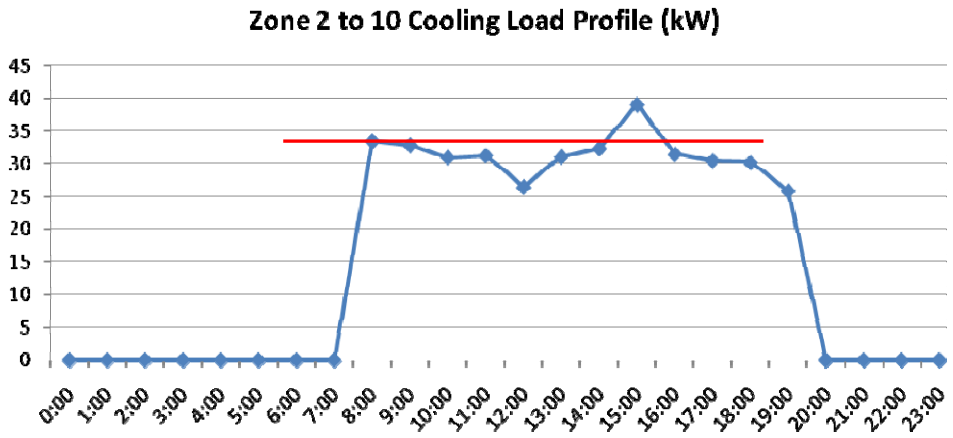
Based on the simulated building cooling load profile for the building operation hours from 8:00 to 19:00, the estimated most frequent occurring part-load condition of the installed capacity is 60% i.e. 13.4 kW for Zone 1

Worked Example 1-2(b) – Cont'd

For VRF System

Computation of Design System Efficiency (DSE) based on expected operating part - load condition

B-1 (b) Zone 2 to 10 design day cooling load profile.



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Based on the simulated building cooling load profile for the building operation hours from 8:00 to 19:00, the estimated most frequent occurring part-load condition of the installed capacity is 70%

i.e. 31.4 kW for Zone 2 to 10

Time	Cooling Load (kW)
0:00 – 7:00	0
8:00	33.5
9:00	32.9
10:00	31.0
11:00	31.3
12:00	26.5
13:00	31.1
14:00	32.4
15:00	39.0
16:00	31.5
17:00	30.5
18:00	30.2
19:00	25.9
20:00–23:00	0

Worked Example 1-2(b) – Cont'd

For VRF System

Computation of Design System Efficiency (DSE) based on expected operating part - load condition

Step B-2 Proposed VRF System Schedule

System	Floor	Location Served	Specification of VRF Outdoor Condensing Unit						
			Total Cooling Capacity (kW)		Power Input (kW)		COP		KW/RT
			Full Installed Capacity	60% Part load	Full Installed Capacity	60% Part load	Full Installed Capacity	60% Part load	60% Part load
1	1	FCC Room	22.4	13.4	5.24	2.55	4.2	5.25	0.67
	1	Lift Lobby + Internal Corridor							
	1	Reception							
System	**Floor**	**Location Served**	Full Installed Capacity	70% Part Load	Full Installed Capacity	70% Part Load	Full Installed Capacity	70% Part Load	70% Part Load
2 to 10	2 to 9	Office	44.8	31.4	10.5	6.28	4.29	5.02	0.70
		Office							
		Office							
		Office							
		Office							
		Lift Lobby							
		Lobby 2							

Step B-3 Determine the Design System Efficiency (DSE) of the VRF systems at the expected operating part-load condition

The Design System Efficiency (DSE) of VRF systems serving the building is:

System	Floor	Total Power Input (kW)	Total Required Cooling (kW)	Total Required Cooling (RT)
1	1	2.55	13.4	3.81
2 to 10	2 to 9	50.24	251.2	71.42
Total:		**52.79**		**75.23**

Design System Efficiency (DSE) for the VRF system = 52.79 / 75.23

= **0.70 kW/RT**

10 points for meeting the prescribed Design System Efficiency of 0.90 kW/RT

0.6 points for every percentage improvement in the air-conditioning system efficiency over the baseline

Points scored = 10 + 0.6 x (% improvement)

= 10 + 0.6 [(0.90 – 0.70)/0.90x 100%] = 23.33 points > 20 points

Therefore, points scored is 20 points (max)

Worked Example 1-2(c)

Computation of equipment efficiency of air distribution system

Option 1 : Fan System Motor Nameplate Power

<u>Calculation of Efficiency for Air Distribution Equipment</u>
Based on Option 1 – Fan System Motor Nameplate Power

<u>Background info</u>
Based on contract or suppliers' specification and design, we have

1. <u>AHUs (VAV system):</u>
   a. Total fan power consumption = 264.5 kW = 264500 W
   b. Total air volume flow rate = 409212 CMH
   Equipment efficiency = 264500/409212 = 0.645 W/CMH

2. <u>AHUs (CAV system):</u>
   a. Total fan power consumption = 275.5 kW = 275500 W
   b. Total air volume flow rate = 678520 CMH
   Equipment efficiency = 275500/678520 = 0.406 W/CMH

3. <u>FCUs having motor nameplate power not exceeding 4kW</u>
   <u>(Note that there is no baseline for this category)</u>
   a. Total fan power consumption = 11.00 kW = 11000 W
   b. Total air volume flow rate = 74233 CMH
   Equipment efficiency = 11000/74233 = 0.148 W/CMH

4. Overall required air distribution system efficiency

$$= \frac{(0.67)(409212)+(0.47)(678520)+(0.15)(74233)}{(409212+678520+74233)}$$

   = 0.52 W/CMH

5. Overall required air distribution system efficiency based on suppliers' specs/contract specs
   = (264500+275500+11000)/(409212+678520+74233)
   = 0.474 W/CMH

Table 1-2(c)(i) : Equipment Efficiency based on Option 1 (Air-Distribution System)

Equipment Type	From Specs		Allowable Motor Nameplate Power SS 553 (W/CMH)	Motor Nameplate Power at design condition (W/CMH)
	Total air flow (CMH)	Nameplate motor power (W)		
1. AHUs (VAV)	409212	264500	0.670	0.645
2. AHUs (CAV)	678520	275500	0.470	0.406
3. FCUs (<4 kW)	74233	11000	0.150	0.148
Total	**1161965**	**551000**	**0.520**	**0.474**

See working (4) above

See working (5) above

% Improvement in Efficiency for Air Distribution Equipment $= \frac{0.520 - 0.474}{0.520} \times 100\%$

$= 8.85\%$

Points scored = 0.2 x (% improvement) = 0.2 x (8.85) = 1.77 points

Worked Example 1-2(c) – Cont'd

Computation of equipment efficiency of air distribution system

Option 2 : Fan System Input Power

<u>Calculation of Efficiency for Air Distribution Equipment</u>
Based on Option 2 – Fan System Input Power

<u>Background info</u>

Based on contract or suppliers' specification and design, we have

1. <u>AHUs (VAV system):</u>
   a. Total fan input power consumption = 221.58 kW = 221580 W
   b. Total air volume flow rate = 409212 CMH
   Equipment efficiency = 221580/409212 = 0.542 W/CMH

2. <u>AHUs (CAV system):</u>
   a. Total fan input power consumption = 248.50 kW = 248500 W
   b. Total air volume flow rate = 678520 CMH
   Equipment efficiency = 248500/678520 = 0.366 W/CMH

3. <u>FCUs having motor nameplate power not exceeding 4kW</u>
   <u>(Baseline of 0.17 W/CMH can be used for Option 2)</u>
   a. Total fan input power consumption = 10.26 kW = 10260 W
   b. Total air volume flow rate = 74233 CMH
   Equipment efficiency = 10260/74233 = 0.138 W/CMH

4. Overall required air distribution system efficiency

$$= \frac{(0.58)(409212)+(0.42)(678520)+(0.17)(74233)}{(409212+678520+74233)}$$

   = 0.460 W/CMH

5. Overall required air distribution system efficiency based on suppliers' specs/contract specs
   = (221580+248500+10260)/(409212+678520+74233)
   = 0.413 W/CMH

Table 1-2(c)(ii): Equipment Efficiency based on Option 2 (Air-Distribution System)

Equipment Type	From Specs		Power Required by the motor in accordance with the baseline set (W/CMH)	Power Required by the motor at design condition (W/CMH)
	Total air flow (CMH)	Total motor power rating (W)		
1. AHUs (VAV)	409212	221580	0.580	0.542
2. AHUs (CAV)	678520	248500	0.420	0.366
3. FCUs (<4 kW)	74233	10260	0.170	0.138
Total	**1161965**	**480340**	**0.460**	**0.413**

See working (4) above

See working (5) above

% Improvement in Efficiency for Air Distribution Equipment $= \frac{0.46 - 0.413}{0.460} \times 100\%$

$= \sim 10\%$

Points scored = 0.2 x (% improvement) = 0.2 x (10) = 2 points

Worked Example 1-2(d)

Computation of overall uncertainty of measurement

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

Item	Measurement System	End-to-End Measurement Uncertainty (% of reading)
1	Temperature	$\frac{\sqrt{0.05^2 + 0.05^2}}{5.5} = 1.3\%$ see note (1)
2	Flow	1% see note (2) + 1% (i.e. 2%)
3	Power	1% see note (3)

Note:

(1) Temperature measurement system shall have an end-to-end measurement uncertainty of ± 0.05°C over the entire measurement range. The combined uncertainty for ΔT is computed based on the root-sum square formula with ΔT assumed to be 5.5 °C as illustrated above.

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

(3) Uncertainty of power measurement system shall include that of the current transformer where applicable.

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

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

$$= \sqrt{(1.3^2 + 2^2 + 1^2)}$$

$$= 2.6\ \%$$

where U_N = individual uncertainty of variable N (%)

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

Therefore, the total uncertainty for the calculated chilled-water plant efficiency (kW/RT) is 2.6 %, which falls within the 5% of the true value.

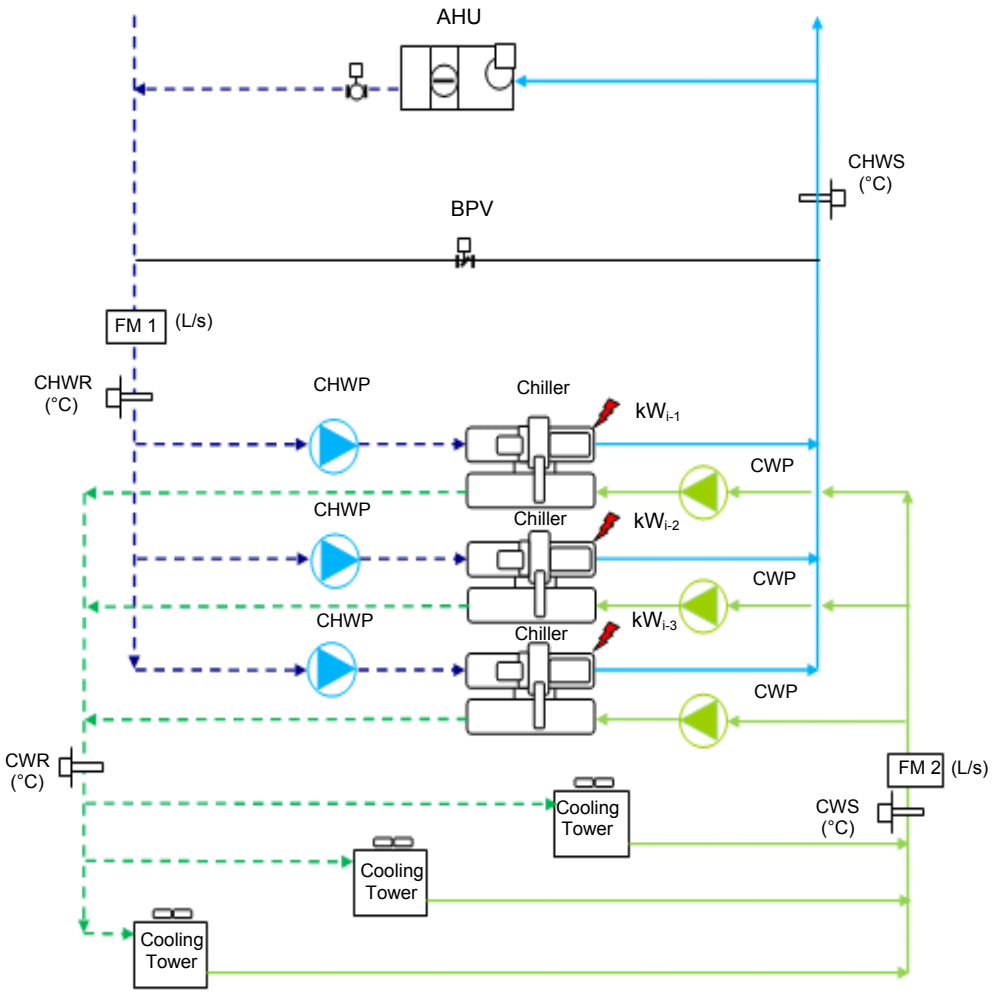
Worked Example 1-2(e)

Determining Heat Balance for Different Plant Configuration

For Constant Primary Chilled Water System

Determining Heat Balance for Different Plant Configuration

Plant A – Constant Primary Chilled-Water System



A: $q_{evaporator}$ = m x Cp x ΔT = FM1 x Cp x (CHWR - CHWS)

B: $q_{condenser}$ = m x Cp x ΔT = FM2 x Cp x (CWR - CWS)

C: W_{input} = kW_{i-1} + kWi_{-2} + kWi_{-3}

where Cp = 4.19 kJ/kg.ºC and density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note : In the event where hydraulic losses of pumps constitute substantial heat gain, the W_{input} and $q_{condenser}$ should be adjusted to account for the additional heat gains. The value shall be determined from certified drive losses, motor efficiency and pump efficiency values provided by the manufacturer.

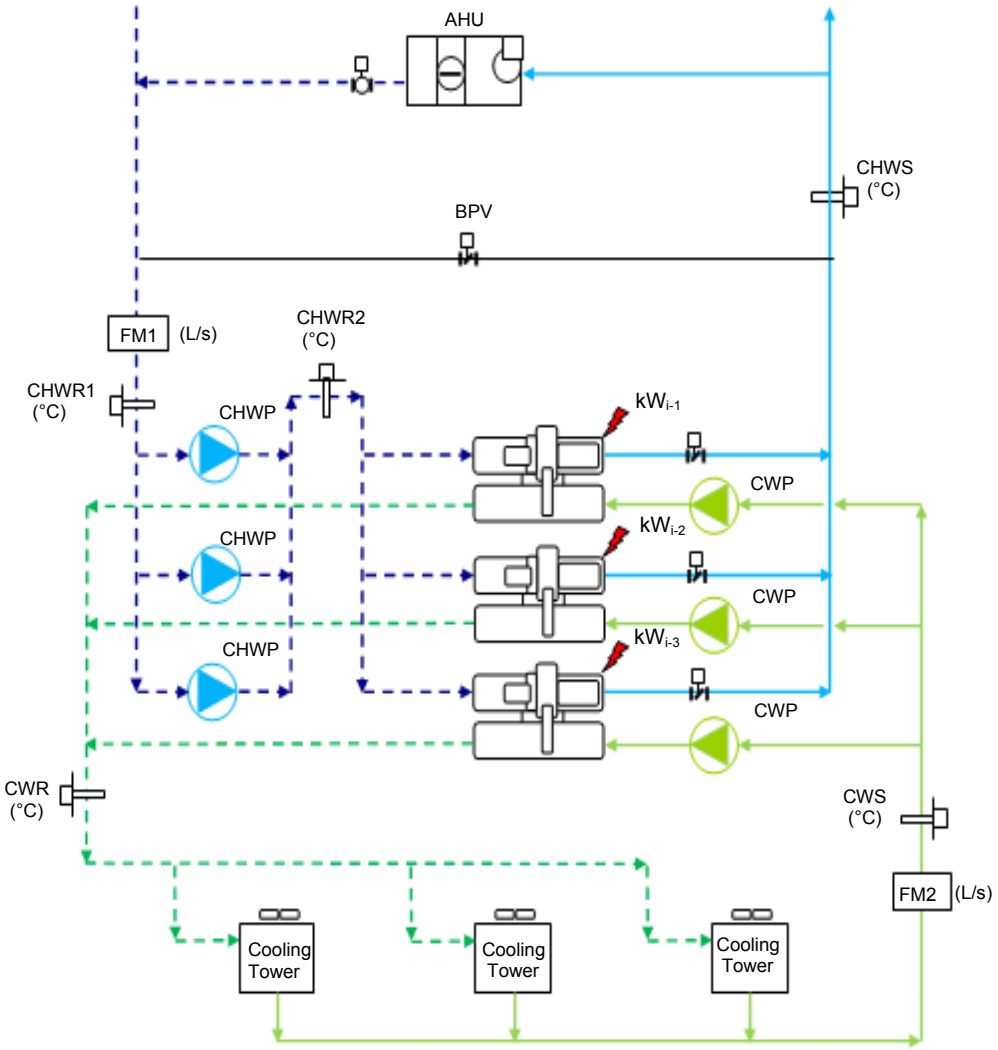
Worked Example 1-2(e)

Determining Heat Balance for Different Plant Configuration

For Variable Primary Chilled Water System

Determining Heat Balance for Different Plant Configuration

Plant B – Variable Primary Chilled-Water System



A: $q_{evaporator}$ = FM1 x Cp x (CHWR2 - CHWS)
B: $q_{condenser}$ = FM2 x Cp x (CWR - CWS)
C: W_{input} = kW_{i-1} + kWi_{-2} + kWi_{-3}

where Cp = 4.19 kJ/kg.ºC and density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note : In the event where hydraulic losses of pumps constitute substantial heat gain, the W_{input} and $q_{condenser}$ should be adjusted to account for the additional heat gains. The value shall be determined from certified drive losses, motor efficiency and pump efficiency values provided by the manufacturer.

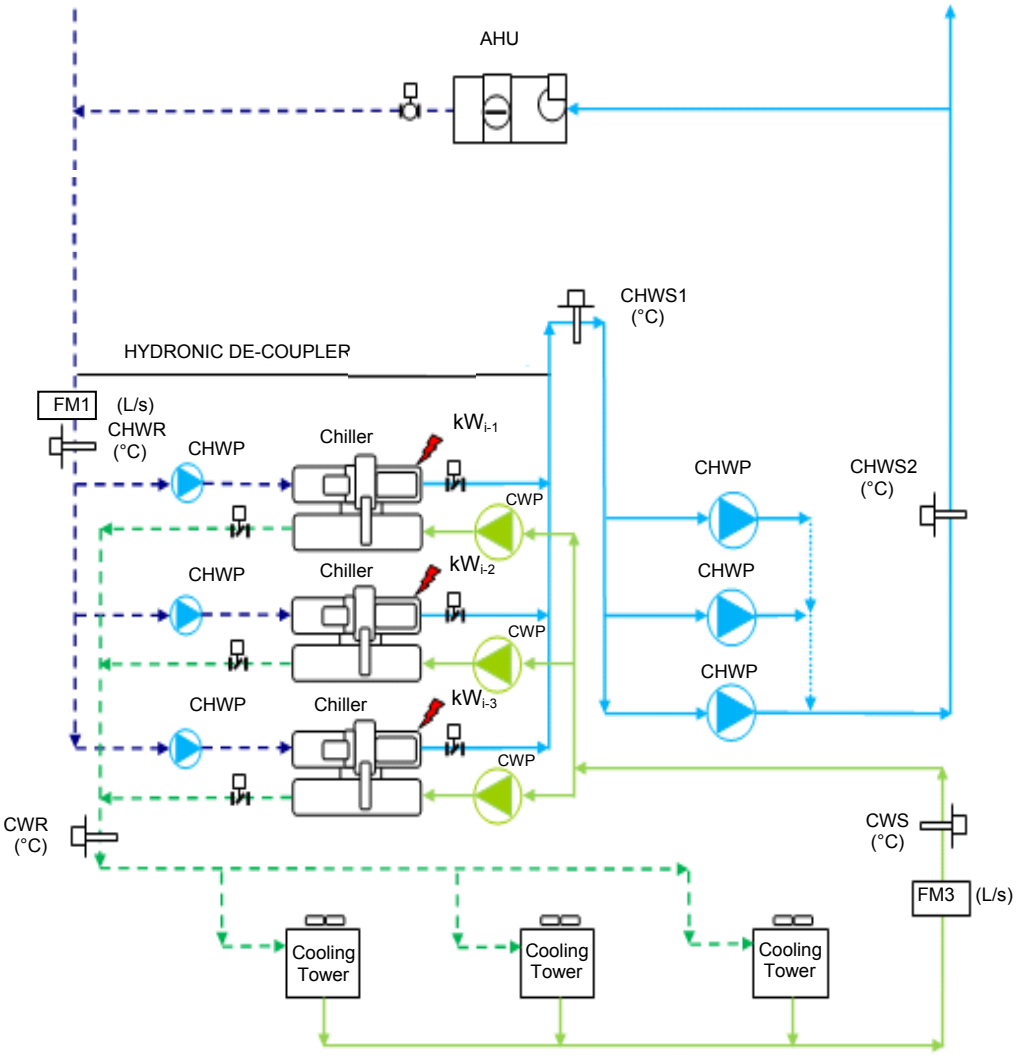
Worked Example 1-2(e)

Determining Heat Balance for Different Plant Configuration

For Constant Primary & Variable Secondary Chilled Water System

Determining Heat Balance for Different Plant Configuration

Plant C – Constant Primary & Variable Secondary Chilled-Water System



A: $q_{evaporator}$ = FM1 x Cp x (CHWR – CHWS1)

B: $q_{condenser}$ = FM3 x Cp x (CWR - CWS)

C: W_{input} = kW_{i-1} + kW_{i-2} + kW_{i-3}

where Cp = 4.19 kJ/kg.ºC and density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note : In the event where hydraulic losses of pumps constitute substantial heat gain, the W_{input} and $q_{condenser}$ should be adjusted to account for the additional heat gains. The value of which shall be determined from certified drive losses, motor efficiency and pump efficiency values provided by the manufacturer.

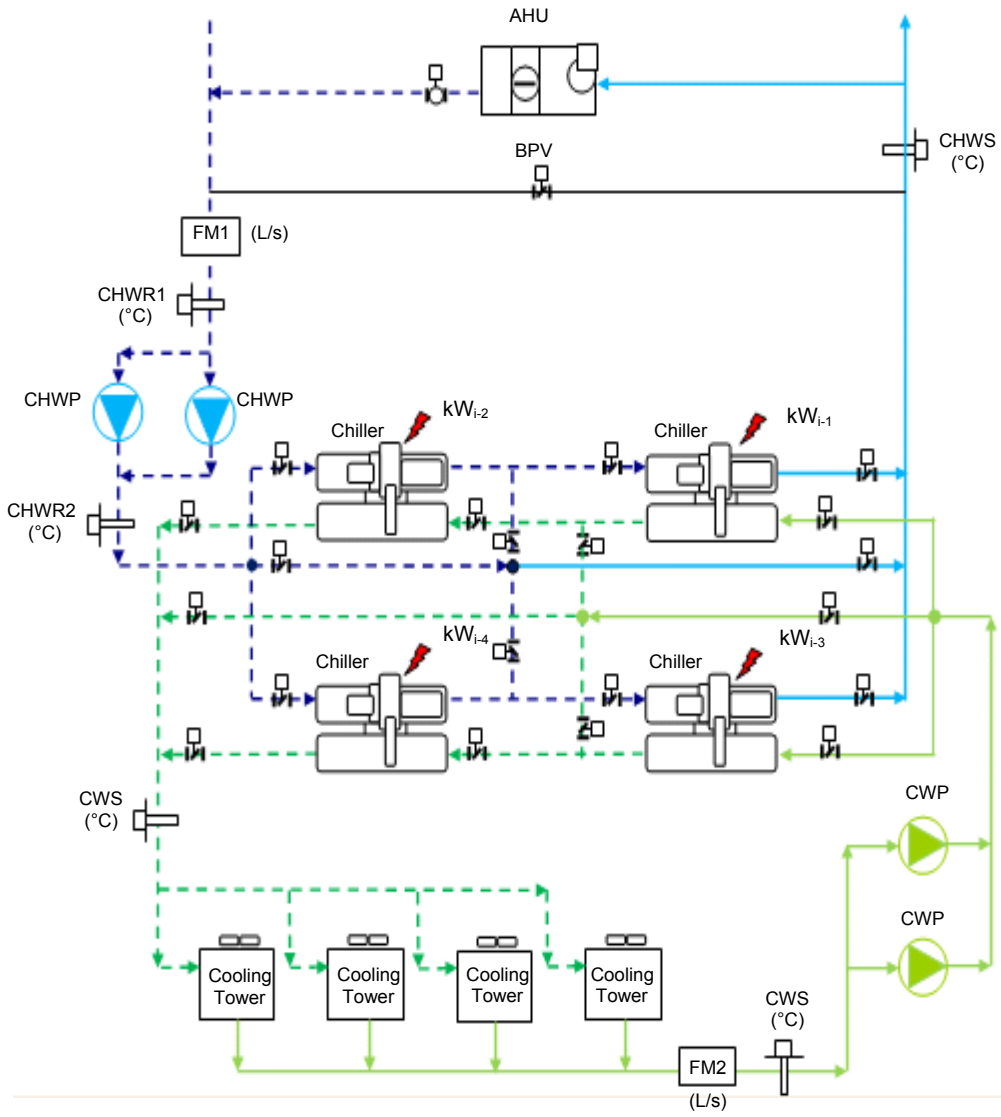
Worked Example 1-2(e)

Determining Heat Balance for Different Plant Configuration

For Series Counter Flow Chilled Water System

Determining Heat Balance for Different Plant Configuration

Plant D – Series Counter Flow Chilled-Water System



A: $q_{evaporator}$ = FM1 x Cp x (CHWR2 - CHWS)
B: $q_{condenser}$ = FM2 x Cp x (CWR - CWS)
C: W_{input} = $kW_{i-1} + kWi_{-2} + kWi_{-3} + kWi_{-4}$

where Cp = 4.19 kJ/kg.ºC and density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note : In the event where hydraulic losses of pumps constitute substantial heat gain, the W_{input} and $q_{condenser}$ should be adjusted to account for the additional heat gains. The value shall be determined from certified drive losses, motor efficiency and pump efficiency values provided by the manufacturer.

Worked Example 1-2(e)

Heat Balance Calculation

The example illustrates the computation required in deriving the percent heat balance based the available data collated.

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

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

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

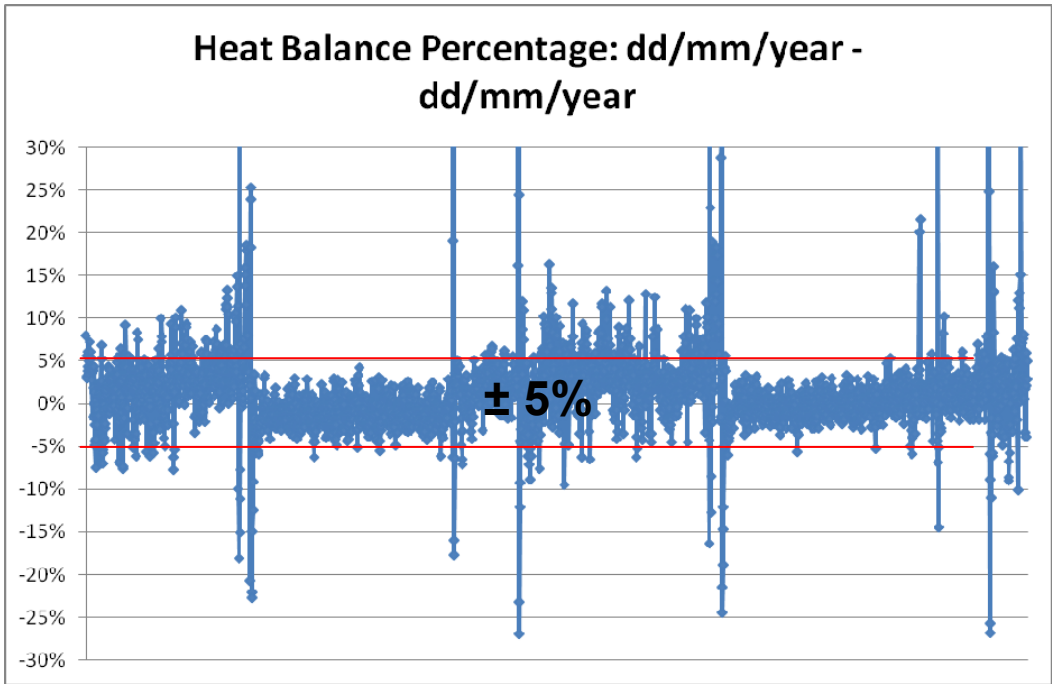
Percent Heat Balance (j) = 100 x [(g) / 3.517 + (h) – (i)] / (i)

Worked Example 1-2(e)

Cont'd

Heat Balance Calculation

System level heat balance plot



Summary of Heat Balance

	Quantity	Unit	Formula
Sum of total electrical energy used	6814	kWh	(A)
Sum of total cooling produced	12,202	RTh	(B)
Sum of total heat rejected	14,367	RTh	(C)
Chiller Plant Efficiency	0.56	kW/RT	(A) / (B)
Total Heat Balance Data Count	22	-	(D)
Data Count > 5% error	0	-	(E)
Data Count < 5% error	4	-	(F)
Data Count within ±5% error	18	-	(G) = (D) – (E) – (F)
% Heat Balance within ±5% error	82	%	(G) / (D) x 100%

Based on the above, 82% of the computed heat balance falls within ±5% > 80% ok

Note : The actual heat balance shall be conducted over the entire normal operating hours with more than 80% of the computed heat balance within ±5% over one (1) week period.

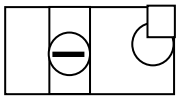
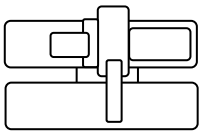
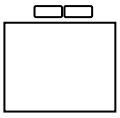
Abbreviations used in Worked Example 1-2(e)

AHU	Air Handling Unit	-
BP	Bypass Line	-
BPV	Bypass Valve (2-Way Modulating)	-
CCV	Cooling Coil Valve	-
CH	Chiller	-
CHWLR	Chilled Water Load Return Temperature	ºC
CHWP	Chilled Water Pump	-
CHWR	Chilled Water Return Temperature	ºC
CHWS	Chilled Water Supply Temperature	ºC
Cp	Specific Heat Capacity of Water	4.19 kJ/kg.ºC
CWP	Condenser Water Pump	-
CWR	Condenser Water Return Temperature	ºC
CWS	Condenser Water Supply Temperature	ºC
CT	Cooling Tower	-
KW	Electrical Power Consumption	kW
KW/RT	Electrical Input kW per Refrigeration Tonnage	I kW/ton
MV	Motorized Valve	-
$q_{evaporator}$	Cooling Load	kW or RT
$q_{condenser}$	Heat Rejection	kW or RT
W_{input}	Energy Balance	-

Abbreviations used in Worked Example 1-2(e)

ºC	Degrees Celsius
l/s	Liters per second
kW	Kilo-Watts
RT	Refrigeration Ton
ΔT	Temperature difference, Delta T

Symbols used in Worked Example 1-2(e)

	AHU
	CCV (2-Way Modulating)
	CH
	CHWP
	CHWR
	CHWS
	CWP
	CWR
	CWS
	CT
	Flow Meter
	MV
	Water Immersion Sensor

NRB 1-3 BUILDING ENVELOPE – DESIGN / THERMAL PARAMETERS

Objectives

Enhance the overall thermal performance of building envelope to minimise heat gain that would improve indoor thermal comfort and encourage natural ventilation.

Applicability

Applicable to non air-conditioned building spaces with aggregate areas > 10% of the total floor areas excluding both carparks and common areas.

Baseline Standard

Baseline standard for 1-3(d) - U value for roof :

Weight Group	Weight range (kg/m^2)	Maximum Thermal Transmittance (W/m^{2}K)
Light	Under 50	0.8
Medium	50 to 230	1.1
Heavy	Over 230	1.5

Requirements

1-3(a) Up to 15 points can be scored if the building envelope is designed with minimum direct west facing façade by having better building orientation. Where there is no west facing façade, the points scored will be 30 points and the requirements under 1-3(b)(i), b(ii) and (c) will not be applicable for scoring.

Points scored = 15 – [0.3 x (% of west facing facade areas over total façade areas)]

Note : Orientation of façade that falls within the range of 22.5° N of W and 22.5° S of W will be defined as west facing façade (see illustrations below). Core walls for lifts or staircases and toilets that are located within this range are exempted in computation.

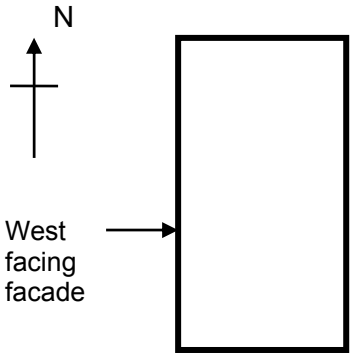


Illustration 1
An example of direct west facing facade

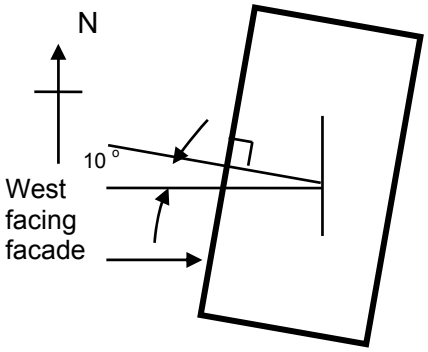


Illustration 2
The block is orientated 10°N of W that is less than of 22.5° N of W. In this instance, the façade is defined as 'west facing façade'.

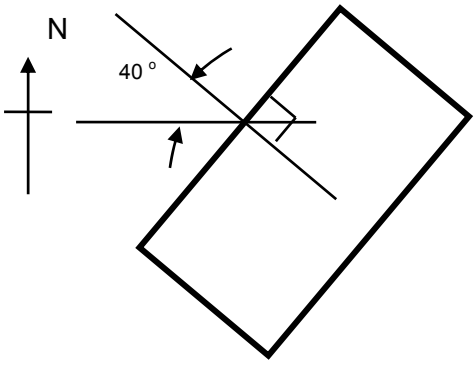


Illustration 3
The block is orientated 40°N of W that exceeds 22.5°N of W and hence the façade is not considered as 'west facing façade' in the computation.

Requirements

Cont'd

Exception: For existing buildings, the requirement NRB 1-3(a) may be excluded in the computation. The total score obtained from NRB 1-3(b), (c) and (d) will be prorated accordingly.

1-3(b) Up to 10 points can be scored for design with (i) minimum west facing window openings and/or (ii) having effective sunshading provision for windows with minimum shading of 30% on the west façade.

For 1-3 (b)(i) Points scored = 10 – [0.1 x (% of west facing window areas over total west facing façade areas)]

For 1-3 (b)(ii) Points scored = 0.1 x (% of west facing window areas with sunshading devices over total west facing façade areas)

Important notes *: For 1-3 (b)(ii) Points can only be scored if the sunshading devices meet at least a shading of 30% as tabulated in Table 1-3(b) below :*

Table 1-3(b) : Minimum Requirement on Shading Devices for West Facade

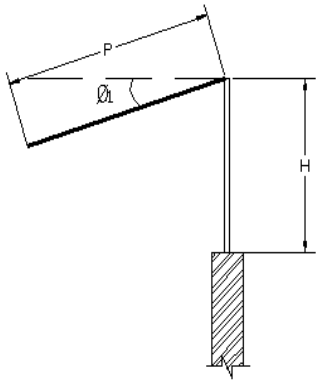
Types of Sunshading Devices	Angle of Inclination	Desired Shading			
		30%	40%	50%	60%
Horizontal Shading (R_1)	**0°**	0.6	0.9	1.5	
	20°	0.4	0.6	0.9	1.8
	40°	0.4	0.5	0.7	1.1
Vertical Shading (R_2)	**0°**	2.1			
	20°	1.1	1.7	2.5	
	40°	0.7	1	1.4	
	50°	0.6	0.9	1.1	2.8

where

Horizontal Shading/Projections (R_1)

$$R_1 = \frac{P}{H}$$

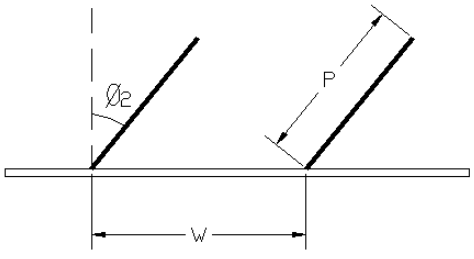
ϕ_1 = Angle of inclination



Vertical Shading/Projections (R_2)

$$R_2 = \frac{P}{W}$$

ϕ_2 = Angle of inclination



	1.3(c) Up to 5 points can be scored for external west facing wall that are designed with better thermal transmittance that is a U-value of wall equal or less than 2 W/m^2K. Points scored = 0.05 x (% of the external west facing walls areas with U-value of 2 W/m^2K or less over the total west facing façade areas) 1.3(d) Up to 5 points can be scored for roof design with better thermal transmittance that is a lower U value of roof than the baseline standard. Points scored = 1 point for every 0.1 W/m^2K reduction from the baseline. Note : If there are combinations of roof types, the average reduction from the baseline can be derived by pro-rating the roof areas
Documentary Evidences	<u>For 1-3(a)</u> • Architectural plan layouts and elevation drawings of the façades of all blocks. Highlight those areas that are considered as west facing façade ; and • Calculation showing the percentage of west facing façade areas in the prescribed tabulated format as shown in the worked example 1-3(a). <u>For 1-3(b)(i) and (ii)</u> • Architectural plan layouts and elevation drawings of west facing façade and window openings; • Sectional drawings showing the details of the sunshading devices. Highlight those sunshading devices that meet the 30% shading requirement ; • Window schedules or drawings showing the areas of the west facing windows; and • Calculation showing the percentage of west facing window areas in the prescribed tabulated format as shown in worked example 1-3(b). <u>For 1-3(c)</u> • Architectural drawings highlighting the material types and wall areas that are of better thermal transmittance (U-value); • Detailed sectional drawings showing the wall composition and the respective U-values; • Extracts of the tender specification that states the thermal transmittance properties to be adopted for west facing walls; and • Technical product information and relevant calculation on the U-value of the wall materials used. <u>For 1-3(d)</u> • Plan layout and sectional details of the different roof types of the development; • Extracts of the tender specification that states the thermal transmittance properties of roof ; • Detailed sectional drawings showing the roof composition and the respective U-values; and • Technical product information and relevant calculation of the U-value of the roof.
References	-

Worked Example 1-3(a)

(1) Determine the total areas of external façade.
(2) Identify the façade areas that are within the range of 22.5° N of W and 22.5° S of W as west facing facades

Background info

Block 1: Total façade areas = 6000 m^2
West facing façade areas = 1500 m^2

Block 2 : Total façade areas = 8000 m^2
West facing façade areas = 1500 m^2

Block 3 : Total façade areas = 3000 m^2
West facing façade areas = 1000 m^2 (These wall areas are envelope of core wall for lifts and staircases)

Table 1-3(a) Minimum direct west facing external facade

	Area of west facing external façade (m^2) (a)	**Total area of external facade (b)**	**% of west facing external facade**
Block 1	1500	6000	$\sum$ (a)/ $\sum$ (b) x100%
Block 2	1500	8000	
Block 3	Exempted	3000	
Total	3000	17000	

Points scored for 1-3(a) = 15 – [0.3 x ($\sum$ (a)/ $\sum$ (b)) x100%)]
= 15 – [0.3 x (3000/17000) x 100%] = 9.71 points

Example 1-3(b)

(1) Identify the façade areas that are within the range of 22.5° N of W and 22.5° S of W as west facing façade.
(2) Determine the window areas on these facades.
(1) Determine if the sunshading provisions meet the minimum 30% shading.

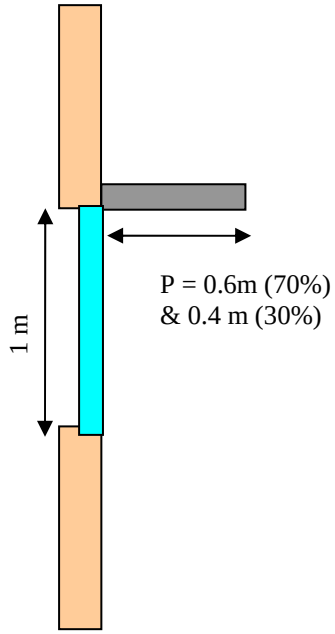
Background info

Block 1 : West facing façade areas = 1500 m^2
Window areas = 600 m^2

There are two types of sunshading devices; 70% of the units have sunshading devices with horizontal projection (P) of 0.6 m and the rest of the 30% have sunshading devices with projection of 0.4 m.

Worked Example 1-3(b)

Illustration 1 : Sectional detail of horizontal sunshading devices



Check

To determine if the sunshading provisions (i.e. horizontal projection (P)) meet the minimum 30% shading.

Refer to Table 1-3(b)

Angle of inclination – 0^o

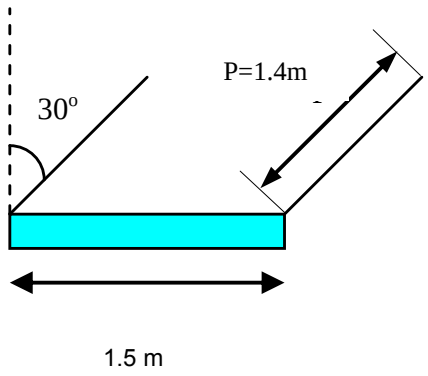
$R_1 = 0.6 / 1.0 = 0.6$

Min horizontal projection P = R_1 x H
= 0.6 x 1
= 0.6 m

Therefore sunshading devices with horizontal projection of 0.4 m will not be considered as effective.

Block 2 : West facing façade areas = 1500 m^2
Window areas = 1000 m^2

Illustration 2 : Plan view of vertical sunshading devices



Check

To determine if the sunshading provisions meet (i.e. vertical projection (P)) the minimum 30% shading.

Refer to Table 1-3(b)

Tilted Angle – 30^o

$R_2 = (1.1+0.7) / 2 = 0.9$ (interpolation)

Min vertical projection P = R_2 x W
= 0.9 x 1.5
= 1.35 m

Therefore, sunshading devices with vertical projection of 1.4 m ok.

Block 3 : West facing façade areas = 1000 m^2 (These wall areas are envelope of core wall for lifts and staircases)
Window areas = 0 m^2

Worked Example 1-3(b) – Cont'd

Points scored for 1-3(b)(i) and 1-3(b)(ii) are as follows:

Table 1-3(b)(i) : Minimum west facing windows openings

Description	Area of west facing window area (m^2) (a)	Total area of west facing external façade (m^2) (b)	% of west facing window areas over total west facing external façade areas
Block 1	600	1500	$\sum$ (a)/ $\sum$ (b) x100%
Block 2	1000	1500	
Block 3	0	1000	
Total	1600	4000	

Points scored for 1-3(b)(i) = 10 – [0.1 x (($\sum$ (a)/ $\sum$ (b)) x 100%)]
= 10 – [0.1 x (1600/4000) x 100%)] = 6 points

Table 1-3(b)(ii) : Effective sunshading provisions for west facing window with minimum 30% shading

Description	Area of west facing window with effective sunshading provision (m^2) (a)	Total area of west facing external façade (m^2) (b)	% of west facing window areas over total west facing external façade areas
Block 1	420 (70% of 600)	1500	$\sum$ (a)/ $\sum$ (b) x100%
Block 2	1000	1500	
Block 3	0	1000	
Total	1420	4000	

Points scored for 1-3(b)(ii) = 0.1 x [($\sum$ (a)/ $\sum$ (b)) x100%]
= 0.1 x [(1420 / 4000) x 100%] = 3.55 points

Therefore, points scored for 1-3(b) = 6 + 3.55 = 9.55 points

Worked Example 1-3(c)

Background info

Block 1 : West facing façade areas = 1500 m^2

Window areas = 600 m^2
Wall areas = 900 m^2

U-value of west facing wall areas is 2.0 W/ m^2K

Block 2 : West facing façade areas = 1500 m^2

Window areas = 1000 m^2
Wall areas = 500 m^2

Window areas = 1000 m^2

U-value of west facing walls is 2.5 W/ m^2K > 2.0 W/ m^2K not ok

Block 3 : West facing façade areas = 1000 m^2

Window areas = 0 m^2
Wall areas = 1000 m^2

U-value of external west facing walls is 2 W/ m^2K

Table 1-3(c): Better thermal transmittance of external west facing walls

Description	Area of external west facing walls with U-value of 2W/m^2K or less (m^2) (a)	Total area of west facing external façade (m^2) (b)	% of west facing window areas over total west facing external façade areas
Block 1	900	1500	$\sum$ (a)/ $\sum$ (b) x100%
Block 2	0	1500	
Block 3	1000	1000	
Total	1900	4000	

Points scored for 1-3(c) = 0.05 x [($\sum$ (a)/ $\sum$ (b)) x100%)]
= 0.05 x [(1900/4000) x 100%] = 2.4 points

Worked Example 1-3(d)

Background info

Proposed development has 3 roof types with the designed U value of the roof as tabulated in the table below

Table 1-3(d) : Better Thermal Transmittance of Roof

Roof Weight Group	Max U-value of Roof (W/m^2K) (A)	U-value of Roof (W/m^2K) (B)	Roof Area (m^2) (C)	Reduction from baseline roof U value W/m^2K D= A-B	Average Reduction prorated based on areas E= (DxC)/Total Area
Light	0.8	0.47	6000.00	0.33	0.27
Medium	1.1	0.53	800.00	0.57	0.06
Heavy	1.5	0.65	600.00	1.42	0.07
Total area ⇒			7400.00	Average Reduction ⇒	0.4

Average reduction = 0.4

Therefore, points scored for 1-3(d) = (0.4 / 0.1) x 1 = 4 points

NRB 1-4 NATURAL VENTILATION / MECHANICAL VENTILATION

Objectives

Encourage building design that facilitates good natural ventilation or with provision for ventilation by efficient mechanical ventilation system.

Applicability

Applicable to non air-conditioned building spaces with aggregate areas > 10% of the total floor areas **excluding carparks and common areas**.

Baseline Standard

1-4(a)(ii) - Ventilation simulation modeling and analysis shall be based on the methodology specified in Appendix C – Ventilation Simulation Methodology and Requirements.

1-4(b) Mechanical Ventilation System

Option 1 – Fan System Motor Nameplate Power

Baseline : SS553:2009 Table 8 – Fan power limitation and as prescribed below :

Baseline **Air Distribution System Type**	**Allowable Motor Nameplate Power**	
Fan systems with motor nameplate power ≥ 4kW	($kW/m^3/s$)	(W/CMH)
▪ Air Handling Units (AHUs) /Fan Coil Units (FCUs) (Constant Volume)	1.7	0.47
Fan systems with nameplate motor power < 4 kW	No baseline	

Option 2 – Fan System Input Power

Baseline : ASHRAE 90.1: 2010 Clause 6.5.3.1 and as prescribed below :

Baseline **Air Distribution System Type**	**Allowable Fan System Input Power***	
Fan systems with motor nameplate power ≥ 4kW	($kW/m^3/s$)	(W/CMH)
• Air Handling Units (AHUs) /Fan Coil Units (FCUs) (Constant Volume)	1.5	0.42
Fan systems with motor nameplate motor power < 4 kW	0.6	0.17

* Applicable pressure drop adjustments can be considered based on ASHRAE 90.1 Table 6.5.3.1.1B and are subject to BCA's evaluation

Requirements

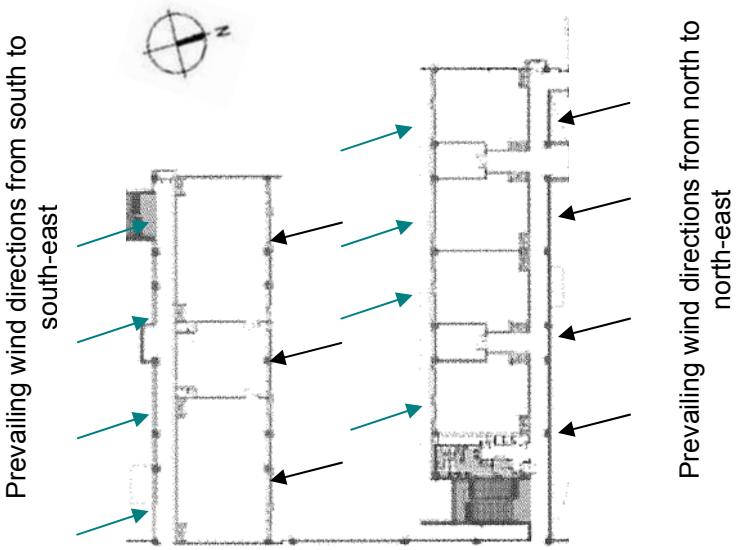
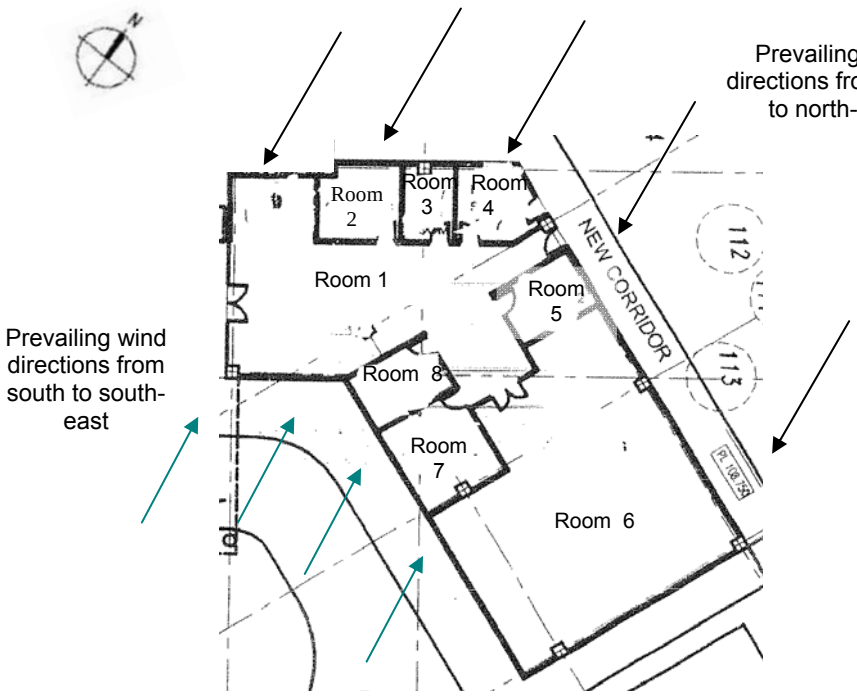
Natural Ventilation

1-4(a)(i) Up to 10 points can be scored for building design that utilises prevailing wind conditions to achieve adequate cross ventilation.

1 point for every 10% of units/rooms with window openings facing north and south directions

Points scored = 1 x (% of units / 10)

Note: In Singapore, 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, buildings designed with window openings facing the north and south directions have the advantage of the

Requirements **Cont'd**	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 (see illustrations below).  Illustration 1 - Building layout shows all rooms with window openings facing the north and south directions.  Illustration 2 - Building layout shows not all rooms with window openings facing the north and south directions. Room 2 to Room 5 would only have prevailing wind in one direction. Only Room 1 and 6 can be considered meeting the requirement 1-4(a). *Alternative compliance : The application of ventilation simulation can be used to prove that the building layout utilises prevailing wind conditions and could achieve adequate cross ventilation within the indoor units through sufficient window openings. The ventilation simulation should be carried out in the same conditions outlined in para 1-4(a)/(ii) below. Points shall only be scored if the recommendations from the simulation are implemented.*

Requirements **Cont'd**	1-4(a)(ii) 5 points for the use of ventilation simulation modeling and analysis or wind tunnel testing to identify the most effective building design and layout in achieving good natural ventilation. Additional 5 points can only be scored if the recommendations from the ventilation simulation or wind tunnel testing are implemented and the weighted average wind velocity within the units meets 0.60 m/s. The ventilation simulation shall be carried in accordance with the assumptions and methodology stated in Appendix C – Ventilation Simulation Methodology and Requirement <u>Mechanical Ventilation</u> 1-4 (b) 15 points can be scored for building with energy efficient mechanical ventilation system design 0.6 point for every percentage improvement in the air distribution system efficiency from the baseline standard. Points scored = 0.6 x (% improvement) ***Important notes :*** *Where there is a combination of naturally ventilated and mechanical ventilated spaces, the points scored will only be based on the predominant ventilation modes of normally occupied spaces.*
Prerequisites	To be eligible for Green Mark Platinum, it is a requirement to use ventilation simulation modeling and analysis to identify the most effective building design and layout. The simulation results and the recommendations derived are to be implemented to ensure good natural ventilation.
Documentary Evidences	<u>Natural Ventilation</u> <u>For 1-4(a)(i)</u> • Architectural plan layouts showing the units / rooms of all blocks with highlights of those with window openings in the N-S direction and/or with air-conditioned systems; • Calculation showing the percentage of units or rooms with window openings facing north and south directions in the prescribed tabulated format as shown in the worked example 1-4(a)(i). <u>For 1-4(a)(ii)</u> • Ventilation simulation or wind tunnel testing reports summarising the analysis and simulation results for each typical space as well as the recommendations for design as specified in Appendix C. <u>Mechanical Ventilation</u> <u>For 1-4(b)</u> • Architectural plan layouts showing the mode of ventilation for units / rooms of all blocks are mechanically ventilated • Mechanical ventilation design plan layouts • Detailed calculations of fan static calculations and design air flow rate • MV fan equipment schedule • Technical product information of all MV fans (to include fan curve)
References	-

Worked Example

1-4(a)(i)

Background info

A school development comprises two 3-storey classroom block A and A1 with majority of the window openings facing the N-S direction, a 4 storey classroom Block B with window opening in the E-W direction and three blocks of office, meeting rooms and computer rooms that are air-conditioned.

Ref	Description	Units/Rooms with window openings in the N-S direction (a)	Total no. of naturally ventilated units/room (b)	% of units/rooms with window openings in N-S direction
1	Classroom Blk A & A1	40	60	$\sum$ (a)/ $\sum$ (b) x100%
2	Classroom Blk B	0	40	
3	Offices, meeting rooms and computer rooms with air-conditioning	NA	NA	
	Total :	40	100	

Points scored = 1 x (% of units / 10)

= 1 x [($\sum$ (a)/ $\sum$ (b) x100%) /10]

= 1 x [(40/100 x 100%) / 10] = 4 points < 10 points (max)

Worked Example

1-4(b)

Option 1 – Fan Motor Nameplate Power

Background info

The small industrial factory development comprises of 4-storey block with 6 workshop spaces that are mechanically ventilated.

MV fan schedule:

Work-shop	Fan	Fan Type	Floor Area (m2)	Space Height (m)	ACH	Air Flow Rate (CMH)	External Static (Pa)	Motor Nameplate Power (kW)	Fan Efficiency (W/CMH)
1	FAF 1-1	Axial	650	10	6	39000	650	11	0.28
2	FAF 1-2		650	10		39000	650	11	0.28
3	FAF 1-3		650	10		39000	650	11	0.28
4	FAF 2-1		500	8		24000	500	5.5	0.23
5	FAF 2-2		500	8		24000	500	5.5	0.23
6	FAF 2-3		500	8		24000	500	5.5	0.28
1	EAF 1-1		650	10		39000	650	11	0.28
2	EAF 1-2		650	10		39000	650	11	0.28
3	EAF 1-3		650	10		39000	650	11	0.28
4	EAF 2-1		500	8		24000	500	5.5	0.23
5	EAF 2-2		500	8		24000	500	5.5	0.23
6	EAF 2-3		500	8		24000	500	5.5	0.23

Total fan power = **99 kW**

Total air flow rate = **378,000 CMH**

Baseline: Total fan power = 378,000 CMH x 0.47 W/CMH

= 177.66 kW

Points scored = 0.6 x (% improvement)

= 0.6 x [(177.66 – 99)/177.66 x 100%]

= 0.6 x 44%

= 26.6 points > 15 (max)

Therefore, point scored is 15 points.

Option 2 – Fan System Input Power

MV fan schedule:

Work-shop	Fan	Fan Type	Floor Area (m2)	Space Height (m)	ACH	Air Flow Rate (CMH)	External Static (Pa)	Fan System Input Power (kW)	Fan Efficiency (W/CMH)
1	FAF 1-1	Axial	650	10	6	39000	650	8.28	0.21
2	FAF 1-2		650	10		39000	650	8.28	0.21
3	FAF 1-3		650	10		39000	650	8.28	0.21
4	FAF 2-1		500	8		24000	500	3.92	0.16
5	FAF 2-2		500	8		24000	500	3.92	0.16
6	FAF 2-3		500	8		24000	500	3.92	0.16
1	EAF 1-1		650	10		39000	650	8.28	0.21
2	EAF 1-2		650	10		39000	650	8.28	0.21
3	EAF 1-3		650	10		39000	650	8.28	0.21
4	EAF 2-1		500	8		24000	500	3.92	0.16
5	EAF 2-2		500	8		24000	500	3.92	0.16
6	EAF 2-3		500	8		24000	500	3.92	0.16

Total fan power = **73.24 kW**

Total air flow rate = **378,000 CMH**

Baseline: Total fan power = 378,000 CMH x 0.42 W/CMH

= 158.76 kW

Points scored = 0.6 x (% improvement)

= 0.6 x [(158.76 – 73.24)/158.76 x 100%]

= 0.6 x 54%

= 32 points > 15 (max)

Therefore, point scored is 15 points.

NRB 1-5 DAYLIGHTING

<table>
<tr><td>Objectives</td><td>Encourage design that optimises the use of effective daylighting to reduce energy use for artificial lighting.</td></tr>
<tr><td>Applicability</td><td>1-5(a) Applicable to all normally occupied areas within the development.
1-5(b) Applicable to all common areas within the development.</td></tr>
<tr><td>Baseline Standard</td><td>1-5(a) The computation of daylighting and glare simulation shall be based on the methodology specified in Appendix D – Daylighting and Glare Simulation Methodology and Requirements.

Minimum illuminance level and comfortable Unified Glared Rating (UGR) shall be in accordance with SS 531: Part 1 – Code of Practice for Lighting of Work Places – Indoor and the design intent.</td></tr>
<tr><td>Requirements</td><td>1-5(a) Up to 3 points can be scored for the use of daylight and glare simulation analysis to optimise the use of effective daylighting for normally occupied spaces.

The daylighting provision is deemed to be effective if the areas within the prescribed distances from building perimeters (that is the perimeter daylight zones) meet the minimum illuminance level and acceptable Unified Glared Rating (UGR) at all glare viewpoints.

Points can be scored if at least 75% of the units are designed with effective daylighting provision. The scoring will be based on the extent of the perimeter daylight zones, which is expressed as in term of the distances from façade perimeters as shown in the table below.

<table>
<tr><th>Distance from Façade Perimeters (m)</th><th>Points Allocation</th></tr>
<tr><td>≥ 3.0</td><td>1</td></tr>
<tr><td>4.0 - 5.0</td><td>2</td></tr>
<tr><td>> 5.0</td><td>3</td></tr>
</table>

1-5(b) Up to 3 points can be scored for daylighting provision for the following common areas; 0.5 point can be scored if at least 80% of each applicable area is designed with daylighting provision:

▪ Toilets
▪ Staircases
▪ Corridors
▪ Lift lobbies
▪ Atriums
▪ Carparks

Important Notes: All daylit areas must be integrated with automatic electric lighting control system.</td></tr>
<tr><td>Documentary Evidences</td><td><u>For 1-5(a)</u>
• Schedules showing the total number of normally occupied areas in the development and those with acceptable glare exposure and effective daylighting; and
• Daylight and glare simulation report summarizing the analysis and modeling results for each normally occupied area that meets the requirement as specified in Appendix D.</td></tr>
</table>

<table>
<tr><td></td><td>For 1-5(b)
• Extracts of the tender specification or drawings showing the use of daylighting for toilets, staircases, corridors, lift lobbies, atriums and carparks where applicable.</td></tr>
<tr><td>References</td><td>SS 531: Part 1 – Code of Practice for Lighting of Work Places – Indoor</td></tr>
<tr><td>Worked Example 1-5(a)</td><td>Proposed development comprises a 30 storey office block with 60 office units. Daylight and glare simulation has been conducted for the development. Based on simulation, 75% of all office units (i.e. 45 units) can achieve effective daylighting at a distance of 4.5m from building façade perimeters and meet the acceptable Unified Glared Rating .

<table>
<tr><th>Office Unit type</th><th>No. of Units</th><th>Average Distance from Façade Perimeter (m)</th></tr>
<tr><td>1</td><td>10</td><td>4.6</td></tr>
<tr><td>2</td><td>20</td><td>5.3</td></tr>
<tr><td>3</td><td>15</td><td>5.1</td></tr>
<tr><td>4</td><td>15</td><td>2.8</td></tr>
</table>

Percentage of units meeting the minimum requirement = $\frac{(10+20+15)}{60} \times 100 = 75\%$

Weighted average distance = $\frac{(10)(4.6)+20(5.3)+(15)(5.1)+(15)(2.8)}{60}$ = 4.5 m

Distance for 4.5 m from building perimeters ⇨
<table>
<tr><th>Distance from Façade Perimeters (m)</th><th>Points Allocation</th></tr>
<tr><td>≥ 3.0</td><td>1</td></tr>
<tr><td>4.0 - 5.0</td><td>2</td></tr>
<tr><td>> 5.0</td><td>3</td></tr>
</table>

Points scored for 1-5(a) = 2 points</td></tr>
<tr><td>Worked Example 1-5(b)</td><td>Proposed development has the following provision:

All staircases, corridors, lift lobbies and atriums are designed with adequate daylighting that would eliminate the need for artificial lightings during daytime.

70% of of the carpark areas have daylighting provision while the other 30% of the carpark areas would need to employ the use of artificial lightings during daytime to maintain proper lighting level.

0.5 point each for staircases, corridors, lift lobbies and atriums

No point for carparks as it does not meet the minimum 80% of the applicable areas

Therefore, points scored for 1-5(b) = 2 points</td></tr>
</table>

NRB 1-6 ARTIFICIAL LIGHTING

Objectives	Encourage the use of better efficient lighting to minimise energy consumption from lighting usage while maintaining proper lighting level.
Applicability	Applicable to lighting provisions for the type of usage specified in the SS 530 Clause 7 – Lighting power budget.
Baseline Standard	Maximum lighting power budget stated in SS 530 - Code of Practice for Energy Efficiency Standard for Building Services and Equipment.
Requirements	Up to 12 points if tenants' light is provided OR Up to 5 points if tenants' light is excluded for the improvement in the lighting power consumption. 0.3 point for every percentage improvement in the lighting provisions over the baseline standard. That is Points scored = 0.3 x (% improvement) Display lighting and specialised lighting are to be included in the calculation of lighting power budget. The design service illuminance, lamp efficacies and the light output ratios of luminaries shall be in accordance with SS 531 : Part 1 – Code of Practice for Lighting of Work Places - Indoor
Documentary Evidences	• Lighting layout plan; • Lighting schedules showing the numbers, locations and types of lighting luminaries used; • Calculation of the proposed lighting power budget and the percentage improvement in the prescribed tabulated format as shown in the worked example 1-6; • Tabulation showing the designed lux level and the minimum lux level based on code requirement for the respective areas; and • Technical product information of the lighting luminaries used.
References	SS 530 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment. SS 531 : Part 1 – Code of Practice for Lighting of Work Places - Indoor
Worked Example 1-6	(1) Determine the total power consumption based on the lighting layout design for each area and light fitting types used. (2) Calculate the total power consumption based on the maximum lighting power budget stated in SS 530. (3) Calculate the percentage improvement in the total power consumption.

Worked Example 1-6 – Cont'd

Table 1-6-1: Total power consumption based on each fitting type

Description	Areas (m^2) (A)	Light Fitting Type (B)	Power Consumption per fitting (W) (C)	Ballast Loss (W) (D)	No. of Fittings (E)	Total power consumption based on fitting type [(C+D) x (E)]
Office Space Type 1	1500	T5	2x28	3	245	14455
Office Space Type 2	1250	T5	2x 28	3	210	12390
Meeting Room	75	T8	1x36	3	15	585
		Surface downlight	2x26	0	8	416
Corridors Type 1	150	T5	2x28	3	15	885
Corridors Type 2	205	T5	2x28	3	15	885
		Surface downlight	1x70	0	9	630
Atrium	850	T8	2x36	3	87	6525
		Surface downlight	1x150	0	10	1500
Carparks	7500	T5	2x28	3	436	25724
Staircase	300	T5	2x28	3	20	1180
					Total :	65175

Table 1-6-2 : Total power consumption based on design and SS 530 requirements

Description	Areas (m^2) (A)	Design Data		SS 530 Requirements	
		Total Power Consumption (by area)(W) (F)	Design Lighting Power Budget (W/m^2) (F/A)	Reference Lighting Power Budget (W/m^2) (H)	Reference Total Power Consumption (by area) (W) (H x A)
Office Space Type 1	1500	14455	9.64	15	22500
Office Space Type 2	1250	12390	9.91	15	18750
Meeting Room	75	1001	13.35	15	1125
Corridors Type 1	150	885	5.90	10	1500
Corridors Type 2	205	1515	7.39	10	2050
Atrium	850	8025	9.44	10	8500
Carparks	7500	25724	3.43	5	37500
Staircase	300	1180	3.93	6	1800
Total :		65175			93725

Worked Example 1-6 – Cont'd	% improvement in the lighting power consumption = [Σ(HxA) - Σ(F)] / Σ(HxA) x 100% = (93725-65175)/93725 x 100% = 30.46% Points scored = 0.3 x 30.46% = 9.14 points Therefore, points scored is 9.14 points if tenant's lighting is included ; and points scored is 5 points (max) if tenant's lighting is excluded.

NRB 1-7 VENTILATION IN CARPARKS

Objectives	Encourage the use of energy efficient design and control of ventilation systems in carparks.
Applicability	Applicable to all carpark spaces in the development.
Baseline Standard	-
Requirements	1-7(a) 4 points can be scored if the carparks spaces that are fully naturally ventilated. 1-7(b) For carparks have to be mechanically ventilated, points can be scored for the use of carbon monoxide (CO) sensors in regulating such demand based on the mode of mechanical ventilation (MV) used; 2.5 points for carparks using fume extract system and 2 points for those with MV with or without supply. Note : Where there is a combination of different ventilation mode adopted for carpark design, the points scored under this requirement will be prorated accordingly.
Documentary Evidences	<u>For 1-7(a) and (b)</u> • Plan layouts showing all carpark provisions for the development with highlights of the carpark spaces that are designed to be naturally ventilated and/or mechanical ventilated; • Plan layouts indicating the locations of CO sensors and the mode of ventilation adopted for the design; and • Calculation showing the points allocation if there is a combination of different ventilation modes adopted for the carpark design.
References	SS 553 – Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.
Worked Example 1-7	Proposed development has a 6-storey naturally ventilated carparks and one level of mechanically ventilated basement carparks with CO sensors to be installed to regulate MV. Areas of naturally ventilated carparks = 6 x 600 = 3600 m^2 Areas of basement carparks = 600 m^2 Total areas = 4200 m^2 Points scored for 1-7 = (3600/4200) x 4 + (600/4200) x 2 = 3.71 points

NRB 1-8 VENTILATION IN COMMON AREAS

Objectives	Encourage the use of energy efficient design and control of ventilation systems in common areas.
Applicability	Applicable to the following common areas of the development. ▪ Toilets ▪ Staircases ▪ Corridors ▪ Lift Lobbies ▪ Atriums
Baseline Standard	-
Requirements	Up to 5 points can be scored for the use of natural ventilation as an effective passive cooling design strategy to reduce the energy used by air-conditioning systems in these common areas. Extent of coverage : At least 90% of each applicable area (by numbers). Points are scored based on the mode of ventilation provided in these applicable areas. Natural ventilation – 1.5 points for each area Mechanical ventilation – 0.5 point for each area
Documentary Evidences	• Plan layouts showing the applicable areas and the respective modes of ventilation; and • Schedules showing the numbers, locations of the applicable areas and the modes of ventilation used.
References	SS 553 – Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.
Worked Example 1-8	Proposed development has the following details : No. of toilets = 45 ; where 10 units are designed with air-conditioning % of toilet units with natural ventilation = (45-10)/45 = 77.8 % < 90% and hence no point for this item No. of staircases = 100 ; all are mechanical ventilated – 0.5 point No. of lift lobbies = 22 ; all are naturally ventilated – 1.5 points Points scored for 1-8 = 0.5 +1.5 = 2 points < 5 points(max)

NRB 1-9 LIFTS AND ESCALATORS

Objectives	Encourage the use of energy efficient lifts and escalators.
Applicability	Applicable to all lifts and escalators in the development.
Baseline Standard	-
Requirements	1 point can be scored for the use of lifts with energy efficient features such as AC variable voltage and variable frequency (VVVF) motor drive or equivalent, and sleep mode. 1 point can be scored for the use of escalators with occupancy sensors to regulate usage.
Documentary Evidences	• Extracts of the tender specification indicating the types of lifts, escalators and related features used; and • Technical information of the lifts and escalators.
References	-
Worked Example 1-9	Proposed development has the following provision : Two lift types : Type L1 with VVVF motor drive and sleep mode features Type L2 with VVVF motor drive and sleep mode features Two escalator types : Type E1 with VVVF motor drive and occupancy sensors Type E2 without VVVF motor drive and occupancy sensors 1 points for the use of lifts with VVVF and sleep mode features. No point for escalators as not all escalators are designed with occupancy sensors Points scored for 1-9 = 1 point

NRB 1-10 ENERGY EFFICIENT PRACTICES & FEATURES

Objectives	Encourage the use of energy efficient practices and features that are innovative and have positive environmental impact in terms of energy saving.
Applicability	Applicable to practices and features that are not listed in the requirements under Part 1 – Energy Efficiency.
Baseline Standard	-
Requirements	1-10 (a) 1 point can be scored for the practice of using Energy Efficiency Index (EEI) as a building performance indicator to measure the building's unit area energy consumption for future monitoring and improvements. Calculation of EEI : EEI = [(TBEC - DCEC) / (GFA – DCA)] x (NF/OH) *where:* (a) TBEC : Total building energy consumption (kWh/year) (b) DCEC : Data centre energy consumption (kWh/year) (c) GFA : Gross floor area (exclude car park area) (m^2) (d) DCA : Data centre area (m^2) (e) NF : Normalising factor based on a typical weekly operating hours that is 55 hrs/week (g) OH : Weighted weekly operating hours (hrs/week) Note : (1) EEI is based on 100% occupancy rate for consistency. (2) All major energy consumption equipments are to be included in the estimation of total building energy consumption. (3) For industrial buildings, process load should be excluded. 1-10(b) Up to 1 point can be scored for the provision of greenery system on east and west façade to reduce the heat gain through the building envelope. 1 point for high impact where provision is more than 50% of applicable facade areas. 0.5 point for low impact where provision is at 25% of the same. 1-10(c) 0.5 point for the use of energy efficient equipment or products that are certified by approved local certification body for at least 90% of the applicable equipment types or products (Up to 2 points) 1-10(d) Up to 8 points can be scored for the use of the following approved energy efficient features depending on the potential energy saving. 3 points for every 1% energy saving over total building consumption. ▪ Thermal storage system ▪ Heat recovery devices ▪ Light shelves ▪ Occupancy sensors for staircases half landing and toilets ▪ Lifts with better energy efficient features such as regenerative or gearless drive system ▪ Sun pipes for natural lighting ▪ Ductless fans for basement ventilation ▪ Auto-condenser tube cleaning system ▪ Photo sensors to maximize the use of daylighting

Important notes :

(i) For features that are not listed NRB 1-10(c), the QP is required to submit the details showing the positive environmental impacts and potential energy savings of the proposed features to BCA for assessment.

(ii) The potential energy savings for the following devices are subject to the cap based on the following norm.

List of Systems/Devices	Energy Savings Cap
CO sensors	15%
Occupancy Sensors	15%
Photo Sensors	15%

Documentary Evidences

For 1-10(a)

- Calculation of the Energy Efficiency Index (EEI) in the prescribed tabulated format as shown in the worked example 1-10(a).

For 1-10(b)

- Plan layouts showing the vertical greenery provision and building elevations; and
- Calculation showing the extent of the vertical greenery provision over the east and west façade areas as shown in worked example 1-10(b).

For 1-10(c) and (d)

- Extracts of the tender specification showing the provision of the proposed energy efficient features /equipment/products and the extent of implementation where applicable;
- Technical product information on the energy efficient features used; and
- Calculation of the potential energy savings that could be reaped from the use of these energy efficient features.
- Certification details from approved local certification body

References

NUS Centre for Total Building Performance:
http://www.bdg.nus.edu.sg/buildingenergy/e_energy/audit_results.html

Worked Example 1-10(a)

(1) Determine the total annual building electricity consumption (TBEC) based on the estimated electricity consumption and usage pattern in term of operation hours of all the major energy consumption systems and equipments.
(2) Compute the Energy Efficiency Index of the building .

Background info :

Assume a proposed development with GFA of 86 000 m^2, operational hours per week is 55 hours at 100% occupancy rate. No data centre in the building.

Note that for tenant receptacle load, the nominal values shown in the following table can be adopted.

Receptacle Loads	Nominal Values
Computer intensive offices	22 W/m^2
General office areas	16 W/m^2
Large conference areas	11 W/m^2
Server/Computer rooms	540 W/m^2

Source: ASHRAE STD 90.1

Worked Example 1-10(a) – Cont'd

Table 1-10(a) : Total Building Electricity Consumption (TBEC) per year

System/ Equipment	Total Annual Building Electricity Consumption (KWh)/year
Lighting – (Air-Conditioned Space)	3094380
Lighting- (Non Air-Conditioned Space)	236321
Exterior Lighting	405800
Air-Conditioned Plant	7924425
Air System Fans	632293
Mechanical Ventilation Fans	207571
Lifts	792966
Escalators	45865
Receptacle Equipment * (@16W/m^2)	3936517
Domestic Water Pump Systems	226088
Hot Water Systems	93789
Others	-
Total :	17596015

Total annual building electricity consumption (TBEC) = 17596015 kWh/year

Therefore, the Energy Efficiency Index (EEI) of the building is as follows:

EEI = (TBEC/GFA) X (NF/ OH) *where NF is assumed to be 55 hrs/week*

= (17596015 / 86000) x (55/55)

= 204.6 kWh/m^2 /yr

Points scored for 1-10(a) = 1 point

Worked Example 1-10(b)

The same proposed development has incorporated vertical greenery systems on the east and west façade to reduce heat gain to the building.

Areas of vertical greenery systems = 2000 m^2	Percentage = 2000/4800 = 42% < 50%
Total east and west façade areas = 4800 m^2	Therefore , points scored = 0.5 point

Worked Example 1-10(c)

Example of a proposed building development using the following M&E equipment / products that are certified by the approved local certification body.

Equipment/ Products and Extent of coverage	With approved certification	Points scored
(a) All Transformers	Yes	0.5
(b) 3 out of 5 Chillers	Yes	No point (Note that provision < 90% for the same equipment type)

Worked Example 1-10(d)

Proposed building development with installation of occupancy sensors for all staircases. Assume that with occupancy sensors, the light fittings are not required for 10 hours per day and the estimated annual electricity saving is 80 kWh

If the annual electricity for staircase lighting is 360 kWh

Check Cap : 15% of annual electricity on lighting = 0.15 (360) = 54 kWh

Assume that the TBEC = 15500 kWh

Therefore, % energy savings based on cap of 15% = 54/ 15500 = 0.348 %

Points scored for 1-10(c) = 3 points for every 1 % energy saving

= 3 x 0.348= 1.05 points

NRB 1-11 RENEWABLE ENERGY

<table>
<tr><td>Objectives</td><td>Encourage the use of renewable energy sources in buildings.</td></tr>
<tr><td>Applicability</td><td>Includes all renewable energy sources</td></tr>
<tr><td>Baseline Standard</td><td>-</td></tr>
<tr><td>Requirements</td><td>Up to 20 points can be scored based on the expected energy efficiency index and percentage replacement of electricity by the renewable energy source :
<table>
<tr><th rowspan="2">Expected Energy Efficiency Index (EEI)</th><td colspan="2">Every 1 % replacement of electricity (based on total building electricity consumption) by renewable energy source (Up to 20 points)</td></tr>
<tr><th>Include tenant’s usage</th><th>Exclude tenant’s usage</th></tr>
<tr><td>≥ 30 kWh/m^2/yr</td><td>5 points</td><td>3 points</td></tr>
<tr><td>< 30 kWh/m^2/yr</td><td>3 points</td><td>1.5 points</td></tr>
</table>
Condition : The points scored for renewable energy provision shall not result in a double grade jump in the GM rating (i.e. from GM Certified to Gold^{Plus} or Gold to Platinum rating).

Note : For computation of EEI, refer to worked example 1-10(a) under NRB 1-10 – Energy Efficient Features</td></tr>
<tr><td>Documentary Evidences</td><td>• Extracts of the tender specification and plans showing the location of the renewable energy system and the extent of implementation;

• Technical product information on the salient features of the renewable energy system and the expected renewable energy generated; and

• Calculation of the percentage replacement of electricity and the total annual electricity consumption of the development.</td></tr>
<tr><td>References</td><td>-</td></tr>
</table>

(II) Other Green Requirements

Part 2 – Water Efficiency

NRB 2-1 Water Efficient Fittings
NRB 2-2 Water Usage and Leak Detection
NRB 2-3 Irrigation System & Landscaping
NRB 2-4 Water Consumption of Cooling Towers

NRB 2-1 WATER EFFICIENT FITTINGS

<table>
<tr><td>Objectives</td><td>Reduce the use of potable water by using water efficient fittings covered under the Water Efficiency Labelling Scheme (WELS).</td></tr>
<tr><td>Applicability</td><td>Applicable to all water fittings covered by the WELS as follows:
▪ Basin Taps and Mixers
▪ Sink/bib Taps and Mixers
▪ Urinals and Urinal Flush Valves
▪ Shower Taps and Mixers or Showerheads
▪ Dual-Flush Low Capacity Flushing Cisterns
Note: Water closets in public toilets fitted with flush valve and automatic flush devices are to be excluded in computation.</td></tr>
<tr><td>Baseline Standard</td><td>As specified under Water Efficiency Labelling Scheme (WELS).</td></tr>
<tr><td>Requirements</td><td>Up to 10 points can be scored based on the number and water efficiency rating of the fitting type used.
<table>
<tr><th>WELS Rating</th><th>Water Efficiency</th><th>Weightage for Point Allocation</th></tr>
<tr><td>✓✓</td><td>Very Good</td><td>8</td></tr>
<tr><td>✓✓✓</td><td>Excellent</td><td>10</td></tr>
</table></td></tr>
<tr><td>Documentary Evidences</td><td>• Extracts of the tender specification showing all the water fitting provisions for the development;
• Water fitting schedules showing the numbers, types and the approved rating of the proposed fittings in the prescribed tabulated format shown in the worked example; and
• Calculation showing the percentage of proposed water fittings that are approved under WELS.</td></tr>
<tr><td>References</td><td>For more information about WELS, refer to
http://www.pub.gov.sg/wels/Pages /default.aspx</td></tr>
</table>

Worked Example 2-1

Example of a water fitting schedule showing the numbers, types and the approved rating of the proposed fittings.

Table 2-1 –Computation of the percentage of water fittings under WELS

Ref	Water Fitting Type	WELS rating		Mandatory Requirement MWELS	Total no. based on fitting type
		Excellent	Very Good	Good	
1	Shower taps and mixers	0	60	0	60
2	Basin taps and mixers	100	10	100	210
3	Sink/bib taps and mixers	0	0	0	-
4	Dual-flush low capacity flushing cisterns	0	80	0	80
5	Urinals and urinal flush valves	50	0	0	50
Total no. based on rating (A)		150	150	100	∑A =400
Weightage (B)		10	8	0	0
Total (AXB)		1500	1200	0	∑(AxB) =2700

Points scored = ∑(AxB) / ∑A

= 2700/400

= 6.75 points

NRB 2-2 WATER USAGE AND LEAK DETECTION

Objectives	Promote the use of private meters and leak detection system for better control and monitoring of water usage.
Applicability	Applicable to sub-metering provisions for major water uses of the building developments.
Baseline Standard	-
Requirements	2-2(a) 1 point can be scored if private meters are provided for all major water uses i.e. irrigation system, cooling towers and tenant's usage where applicable. 2-2(b) 1 point can be scored if all private meters are linked to the Building Management System (BMS) for monitoring and leak detection. The BMS should have specific alert features that can be set and triggered to detect the possibility of water leakage during operation.
Documentary Evidences	For 2-2(a) • Extracts from the tender specification stating the provision of sub-metering for all major water uses. • Schematic drawings of cold water distribution system showing the location of the sub-metering provided. For 2-2(b) • Extracts from the tender specification and schematic drawings showing the location of sub-metering and its linkage to the BMS.
References	-

NRB 2-3 IRRIGATION SYSTEM AND LANDSCAPING

Objectives	Reduce potable water consumption by provision of suitable systems that utilise rainwater or recycled water and use of plants that require minimal irrigation to reduce potable water consumption.
Applicability	Applicable to development with landscaping provision.
Baseline Standard	-
Requirements	2-3(a) 1 point can be scored for the use of non-potable water including rainwater for landscape irrigation. 2-3(b) 1 point can be scored if more than 50% of the landscape areas are served by water efficient irrigation system with features such as automatic sub-soil drip irrigation system with rain sensor control. 2-3(c) 1 point can be scored if at least 80% of the landscape areas consist of drought tolerant plants or plants that require minimal irrigation.
Documentary Evidences	<u>For 2-3(a)</u> • Extracts of the tender specification showing how the non-potable water source is to be provided; • Relevant drawings showing the location and design of the non-potable water source; and • For rainwater harvesting and storage system, approval letter from PUB is to be provided. <u>For 2-3(b)</u> • Extracts of the tender specification showing the provision and details of water efficient irrigation system; • Relevant layout plans showing the overall landscape areas and the areas that would be served using the system; and • Calculation showing the percentage of the landscape areas that would be served using the system. <u>For 2-3(c)</u> • Relevant layout plans showing the overall landscape areas and the areas that use drought tolerant plants or plants that require minimal irrigation; and • Calculation showing the percentage of the landscape areas that use drought tolerant plants or plants that require minimal irrigation.
References	The list of drought tolerant or resistant plant species may be obtained from the online website: http://florafaunaweb.nparks.gov.sg/.

NRB 2-4 WATER CONSUMPTION OF COOLING TOWERS

Objectives	Reduce potable water consumption for cooling purpose.
Applicability	Applicable to building developments with water-cooled central chillers systems, water cooled package units and air-cooled VRF systems.
Baseline Standard	-
Requirements	2-4(a) 1 point can be scored for the use of cooling tower water treatment system that can achieve 7 or better cycles of concentration at acceptable water quality. 2-4(b) 1 point can be scored for the use of NEWater or on-site recycled water from approved sources to meet the water demand for cooling purpose.
Documentary Evidences	<u>For 2-4(a)</u> • Extracts of the tender specification showing the requirements to incorporate with the cooling tower designs to achieve seven cycles of concentration; • Details showing how the cooling towers have been designed to achieve at least seven cycles of concentration; and • Relevant drawings showing the location of the cooling towers and other supporting systems that are required to achieve the designed concentration. <u>For 2-4(b)</u> • Extracts of the tender specification showing how the NEWater or other recycled water source is to be provided.
References	-

(II) Other Green Requirements

Part 3 – Environmental Protection

- **NRB 3-1 Sustainable Construction**
- **NRB 3-2 Sustainable Products**
- **NRB 3-3 Greenery Provision**
- **NRB 3-4 Environmental Management Practice**
- **NRB 3-5 Green Transport**
- **NRB 3-6 Refrigerants**
- **NRB 3-7 Stormwater Management**

NRB 3-1 SUSTAINABLE CONSTRUCTION

<table>
<tr><td>Objectives</td><td>Encourage the adoption of building designs, construction practices and materials that are environmentally friendly and sustainable.</td></tr>
<tr><td>Applicability</td><td>Generally applicable to all building developments.</td></tr>
<tr><td>Baseline Standard</td><td>-</td></tr>
<tr><td>Requirements</td><td>
3-1(a) Up to 5 points can be scored with the use of (i) Green Cements and (ii) Recycled Concrete Aggregates (RCA) and Washed Copper Slag (WCS) as detailed in the following para 3-1(a)(i) and 3-1(a)(ii) :

3-1(a)(i) 1 point can be scored for use of Green Cements with approved industrial by-product (such as Ground Granulated Blastfurnace Slag (GGBS), silica fume, fly ash) to replace Ordinary Portland Cement (OPC) by at least 10% by mass for superstructure applications

3-1(a)(ii) Up to 4 points can be scored for use of Recycled Concrete Aggregates (RCA) and Washed Copper Slag (WCS) from approved sources to replace coarse and fine aggregates for concrete production of main building elements.

1 point for every incremental of 0.5 times (0.5x) of the usage requirement (Up to 2x)

<table>
<tr><th>Quantity of RCA /WCS (tons)</th><th>Points Allocation</th></tr>
<tr><td>≥ 0.5 x usage requirement</td><td>1 point</td></tr>
<tr><td>≥ 1.0 x usage requirement</td><td>2 points</td></tr>
<tr><td>≥ 1.5 x usage requirement</td><td>3 points</td></tr>
<tr><td>≥ 2.0 x usage requirement</td><td>4 points</td></tr>
</table>

where usage requirement = 0.03 x Gross Floor Area (GFA in m^2)

The RCA/WCS quantity (in tons) used for the concrete production of main building elements can be derived from the concrete volume comprising these recycled materials and based on the following conversion factor:

RCA (tons)= 1.0 (tons/m^3) X (concrete vol in m^3) X (RCA replacement rate)%

WCS (tons)= 0.7(tons/m^3) X (concrete vol in m^3) X (WCS replacement rate)%

Important notes :
For structural building elements, the use of RCA and WCS shall be limited to maximum 10% replacement by mass of coarse/fine aggregates or as approved by the relevant authorities
</td></tr>
</table>

Requirements

Cont'd

3-1(b) Up to 5 points are allocated to encourage more efficient concrete usage for building components based on the Concrete Usage Index (CUI) of the project.

Table 3-1 (b) Points allocation for project CUI

Project CUI (m^3/m^2)	Points Allocation
≤ 0.70	1
≤ 0.60	2
≤ 0.50	3
≤ 0.40	4
≤ 0.35	5

Note : *Concrete Usage Index* (CUI) is 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-structural works such as basements and foundations. CUI is defined as the volume of concrete in cubic metres needed to cast a square metre of constructed floor area. It is expressed as:

$$\text{Concrete Usage Index} = \frac{\text{Concrete Volume in } m^3}{\text{Constructed Floor Area in } m^2}$$

Prerequisites

Minimum score under NRB 3-1 Sustainable Construction

Green Mark Gold^{Plus} ≥ 3 points
Green Mark Platinum ≥ 5 points

Documentary Evidences

For 3-1(a)(i) & a(ii)

- Extract of tender specification and concrete mix design showing the detailed usage of Green Cements
- Extract of tender specification and concrete mix design showing the detailed usage of RCA and WCS.
- Evidence of site delivery of these materials where applicable.

For 3-1(b)

- Architectural and structural plan layout, elevation and sectional plans showing the type of wall system used, the dimensions and sizes of all the building and structural elements; and
- Summary showing the quantity of concrete for each floor level in the prescribed tabulated format shown in worked example 3-1(b). The calculation should include all the building elements as listed in the worked example and the derivation of the concrete volume should be detailed and made available for evaluation.

References

-

Worked Example 3-1(a)

Proposed development comprises a 3 storey office block and the following details :

Gross Floor Area (GFA) = 8,000 m^2

Total Concrete Usage with replacement of coarse and fine aggregate with recycled concrete aggregate and washed copper slag = 2 800 m^3

(i) Use of Green Cements to replace 10% of OPC for superstructural works

Points scored for 3-1(a)(i) = 1 point

(ii) Use of recycled concrete aggregates (RCA) to replace coarse aggregate and the use of washed copper slag (WCS) to replace fine aggregate for main building elements with a replacement rate of 10%.

Usage requirement = 0.03 x GFA = 0.03 x 8000 = 240 tons

RCA (tons) = 1.0 (tons/m^3) X (concrete vol in m^3) X (RCA replacement rate)%

= 1.0 (2 800)(10%) = 280 tons > 240 tons

Points scored for RCA under 3-1(a)(ii) = 2 points

WCS (tons) = 0.7(tons/m^3) X (concrete vol in m^3) X (WCS replacement rate)%

= 0.7 (2 800)(10%) = 196 tons > 120 tons

Points scored for WCS under 3-1(a)(ii) = 1 point

Therefore, total points scored for 3-1(a) = 1(for green cement) + 2(for RCA) + 1(for WCS) = 4 points

Worked Example 3-1(b)

Proposed development comprises a 30 storey office block with two basement carparks and the following details :

Concrete usage for the superstructure	**Constructed floor areas**
For 1st storey = 1035.5 m^3 From 2nd to 30th storey = 27 060 m^3 (including roof level)	For 1st storey = 2200 m^2 From 2nd to 30th storey = 57798 m^2 (including roof level)
Therefore, Total concrete usage = 28 095.5 m^3	Therefore, Total constructed floor areas = 59998 m^2

Note : The concrete usage for foundation and two basements are not required to be included.

Concrete Usage Index CUI = $\frac{28095.5}{59998}$ = 0.47 m^3/m^2

Refer to the following Table 3-1(b) for more details

Based on the point allocation shown in Table 3-1(b)

CUI of 0.47 m^3/m^2 < 0.5 m^3/m^2

Therefore, point scored = 3 points

Worked Example 3-1(b) – Cont'd

Table 3-1(b) – Concrete Usage Index

COMPUTATION OF CONCRETE USAGE INDEX				**NON-RESIDENTIAL BLDG**
Project Reference No.: AXXXX-00001-2007			**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	Precast
	1.2 Beams	300x500, 200x500	320	Precast
	1.3 Slabs	200,225,250	400	Post – tensioned
	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	Nil	0	–
	1.8 External walls – non-loadbearing walls	125	22	RC
	1.9 Internal walls – loadbearing walls	200	55	RC
	1.10 Internal walls – non-loadbearing walls	100	10	Light weight concrete
	1.11 Others (kerbs, ramps, services risers, etc)	Not required	15	RC
	Total volume of concrete for this storey (m^3)		1035.5	
	Total constructed floor area for this storey (m^2)		2200	
2	**Typical floor layout**			
	2.1 Columns	300x300, 400x400	115	Precast
	2.2 Beams	300x500, 200x500	301.5	Precast
	2.3 Slabs	200,225,250	320	Post – tensioned
	2.4 Staircases	175	93.5	Precast
	2.5 Suspended structures like planter boxes, bay windows, ledges etc	Nil	0	–
	2.6 Parapets	Nil	0	–
	2.7 External walls - loadbearing walls	Nil	0	–
	2.8 External walls – non-loadbearing walls	125	22	RC

Worked Example 3-1(b) – Cont'd

COMPUTATION OF CONCRETE USAGE INDEX			NON-RESIDENTIAL BLDG
Project Reference No.: AXXXX-00001-2007		**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 ***
2	**2nd storey to 30th storey (Typical floor layout)**		
2.9 Internal walls – loadbearing walls	250,300	50	RC
2.10.Internal walls – non-loadbearing walls	Nil	0	–
2.11 Others (kerbs, ramps, services risers etc)	Nil	0	–
Volume of concrete for one storey (m^3)		902	
Constructed floor area for one storey		1926.6	
Total volume of concrete for 2nd to 30th storey (including roof level)		902 X 30 = 27060	
Total constructed floor area for 2nd to 30th storey (m^2) (including roof level)		1926.6 x 30 = 57798	
Total volume of concrete for this project (m^3)		28095.5	
Total constructed floor area for this project (m^2)		59998	
Concrete Usage Index (CUI in m^3/m^2)		0.47	

*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

Important notes : *The quantities of the concrete for all the structural and non-structural elements for each floor level are computed. All the elements listed in the table such as columns, beams, slabs, suspended structures (like planter boxes, bay windows and ledges etc) , parapets, walls and others (service risers, kerbs, ramps etc) are to be included. The concrete usages for foundation and basement works are excluded in CUI computation.*

NRB 3-2 SUSTAINABLE PRODUCTS

<table>
<tr><td>Objectives</td><td>Encourage the use of products that are environmentally friendly and sustainable.</td></tr>
<tr><td>Applicability</td><td>Applicable to non-structural and architectural building components.</td></tr>
<tr><td>Baseline Standard</td><td>-</td></tr>
<tr><td>Requirements</td><td>Up to 8 points are allocated to encourage the use of appropriate environmentally friendly products that are certified by approved local certification body. The products used should have considerably contributions in the overall environmental sustainability standard of the development. Points scored will be based on the weightage, extent of coverage and impact.

The weightage given will be based on the extent of environmental friendliness as determined by the approved local certification body and are subject to BCA's evaluation.

<table>
<tr><th>Extent of Environmental Friendliness of Products</th><th>Weightage for Point Allocation</th></tr>
<tr><td>Good</td><td>0.5</td></tr>
<tr><td>Very Good</td><td>1.5</td></tr>
<tr><td>Excellent</td><td>2</td></tr>
</table>

The use of environmental friendly products used for the main building elements or functional spaces will be considered as high impact (1 point) if the quantities used by percentage are more than 50% (i.e. extent of coverage) as compared to the total quantities used for the same intended purpose. Items that do not meet the minimum coverage or are used in other common areas, external works etc will be considered as low impact (0.5 point).

Note : The point allocated for low volatile organic compound (VOC) paints and adhesives certified by approved local certification body can be found in NRB 4-3 and hence shall not be included in the scoring for NRB 3-2.</td></tr>
<tr><td>Prerequisites</td><td>Minimum score under NRB 3-2 Sustainable Products

Green Mark Gold^{Plus} ≥ 3 points
Green Mark Platinum ≥ 4 points</td></tr>
<tr><td>Documentary Evidences</td><td>• Extracts from the tender specification and drawings showing the requirements to incorporate the environmental friendly products that are certified with approved local certification body;

• Certification details from approved local certification body such as the material certification standards, rating and product reference; and

• Technical product information and delivery records.</td></tr>
</table>

References

For more info on product certification, refer to

http://www.sgbc.sg/green-certifications/product-certifications/
http://www.greenlabel.sg/

Worked Example 3-2(i)

1. Determine if the environmental friendly products selected are certified with approved certification body and the product rating.
2. Check if the products used are meant for main building elements or functional spaces and determine the quantities used for these products as compared to the total quantities required for the same intended purpose or applicable areas. It can be considered as high impact if the quantities of the products used constitute more than 50% of the total requirement. Examples are internal drywall partitions in every functional space unit, carpets for office spaces etc for more than 50% of the total quantities or applicable areas. If the selected products are used for less than 50% of the total quantities or applicable areas, it would be considered as low impact.
3. Products that are meant for common areas and external works such as toilets, lobbies and landscaping areas and are adopted in more than 50% of the applicable areas would be considered as low impact.

Example of a proposed development using the following products that are rated to be 'Good' by the approved local certification body.

Products and Extent of coverage		With approved certification	Points allocated based on impact (A)	Weightage based on rating (B)	Points scored (AxB)
(a)	Carpets for all office spaces	Yes	1	0.5	0.5
(b)	Panel boards as internal partition for more than 50% of office spaces	Yes	1	0.5	0.5
(c)	Precast concrete road kerbs	Yes	0.5	0.5	0.25

Points scored for 3-2 (i) = 0.5+0.5+0.25 = 1.25 points

Worked Example 3-2(ii)

Note : Certain products have more environmentally friendly features than others. Other than recycled materials, they may have added features like low VOC assembly or manufactured with resource efficient processes, durability etc that will render the products more environmental friendly than others. If the certified products selected are more environmental friendly and are given a better rating by the approved local certification body, a higher weightage can be considered in point scoring.

Example of a proposed development with the following provisions:

(a) Use of carpets for all office spaces. Product is not certified.

(b) Use of panel boards as internal partitions for more than 50% of the office spaces and the product is rated to be 'Very Good' by the approved certification body.

(c) Precast concrete road kerbs. Product is rated as 'Good' by approved local certification body.

Worked Example 3-2(ii)

Cont'd

(d) Use of roof waterproofing coating. Product is rated as 'Very Good' by approved local certification body.

(e) Use of wooden doors for all areas. Product is rated as 'Excellent' by approved local certification body.

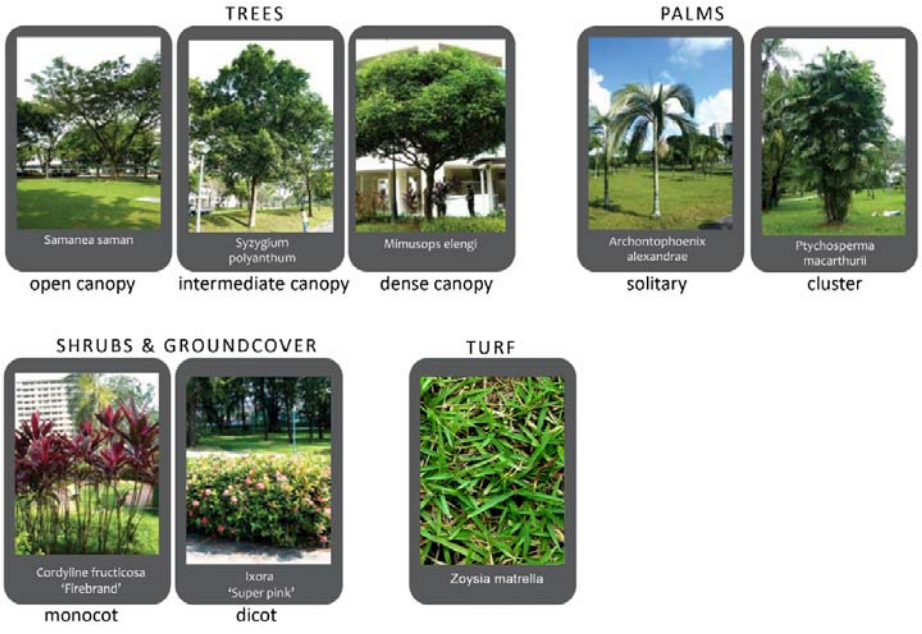
Products and Extent of coverage		With approved certification	Points allocated based on impact (A)	Weightage based on rating (B)	Points scored (AxB)
(a)	Carpets for all office spaces	No	NA	NA	0
(b)	Panel boards as internal partition for more than 50% of office spaces	Yes	1	1.5	1.5
(c)	Precast road kerbs	Yes	0.5	0.5	0.25
(d)	Roof waterproofing	Yes	0.5	1.5	0.75
(e)	Wooden doors for all areas	Yes	1	2	2

Therefore, points scored for 3-2 (ii) = 1.5 +0.25+0.75+2 = 4.5 points

NRB 3-3 GREENERY PROVISION

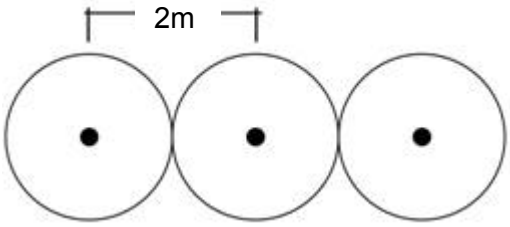
Objectives	Encourage greater use of greenery and restoration of existing trees to reduce heat island effect.
Applicability	Applicable to building developments with landscaping areas.
Baseline Standard	-
Requirements	3-3(a) Up to 6 points can be scored for the provision of greenery within the developments including roof top/ sky garden and green roof. Green Plot Ratio (GnPR) is calculated by considering the 3D volume covered by plants using the following Leaf Area Index (LAI)

Plant group	Trees	Palms	Shrubs & Groundcover	Turf
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	Turf = 2.0
Area	All = 60 m^2	Solitary = 20 m^2 Cluster = 17 m^2	Planted area	Planted area



Green Plot Ratio (GnPR) = Total Leaf Area / Site Area

GnPR	Points Allocation
0.5 to < 1.0	1
1.0 to < 1.5	2
1.5 to < 3.0	3
3.0 to < 3.5	4
3.5 to < 4.0	5
≥ 4.0	6

	3-3(b) 1 point for restoration, conservation or relocation of existing trees on site. 3-3(c) 1 point for the use of compost recycled from horticulture waste.
Documentary Evidences	<u>For 3-3(a)</u> • Plan layouts 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 sub category and LAI values); and • Calculation showing the extent of the greenery provision in the prescribed tabulated format as in worked example 3-3(a). <u>For 3-3(b)</u> • Site layouts showing the existing and final locations (where applicable) and number of the trees to be restored or conserved or relocated. <u>For 3-3(c)</u> • Extracts of the tender specification showing the requirements to use compost recycled from horticulture waste.
Exceptions	**TREES AND PALMS SPACING (CENTRE-TO-CENTRE)** (a) 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 (in m^2).  **COLUMNAR TREES** (b) 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 brachiata . Gnetum gnemon
References	The plant species sub categories and its LAI values may be obtained from the online website: http://florafaunaweb.nparks.gov.sg/

Worked Example 3-3(a)

(1) Determine the number of trees, palms and the areas for shrub and turfs and other greenery area

(2) The Leaf Area Index (LAI) of the individual plant species and its canopy area are predetermined design parameters applicable for all developments.

(3) The plant species sub categories and its LAI values can be obtained from the online website: http://florafaunaweb.nparks.gov.sg/ (see example below) by searching the common / scientific names of the plants.

(4) Compute the green areas as shown in the Table 3-3(a) below

Table 3-3(a) – Calculation of the Green Plot Ratio

Category	Sub category	(A)	(B)	(C)	(A) x (B) x (C)
		LAI value	Canopy Area	Qty/ Planted Area	Leaf Area
Trees (no.)	Open Canopy	2.5	60 m^2	0 no.	0
	Intermediate Canopy	3.0	60 m^2	8 no.	1440
	Dense Canopy	4.0	60 m^2	12 no.	2880
	Intermediate columnar canopy *	3.0	12 m^2	5 no.	180
Palms (no.or m^2)	Solitary	2.5	20 m^2	10 no.	500
	Solitary (trunk-to trunk ≤ 5m)	2.5	NA	20 m^2	50
	Cluster	4.0	17 m^2	5 no.	340
Shrubs (m^2)	Monocot	3.5	NA	0 m^2	0
	Dicot	4.5	NA	20 m^2	90
Turf (m^2)	Turf	2.0	NA	90 m^2	180
Vertical Greenery (m^2)	-	2.0	NA	10 m^2	20
*Note : * refer to the exceptions*				**Total Leaf Area :**	**5680**

Note: Green roof landscaping would be calculated as per illustrated above

Assume site area is 4000m^2

Green Plot Ratio (GnPR) = total leaf area / site area
= 5680 / 4000 = 1.42 < 1.5

where GnPR = 1 to < 1.5

Therefore, points scored for 3-3(a) = 2 points

NRB 3-4 ENVIRONMENTAL MANAGEMENT PRACTICE

Objectives	Encourage the adoption of environmental friendly practices during construction and building operation.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	3-4(a) 1 point can be scored if effective implementation of environmental friendly programmes including monitoring and setting targets to minimise energy use, water use and construction waste are in place. 3-4(b) 1 point can be scored if main builder has good track records in the adoption of sustainable, environmentally friendly and considerate practices during construction such as the Green and Gracious Builder Award. 3-4(c) 1 point can be scored if the building quality is assessed under the Construction Quality Assessment System (CONQUAS). 3-4(d) Up to 1 point if the developer, main builder, M & E consultant and architect are ISO 14000 certified. 0.25 point is allocated for each firm that is certified. 3-4(e) Up to 1 point if the project team comprises one Certified Green Mark Manager (GMM)(0.5 point), one Certified Green Mark Facility Manager (GMFM)(0.5 point) or one Certified Green Mark Professional (GMP)(1 point). 3-4(f) 1 point can be scored for the provision of building users' guide with details of the environmental friendly facilities and features within the building and their uses in achieving the intended environment performance during building operation. 3-4(g) 1 point can be scored for the provision of facilities or recycling bins for collection and storage of different recyclable waste such as paper, glass, plastic etc.
Documentary Evidences	For 3-4(a) • Extracts of the tender specification showing the requirements for builder to provide and implement environmental friendly programmes to minimise energy use, water use and construction waste; and • Details of the environmental friendly programmes implemented. For 3-4(b) • A certified true copy of the main builder's Green and Gracious Builder Award; or • Details of track records in the adoption of sustainable, environmentally friendly and considerate practices during construction. For 3-4(c) • Extracts of the tender specification showing the requirement to adopt CONQUAS.

	For 3-4(d) • A certified true copy of the ISO 14000 certificate of developer, main contractor, M & E consultant and architect where applicable. For 3-4(e) • A certified true copy of the certificate of Green Mark Manager or Green Mark Facility Manager and Green Mark Professional where applicable and a confirmation of their involvement and contribution in the project. For 3-4(f) • A copy of the building users' guide containing the details of the environmental friendly facilities and features within the building and their uses in achieving the intended environment performance during building operation. For 3-4(g) • Plan layout showing the location of the recycling bins for collection and storage of different recyclable waste.
References	-

NRB 3-5 GREEN TRANSPORT

Objectives	Promote environmental friendly transport options and facilities to reduce pollution from individual car use.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	3-5(a) 1 point can be scored for design that provides good access (< 500m walking distance) to public transport networks such as MRT/LRT stations and bus stops. 3-5(b) 1 point can be scored for provision of covered walkway to facilitate connectivity and use of public transport. 3-5(c) 1 point can be scored for provision of electric vehicle charging stations and priority parking lots within the development. (*Minimum provision : 1 charging station and priority parking lot for every 100 carpark lots, round up to the nearest hundreds) (Cap at 5 charging stations and priority parking lots).* 3-5(d) Up to 1 point can be scored for the provision of covered/sheltered bicycles parking lots with adequate shower facilities *(Minimum provision of 10 bicycle parking lots; Cap at 50 bicycle parking lots where applicable)* : o 1 point if the number of bicycles parking lots is at least equivalent to 3% of Gross Floor Areas (GFA)/10 o 0.5 point if the number of bicycles parking lots is at least equivalent to 1.5% of GFA/10
Documentary Evidences	<u>For 3-5(a)</u> • Site layout plan in the context of the surrounding area showing the location of the development site and the location of the MRT/LRT stations and bus stops. <u>For 3-5(b)</u> • Site layout plan showing the connection of covered walkway from the development to the MRT/LRT stations or bus stops. • Extracts of the tender specification showing the requirement to provide covered walkway <u>For 3-5(c)</u> • Extracts of the tender specification showing the requirement to provide electric. vehicle charging stations.. <u>For 3-5(d)</u> • Extracts of the tender specification showing the requirement to provide covered/sheltered bicycles parking lots, shower and changing facilities for the development and the quantity and location of bicycle lots provided.
References	-

Worked Example **3-5(d)**	Example 1 A proposed building development with Gross Floor Areas (GFA) of 5,000 m^2. Check on the minimum requirement For point scoring of 1 point : Minimum number of bicycle parking lots = 3% x $\frac{5000}{10}$ = 15 lots (with adequate shower facilities) (1 point) For point scoring of 0.5 point: Minimum number of bicycle parking lots = 1.5% x $\frac{5000}{10}$ ~ 8 lots (with adequate shower facilities) (0.5 point) Note : There is a minimum number of 10 bicycle parking lots Therefore 1 point will be scored if the number of bicycles parking lots provided is 20 lots *(with adequate shower facilities).* 0.5 point will be scored if the number of bicycles parking lots provided is 10 lots *(with adequate shower facilities).* Example 2 A proposed building development with Gross Floor Areas (GFA) of 40,000 m^2 Minimum number of bicycle parking lots = 3% x $\frac{40000}{10}$ = 120 lots (with adequate shower facilities) (1 point) Minimum number of bicycle parking lots = 1.5% x $\frac{40000}{10}$ = 60 lots (with adequate shower facilities) (0.5 point) 1 point will be scored if the number of bicycles parking lots provided is 50 lots *(with adequate shower facilities).* Note : There is a cap at 50 bicycles parking lots

NRB 3-6 REFRIGERANTS

Objectives	Reduce the potential damage to the ozone layer and the increase in global warming caused by the release of ozone depleting substances and greenhouse gases.
Applicability	Generally applicable to all building developments with air-conditioning systems.
Baseline Standard	-
Requirements	3-6(a) 1 point can be scored for the use of refrigerants with ozone depleting potential(ODP) of zero or with global warming potential (GWP) of less than 100. 3-6(b) 1 point can be scored for the use of refrigerant leak detection system at critical areas of plant rooms containing chillers and other equipments with refrigerants.
Documentary Evidences	<u>For 3-6(a)</u> • Extracts from the tender specification showing the requirement for all refrigerants to have an ODP of zero or GWP of less than 100. <u>For 3-6(b)</u> • Extracts from tender specification showing the requirement to incorporate a refrigerant leak detection system.
References	-

NRB 3-7 STORMWATER MANAGEMENT

Objectives	Encourage the treatment of stormwater runoff through provision of infiltration or design features before discharge to public drains.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	Up to 3 points can be scored for the treatment of stormwater runoff. • 3 points for treatment of run-off from more than 35% of total site area or paved area • 2 points for treatment of run-off from more than 10% to up to 35% of total site area • 1 point for treatment of run-off from up to 10% of total site area Note: (1) The treatment of stormwater runoff shall be through provision of infiltration features or design features as recommended in PUB's ABC Water design Guidelines. (2) Points can be scored if the treatment of run-off covers more than 35% of total paved area of the site. If the percentage of total paved area is less than 35%, points can only be scored based on total site area.
Documentary Evidences	• Site layout plans indicating the total site area, total paved area within the site as well as the total catchment areas where runoff are treated through the provision of ABC Waters design features. Other information such as the total paved areas within the catchment areas, treatment areas and the hydraulic retention time of the design features are to be included where applicable. • Drainage plan, schematic plan, location plan and section details of ABC Waters Design features such as the specification of filtration layer, transition layer and drainage layer, sub-soil drainage system, overflow arrangement, plant list etc. Relevant design calculations and simulation/ modeling results are to be provided where applicable.
References	Public Utilities Board (PUB), Singapore publication on - ABC Waters Design Guidelines - Engineering Procedure for ABC Waters Design Features For more information about ABC Waters Design Guidelines, refer to http://www.pub.gov.sg/abcwaters/abcwatersdesignguidelines/Pages/ABCDesignGuidelines.aspx

Worked Example 3-7	A development has a site area of 1000 m^2 that includes 500 m^2 paved area. It was planned that 300 m^2 of the site area would be treated through a bio-retention system designed according to PUB's ABC Waters design guidelines. <u>Based on total site area</u> Percentage of run-off being treated = 300/1000 x 100% = 30% Points scored = 2 points <u>Based on paved area</u> If 200 m^2 out of the 300m^2 catchment area treated, was paved Percentage of run-off being treated = 200/500 x 100% = 40% Points scored = 3 points Therefore, points scored for 3-7 = 3 points

(II) Other Green Requirements

Part 4 – Indoor Environmental Quality

NRB 4-1 THERMAL COMFORT

Objectives	Recognise buildings that are designed with good thermal comfort.
Applicability	Generally applicable to all building developments with air-conditioning systems.
Baseline Standard	-
Requirements	2 points can be scored if the air-conditioning systems are designed to allow for cooling load variations due to fluctuations in ambient air temperature and to maintain consistent indoor conditions for thermal comfort. Indoor temp between 24° C to 26 ° C Relative Humidity < 65%
Documentary Evidences	Extracts of the tender specification showing the requirement to design the air-conditioning systems that would provide consistent indoor conditions for thermal comfort as stated in the above requirement.
References	-

NRB 4-2 NOISE LEVEL

Objectives	Recognise buildings that are designed to control and keep the background noise in occupied spaces at levels appropriate to the intended use of the spaces.
Applicability	Generally applicable to all building developments.
Baseline Standard	SS 553 – Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings.
Requirements	1 point can be scored if the occupied spaces in buildings are designed with the recommended ambient sound levels stated in SS 553.
Documentary Evidences	• Extracts of the tender specification showing the requirement to design the occupied space with the ambient sound levels to the recommendation stated in SS 553 ; and • Detailed analysis, calculations and/or measurements to ensure that the designed ambient sound levels are met.
References	-

NRB 4-3 INDOOR AIR POLLUTANTS

Objectives	Minimise airborne contaminants, mainly from inside sources to promote a healthy indoor environment.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	4-3(a) 1 point can be scored for the use of low volatile organic compounds (VOC) paints certified under approved local certification body for at least 90% of the internal wall areas. 4-3(b) 1 point can be scored for the use of adhesives certified by approved local certification body for at least 90% of the applicable building works or areas.
Documentary Evidences	<u>For 4-3(a)</u> • Extracts of the tender specification showing the requirement to use low VOC paints that are certified by approved local certification body. • Technical Product Information <u>For 4-3(b)</u> • Extracts of the tender specification showing the requirement to use adhesive with low emission formaldehyde and are certified under approved local certification body. • Technical Product Information
References	-

NRB 4-4 INDOOR AIR QUALITY (IAQ) MANAGEMENT

Objectives	Ensure building ventilation systems are designed and installed to provide acceptable IAQ under normal operating conditions.
Applicability	Applicable to air-conditioned buildings.
Baseline Standard	-
Requirements	4-4(a) 1 point can be scored for the provision of filtration media and differential pressure monitoring equipment in Air Handling Units (AHU) in accordance with the guidelines given in SS 554: Clause 4.3.4.5 & Annex E. 4-4(b) 1 point can be scored for implementing effective IAQ management plan to ensure that building ventilation systems are clean and free from residuals left over from construction activities. Internal surface condition tests for ACMV system are to be included. Refer to guidelines given in SS554: Clause 4.6 & Annex F.
Documentary Evidences	<u>For 4-4(a)</u> • Extracts of the tender specification showing the requirement of the filter media and pressure monitoring equipment; • Technical product information which should include the minimum efficiency reporting value (MERV) parameters of the filters; and • Technical product information of the differential pressure monitoring equipment. <u>For 4-4(b)</u> • Extracts of the tender specification showing the requirement for builder to provide and implement effective IAQ management and the details of the management plan; and • Test result of the internal surface condition testing for ACMV systems
References	

NRB 4-5 HIGH FREQUENCY BALLASTS

Objectives	Encourage the use of high frequency ballasts in fluorescent luminaries to improve the workplace lighting quality.
Applicability	Generally applicable to workplace such as offices, classrooms and training rooms and the like.
Baseline Standard	-
Requirements	2 points can be scored for the use of high frequency ballasts in the fluorescent luminaries if it is adopted in at least 90% of the applicable areas that are served by fluorescent luminaries.
Documentary Evidences	• A summary sheet listing all fluorescent luminaries used for the developments and those with high frequency ballasts; and • Extracts of the tender specification showing the requirement to have high frequency ballasts are to be used in all fluorescent luminaries listed.
References	-

(II) Other Green Requirements

Part 5 – Other Green Features

NRB 5-1 Green Features and Innovations

NRB 5-1 OTHER GREEN FEATURES

Objectives	Encourage the use of green features that are innovative and have positive environmental impact on water efficiency, environmental protection and indoor environmental quality of the buildings.
Applicability	Generally applicable to all building developments.
Baseline Standard	-
Requirements	Up to 7 points are awarded for the use of the following green features depending on their potential environmental benefits or reduced environmental impacts. <u>Water Efficiency</u> (i) Use of self cleaning façade system • 2 points for more than 75% of the applicable facade areas • 1 point for more than 50% of the applicable facade areas • 0.5 point for at least 25% of the applicable facade areas (ii) Use of grey water recycling system • 2 points for all blocks of the development • 1 point for at least one block of the development (iii) Recycling of AHU condensate • 1 point for more than 75% of the AHU condensate • 0.5 point for at least 50% of the AHU condensate (iv) Provision of system to recycle surface runoff from the vertical green wall and sky garden • 1 point for at least 25% of the green areas • 0.5 point for less than 25% of the green areas (v) 0.5 point for the use of air-cooled variable refrigerant flow (VRF) system as the main air-conditioning system. <u>Environmental Protection</u> (i) Provision of green roof and roof top garden • 1 point for more than 50% of the roof areas • 0.5 point for at least 25% of the roof areas (ii) Provision of vertical greening • 1 point for more than 50% of the applicable wall areas • 0.5 point for at least 25% of the applicable wall areas (iii) 1 point for the provision of double refuse chutes for separating recyclable from non-recyclable waste. (iv) 0.5 point for the use of non-chemical termite treatment system. (v) 0.5 point for the provision of at least 5 nos. of compost bins to recycle organic waste.

	(vi) 0.5 point for the use of non-chemical water treatment system for swimming pools. (vii) Conservation of existing building structure or building envelopes (by areas). • 2 points for conserving more than 50% of the existing structure or building envelope • 1 point for conserving at least 25% of the existing structure or building envelope (viii) Buildable design with development's buildability scores (BScore) above the prevailing minimum requirement (Refer to COP on Buildable Design). • 1 point for BScore > 5 points above minimum requirement • 0.5 point for BScore > 3 to ≤ 5 points above minimum requirement (ix) Calculation of carbon footprint of the development comprising energy usage data of production and on-site construction of building materials listed in the prescribed form. • 1 point for the submission of complete carbon footprint calculation for all building materials listed and in the prescribed format or a complete carbon footprint report of the development prepared by an independent carbon consultant • 0.5 point for the submission of carbon footprint calculation for any four building materials listed and in the prescribed format (x) 1 point for the computation of Concrete Usage Index (CUI) of the building development. (xi) Adoption of demolition protocol to maximise resource recovery of demolition materials for reuse or recycling. • 2 points for recovery rate of more than 35% crushed concrete waste to be sent to the approved recyclers with proper facilities • 1 point for recovery rate of at least 20% crushed concrete waste to be sent to the approved recyclers with proper facilities *Refer to details at http://www.bca.gov.sg/SustainableConstruction/sc_demolition.html for compliance.* <u>Indoor Air Quality</u> (i) 1 point for the use of pneumatic waste collection system. (ii) 0.5 point for the use of Ultraviolet light-C band (UV) emitters in <u>all</u> air handling units (AHUs) to improve indoor air quality. <u>Others</u> (i) 0.5 point for the use of siphonic rainwater discharge system at roof. (ii) 0.5 point for the provision of carpark guidance system. ***Important notes :*** *For features that are not listed above, the QP is required to submit the details showing the positive environmental impacts, possible savings and benefits of the proposed features to BCA for assessment.*
Documentary Evidences	• Extracts of the tender specification showing the provision of the specific green features used and the extent of implementation where applicable; • Technical product information (including drawings and supporting documents) of the green features; • A summary sheet listing the breakdown and the extent of implementation as well as the total requirements for the same intended purpose for the specific green features used; and

Documentary Evidences

Cont'd

- Quantified evidences on the potential environmental benefits that the features can bring to the development.
- The carbon footprint calculation to be submitted in the following prescribed form and format.

ENERGY USAGE OF MATERIALS PRODUCTION AND ON-SITE CONSTRUCTION

Project Title: _____

Project GFA: _____

Section A: Materials Production											
Material	Total Energy usage per month										
	Electricity		Diesel		Petrol		Gas		Others (Pls Specify)		
	kWh	$/kWh	Litres	$/litres	Litres	$/litres	KG	$/KG	Fuel	Units	$/unit
Cement											
Sand											
Concrete											
Aggregate											
Brick											
Steel											
Aluminium											
Glass											
Paint											
Tiles: Ceramic											
Tiles: Granite											

Section B1: Material Usage (On-Site)	
Material	Total Quantity Used
Cement	
Sand	
Concrete	
Aggregate	
Brick	
Steel	
Aluminium	
Glass	
Paint	
Tiles: Ceramic	
Tiles: Granite	

Section B2: Energy Usage (On-Site)		
	Units used	$/unit
Electricity (kWh and $)		
Diesel (litres and $)		
Petrol (litres and $)		
Gas (KG and $)		
Coal (ton)		
Crude Oil (KL)		

Section C: Operational Carbon (Post-Occupancy)		
	Units used	$/unit
Electricity (kWh and $)		
Renewable Energy Sources		

- Computation of Concrete Usage Index (CUI) and supporting documents as stated under Part 3 – NRB 3-1(b)
- Demolition audit form showing the summary of the total and actual quantity of concrete waste and delivery records or receipts from approved recycling firm.

References

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Appendix C

VENTILATION SIMULATION METHODOLOGY AND REQUIREMENTS

C1 General

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.

C2 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 on a body conforming computational grid. Turbulence modeling shall also be included with the minimum requirement of using the standard k-ε turbulence model, coupled with standard wall function.

C3 Ventilation Simulation Methodology

C3.1 All simulation models shall be carried out under isothermal condition of 33.0°C air temperature at steady state condition.

C3.2 The computational domain shall include the development of interest, the characteristics of the immediate surroundings and buildings reside within the proximity of minimum 3 times or more the length of the longest distance measured across the boundary of the development. In the event that the building and surrounding development are located within hilly terrain, the topography information shall also be included in the simulation models. The computational domain shall be further extended from the outer edge of the proximity regions to the boundary such that it would not result in non-physical airflow solution, after the solution has converged. The computational domain shall also be aligned along with the wind flow direction. The domain height shall be extended, approximately 3 times the height of the tallest building within the defined vicinity.

C3.3 The computational grid generated for all simulations should resolve the salient flow features in the apartment units and around the development. As a guide, the dimension of the computational element should be set at 0.1 to 0.2 m in the apartment unit, 0.5 to 1.0 m at all buildings and ground level and 10 m at the far field boundary with a minimum of 50 m away from the ground.

C3.4 Based on local climatic wind condition, meteorological data on the precise wind direction and velocity of the proposed site location for the month of December, March, June and September shall be used for the CFD simulation. The prevailing wind condition such as the mean speed and direction for Singapore shall be taken from Table C3.4 below. The inbound vertical wind profile shall assume to be given by the Logarithmic Law with reference height at 15.0m.

Table C3.4: Tabulation of Prevailing Wind Direction & Speed obtained from NEA over a Period of 18 Years.

Wind Direction	Mean Speed (m/s)
North	2.0
North-East	2.9
South	2.8
South-East	3.2

C3.5 There shall have two large scale simulation models using the specified computational domain and grid stated in paragraph C3.2 and C3.3, to assess the wind flow conditions and air-flow pattern within the development and units. The simulation modeling can be conducted based on the two best prevailing wind directions for the building development that is North or North-East (N or NE) and South or South-East (S or SE).

Stage 1 **CFD Simulation model for development**	(i)	Determine up to five (5) typical unit design layouts that have the majority number of units. If the proposed building development comprises less than 5 typical unit types, all the typical unit design layouts are to be selected for the simulation.
	(ii)	Conduct a large scale CFD simulation to assess the wind flow conditions around the proposed building development and adjacent buildings. Natural ventilated corridor linked to the unit should be taken into consideration for the simulation models.
	(iii)	From the simulation results, determine the wind pressure taken at 0.5 m from every assumed opening of all units at mid height level (capped at 20 storey height) and the pressure difference (i.e. the difference of the maximum and minimum wind pressure) of each unit. In instances, where all or some of the typical unit layouts are not designed at mid-height level, the average wind pressure and respective pressure differences should be determined for these typical units located at the level closest to the mid-height level.
	(iv)	Derive the average pressure difference of all units at mid-height or selected level.
	(v)	Select the unit with pressure difference that is closest to the average pressure difference derived in C3.5(d) from each typical unit design layout as determined in C3.5(a) for Stage 2 simulation. The maximum allowable margin of ± 10% difference from the average pressure difference is deemed acceptable.
Stage 2 **CFD Simulation Model for Units**	(vi)	Conduct a large scale CFD simulation to assess the air flow conditions of these five (5) selected units. All living or functional spaces in the unit are to be included in the simulation modeling except for enclosed spaces such as storeroom or CD shelter. For the simulation model, all windows and doors are assumed to be fully opened except for the main door, which is assumed to be closed at all time.
	(vii)	From the simulation results, determine the area-weighted average wind velocity of each selected unit by considering the air flow conditions of the applicable areas. For residential buildings, the applicable areas refer to living room, open kitchen (that is connected to the living room), study rooms and all bedrooms. The area-weighted average wind velocities of these areas are to be computed at horizontal-plane 1.2 m above the floor level. The same applies to naturally ventilated functional spaces for non-residential buildings.

C3.6 The selected unit is deemed to have good natural ventilation if the area-weighted average wind velocity of the unit is not less than 0.6 m/s. The overall percentage of units achieving good natural ventilation is given by :

$$\frac{\Sigma(\text{No. of Selected Units for Each Layout} \times \text{Area-Weighted Average Wind Velocity})}{\text{Total Number of Selected Units} \times 0.60 \text{ m/s}} \times 100\%$$

C4 Documentation Requirements

C4.1 The Qualified Person (QP) and the other appropriate practitioners shall ensure that the following report is available as evidences to demonstrate compliance with the ventilation simulation framework. The report should comprise the following items:

(i) Cover page with a proper title, photo 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)

(ii) Table of Contents

(iii) Executive Summary
- Background of the development
- Main findings
- Concluding remarks

(iv) Background/ Introduction

(v) Methodology
- Describe methodology used in the study
- Provide the rationale for the units selection as well as salient information such as the total no. of units and different design units layout and location

(vi) Geometrical Model should include
- Isometric view of the development from various angles
- Domain size used
- Plan and 3D isometric model of units from various angles

(vii) Simulation settings
- Boundary conditions
- CFD software/ models used/ numerical scheme
- Mesh / cell sizing
- Solution control-convergence criteria

(viii) Result and discussions
- Simulation results for 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 typical unit types and the selected unit types as well as the corresponding number of units and the area-weighted average wind velocity within each selected unit where applicable.
- Calculation of percentage of units with good natural ventilation and area-weighted average wind velocity of 0.60 m/s or more.

(ix) Conclusion

(x) 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, isometric views on building façade)
  - Velocity vector and contour showing the plan view at ground & mid elevation and a few isometric sectional cut plans to show air-flow patterns across the development
- Simulation results for the units for each direction
  - Static pressure (plan view-ground & mid elevation)
  - Velocity vector and contour showing the plan view at ground & mid elevation

Appendix D

DAYLIGHTING & GLARE SIMULATION METHODOLOGY AND REQUIREMENTS

D1 General

The daylighting and glare simulation shall be carried out using computational modeling to quantify the availability of natural daylighting to effectively replace the use of artificial lightings, while maintaining proper and comfortable lighting level. The simulation results and recommendations derived are to be adopted to meet the intent of the criteria.

D2 Simulation Software

The computational modeling shall be carried out using well documented software that has the capability to take into consideration the direct sky component, externally reflected component, internally reflected component and multiple light reflections as detailed in the following table :

Component	**Parameters**
Direct Sky	• Relative direct illuminance and angle of that particular sky • Visible transmittance of each glazing material through which daylight travels
Externally Reflected	• Reflectance of materials assigned to all external objects, such as ground and other buildings • Relative surface angle of materials and glazing transmittances
Internally Reflected	• Reflectance of materials assigned to all interior objects, such as walls, doors, ceilings and partitions • Relative surface angle of materials
Multiple Light Reflections	• Inter-reflections of light off multiple surfaces • Relative surface angle of materials

D3 Daylighting and Glare Simulation Methodology

D3.1 The computational domain of all simulations shall include the development of interest, the characteristics of the immediate surroundings and buildings at a large scale level.

D3.2 All storey levels of each building tower together with the all interior design layout (such as walls and partitions) and properties of materials used are to be considered in the simulation. The reflectance value of materials used shall be based on the following:

Materials		**Reflectance Value**
Wall	Brick plaster	0.70
Partition	Plasterboard	0.70
Floor	Concrete tiles	0.40
	Concrete plaster	0.70
	Carpeted	0.20
Ceiling	White paint finishing	0.80
Roof	Clay tiled roof	0.10
Railing	Stainless steel	0.85
Glass	Clear glass	0.70
External	Paving blocks	0.30
	Asphalt pavement	0.10
	Swimming pool water	0.90
	Grass	0.20

D3.3 All simulations shall be carried out based on the local meteorological data of the proposed site location and on the selected date 22nd for the month of December, March, June and September.

(i) Simulation model for daylighting analysis: To assess the distribution of effective daylighting across the depth of room under Overcast sky condition, at 1300 hrs. The computational grid generated shall be at the height of working desk level, approximately 0.7m off the ground. The illuminance colour scale should be set in the range of 0 lux to 500 lux, with an interval of 50 lux.

(ii) Simulation model for glare analysis: To assess the comfortability of occupants' glare exposure under Sunny sky condition, at 1000 hrs and 1600 hrs. At least one computational viewpoint should be considered for each building façade orientation; all viewpoint locations shall be determined through Sunpath analysis to capture the worst-case scenarios. The computational viewpoints generated shall consider measurements both vertically and horizontally, of at least 120 degrees measured from the centre of each viewpoint. The viewpoints should be placed at the height of human eye level when seated, approximately 1.25m off the ground.

D3.4 Computation on qualifying units:

The percentage of units achieving effective daylighting is given by:

$$\frac{\text{Units achieving minimum required illuminance level}}{\text{Total number of units}} \times 100\%$$

D4 Documentation Requirements

D4.1 The Qualified Person (QP) and the other appropriate practitioners shall ensure that the following report is available as evidence to demonstrate compliance with the daylighting and glare simulation framework. The report should comprise the following items:

(i) Cover page with a proper title, photo of development, developer's information (including developer's name and address and person-in-charge), and Consultant's details (including the principal's name and authorized signature, firm's address and person-in-charge).

(ii) Table of Contents

(iii) Executive Summary
- Background of the development
- Main findings
- Concluding remarks

(iv) Background/ Introduction

(v) Methodology
- Describe methodology used in the study
- Provide rationale for the selection of viewpoint locations for glare analysis, as well as salient information such as different design room layout

(vi) Geometrical Model should include
- Isometric view of the development from various angles
- Domain size used
- Plan and 3D isometric model of different storey from various angles

(vii) Simulation settings

- Boundary conditions and meteorological data used
- Simulation software/ models used/ numerical scheme
- Mesh/ grid sizing
- Inputs of materials' properties, such as Visible Light Transmittance (VLT) value of glazing and reflectance value of all materials
- Computational grid and viewpoint locations for the analyses

(viii) Results and discussions

- Simulation results for the whole development showing the main graphical plots of the illuminance level and glare exposure distribution across the room depth
- Recommendations on the provision and locations of photo sensors to control the usage of electrical lightings in the presence of effective daylighting
- Recommendations on measures to minimise unfavourable glare conditions (if any)

(ix) Conclusion

(x) The following documentations are to be placed in the appendices

- Daylighting simulation results (done for each analysis)
  - Technical product information on material properties used such as Visible Light Transmittance (VLT) value of glazing and reflectance value of all materials
  - Plan and 3D isometric model diagrams showing the distribution of illuminance level across the room depth in false colours
  - Tabulation of illuminance data for all areas
  - Tabulation of illuminance data for areas achieving minimum required illuminance level as well as the calculation showing the percentage of area compliance

- Glare simulation results (done for each analysis)
  - Technical product information on material properties used such as Visible Light Transmittance (VLT) value of glazing and reflectance value of all materials
  - Model diagrams illustrated in contours showing the distribution of Unified Glare Rating (UGR) across each viewpoint
  - Tabulation of UGR data for all viewpoints
  - Tabulation of UGR data for areas achieving acceptable glare exposure as well as the calculation showing the percentage of area compliance

Appendix E

ENERGY MODELING METHODOLOGY AND REQUIREMENTS

E1 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.

E2 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 mult-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 standard.

E3 Reference Model

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 E3.

Table E3 – Baseline Standard

<table>
<tr><th>S/No.</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</td><td>(a) ETTV shall not exceed 50 W/m^2

(b) For roof with skylight, RTTV shall not exceed 50 W/m^2

(c) For roof without skylight, the average U value of the gross area of the roof shall not exceed the limit below :

Maximum Thermal Transmittance for Roof of Air-Conditioned Buildings
<table>
<tr><th>Weight Group</th><th>Weight range (kg/m^2)</th><th>Maximum 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>
(d) All windows on the building envelope shall not exceed the air leakage rates specified in SS 212 – Specification for Aluminium Alloy Windows.

(e) 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; and

(ii) has its air-conditioning system separated from and independent of the central system.</td></tr>
</table>

<table>
<tr><th>S/No.</th><th>Component</th><th>Baseline Standard</th><th>Minimum Requirement</th></tr>
<tr><td>1</td><td colspan="3">Building Description (cont'd)</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 modeled based on the approved building plan except for floor areas that conform to the provisions for Passive Design Enhancement to reduce air-conditioned spaces. (Refer to Para 3.7 for more details)

Where ACMV zones are defined on the ACMV design drawings, each ACMV zone shall be modeled as a separate thermal block.</td></tr>
<tr><td>2</td><td colspan="3">System Description</td></tr>
<tr><td>2.1</td><td>Air-conditioning and Mechanical Ventilation (ACMV) System Types</td><td></td><td>(a) Reference system to be used will be based on the peak building cooling load :

(i) For buildings with peak building cooling load of 500 RT or more, the reference system will be centrifugal chiller.

(ii) For buildings with peak building cooling load of less than 500RT, the reference system will be screw chiller.

(iii) For buildings with peak building cooling load of less than 500RT and the air-conditioned floor areas is less than 5000 m^2, the reference system will be of the same type as the proposed system. For VRV system, the baseline COP of 3.37 shall be adopted.

(b) For buildings with cooling provision from a District Cooling System (DCS) supplier that is authorised by a licence to carry out all or any of the functions of providing district cooling services to the services areas.

(i) the energy consumption contribution from DCS plant may be excluded in the energy modeling

(ii) all ACMV components dedicated to the building designed shall be included and considered

(iii) the following two criteria are to be complied with
<table>
<tr><th>S/No.</th><th>Criteria</th><th>Gold^{Plus}</th><th>Platinum</th></tr>
<tr><td>1</td><td>Cooling Load Savings</td><td>10%</td><td>15%</td></tr>
<tr><td>2</td><td>Energy Consumption Savings (exclude air-conditioned plant) and from energy efficiency improvements that reduce the cooling load requirement</td><td>27%</td><td>33%</td></tr>
</table></td></tr>
<tr><td>2.2</td><td>Chiller Efficiency</td><td>SS 530: 2006 – Code of Practice for Energy efficiency Standard for Building Services and Equipment</td><td>Minimum energy efficiency standard stated in SS 530</td></tr>
</table>

S/No.	Component	Baseline Standard	Minimum Requirement
2	*System Description (cont'd)*		
2.3	Air-Conditioning Hydronic Systems	SS 553 : 2009 – Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings	<u>Pumping system design criteria</u> 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/m^3/s. The pump power limitation for condensing water systems is 301 kW/m^3/s. Motors exceeding 15 kW shall have controls/ and/or devices that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.
2.4	Cooling Tower	SS 530 : 2006 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment	Performance requirement for heat rejection equipment. <u>*Propeller or axial fan cooling towers*</u> Cooling Tower performance shall not be less than 3.23 L/s/kW. <u>*Centrifugal fan cooling towers*</u> Cooling Tower performance shall not be less than 1.7 L/s/kW.
2.5	Air Conditioning Fan Systems	ASHRAE 90.1:2010 – Energy Standard for Buildings Except Low-Rise Residential Buildings Non-domestic Building Services Compliance Guide 2010 Edition SS 553:2009– Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings	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 allowable fan system power. <u>Fan System design criteria</u> (a) For fan system having a motor nameplate power exceeding 4 kW, the fan power limitation in air-conditioning system that is the allowable fan system input power shall be as follows : (i) Constant volume shall not exceed 1.5 kW/m^3/s (or 0.42 W/CMH) of supply air (ii) Variable volume shall not exceed 2.1 kW/m^3/s (or 0.58 W/CMH) of supply air (b) For fan system having a motor nameplate power not exceeding 4 kW, the allowable fan system input power shall not exceed 0.6 kW/m^3/s (or 0.17 W/CMH) of supply air. <u>Part load fan power limitation</u> (c) Individual VAV fans with motors 11 kW and larger shall meet one of the following requirements: (i) Be driven by a mechanical or electrical variable speed drive or the fan shall be vane-axial fan with variable pitch blades; (ii) 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 setpoint equals one-third of the total design static pressure based on manufacturer's certified fan data.

<table>
<tr><th>S/No.</th><th>Component</th><th>Baseline Standard</th><th>Minimum Requirement</th></tr>
<tr><td>2</td><td colspan="3">System Description (cont'd)</td></tr>
<tr><td>2.6</td><td>Mechanical Ventilation Fan Systems</td><td>ASHRAE 90.1:2010 – Energy Standard for Buildings Except Low-Rise Residential Buildings

Non-domestic Building Services Compliance Guide 2010 Edition

SS 553 : 2009 – Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings</td><td>The ratio of fan system to the supply fan air flow rate (main fan) of each mechanical ventilation system at design conditions shall not exceed allowable fan system power.

<u>Fan system design criteria</u>

(a) For fan system having a motor nameplate power exceeding 4 kW, the fan power limitation in air-conditioning system that is the allowable fan system input power shall not exceed 1.5 kW/m^3/s (or 0.42 W/CMH) of supply air

(b) For fan system having a motor nameplate power not exceeding 4 kW, fan system input power shall not exceed 0.6 kW/m^3/s (or 0.17 W/CMH) of supply air.

<u>Part load fan power limitation</u>

(c) Individual VAV fans with motors 11 kW and larger shall meet one of the following requirements:

(i) Be driven by a mechanical or electrical variable speed drive or the fan shall be vane-axial fan with variable pitch blades;

(ii) 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 setpoint equals one-third of the total design static pressure based on manufacturer's certified fan data.</td></tr>
<tr><td>2.7</td><td>Lighting Systems</td><td>SS530: 2006 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment

The allowable lighting power density stated in ASHRAE 90.1:2010 can be considered if the lighting power budget for the types of usage are not made available in SS 530</td><td>Maximum lighting power budget stated in SS 530 - Table 7 and as prescribed below :

<table>
<tr><th>Type of Usage</th><th>Maximum Lighting Power Budgets (W/m^2)</th></tr>
<tr><td>Hotel guestroom</td><td>15 W/m^2 (including decorative and task lighting)</td></tr>
<tr><td>Hotel Lobby</td><td>10 W/m^2 (including reception lobby, lift lobby and lounge)

15 W/m^2 (for localized areas with special lighting). However, the overall baseline for energy modeling remains as 10 W/m^2</td></tr>
</table>
</td></tr>
</table>

S/No.	Component	Baseline Standard	Minimum Requirement
2	*System Description (cont'd)*		
2.8	Water Heaters	SS530:2006 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment	Water heating equipment efficiency and performance stated in SS 530
2.9	Energy Recovery Systems	SS 553:2009 – Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings	<u>Energy recovery from conditioned space exhaust air</u> Exhaust air of 2.5m^3/s or greater from conditioned space in a single location shall have energy recovery system with at least 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 ARI Standard 1060
3	*Others*		
3.1	Receptacle & Process loads		Same as proposed design
3.2	Occupancy Rates		Same as proposed design
3.3	Operation Schedules		Same as proposed design
3.4	Indoor Thermal Comfort Conditions	SS554 :2009 – Code of Practice for Indoor Air Quality for Air-conditioned Buildings	Same as proposed design
3.5	Minimum Ventilation Rates	SS 553 : 2009 – Code of Practice for Air-conditioning and Mechanical Ventilation in Buildings	Same as proposed design
3.6	Modeling Limitation or Simulation Program		Same as proposed design
3.7	Passive Design Enhancement		For projects that demonstrate considerable efforts to reduce air-conditioned spaces, a cap of 2% additional energy savings over its referenced model can be considered. This would not apply to areas that would normally be non air-conditioned such as warehouses, carparks, school classrooms, staircases, toilets and pantries. Circulation spaces such as atria, plaza and corridors can be considered if these spaces are largely designed to be non air-conditioned and sizeable. 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 the energy saving estimate would be required for evaluation.

Important notes :

1. Where there is no baseline standard for certain energy related features such as such as chilled beams, underfloor air distribution systems, receptacle loads, lifts & escalators, hot water systems, the following shall apply :

   (a) Reference can be made to ASHRAE 90.1:2010 Appendix G.

   (b) For buildings with special requirements where there is no reference based on ASHRAE 90.1:2010 Appendix G, the baseline set for similar building type completed after 2005 can be considered.

   (c) Detailed calculations to be provided to justify the savings in energy consumption from the use of salient energy efficient features /equipment. Where justification could not be provided, the same input parameters for good design practice shall apply to both the Reference and Proposed Models.

2. For receptacle loads, Table A below is for reference.

Table A: Receptacle Loads	Standard	Nominal Values
a. Computer intensive offices	Source:-	22.0 W/m^2
b. General office areas	ASHRAE STD	16.0 W/m^2
c. Large conference areas	90.1:2010	11.0 W/m^2
d. Server/Computer rooms		540.0 W/m^2

E4 Energy Modeling Methodology

E4.1 The simulation model of the proposed design (known as Proposed Model) shall be developed in accordance with the design parameters of the building. This includes :

(i) Building design layout in terms of shape, size and orientation.
(ii) Materials for walls, windows, roofs, floors, doors and permanent shading devices, internal partitions between conditioned and non-conditioned spaces.
(iii) Internal loads such as levels and schedules for occupancy, lighting systems, equipment, appliances and machinery within the building
(iv) ACMV equipments, controls and other associated components selected for use in the building.

E4.2 The Reference Model shall be developed using similar data as stated in paragraph E4.1.

E4.3 The simulations for the Proposed Model and Reference Model shall be calculated using

(i) the same software
(ii) the same weather data[1]
(iii) the same operating schedules
(iv) the same occupancy rates
(v) the same building design in terms of shape, size and orientation
(vi) the same receptacle loads
(vii) the same indoor environmental conditions in terms of thermal comfort level[2], and
(viii) the same internal illuminance levels (lux) for space lightings

E4.4 The overall energy consumption of the Reference Model is to be computed over a period of one (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 (eg. water pumps, cooling towers, tube cleaning devices, chillers, etc.), and non-ACMV systems such as lightings, lifts, escalators, ceiling fans and receptacle loads from equipment (eg. photo-copiers, printers, fax machines, computers, laptops, fridges, projectors, audio-cum video

[1] Appropriate up-to-date weather set should be used for energy modeling such as ASHRAE's International Weather for Energy Calculation data for Singapore.

[2] 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.

systems, water heaters, dryers, washers, etc). Similarly, the overall energy consumption of the Proposed Model can be computed over a period of one (1) year.

E4.5 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 are subject to the cap based on the following norm.

List of Systems/Devices		Energy Savings Cap
Escalator		30%
Lifts	With VVVF and Sleep mode	10%
	Regenerative features	18%
CO sensors		15%
Occupancy Sensors		15%
Photo Sensors		15%

E4.6 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.

E4.7 The normalized Energy Efficiency Index for both the Proposed and Reference Models shall also be computed. The details are as follows :

Calculation of EEI :

EEI = [(TBEC - DCEC) / (GFA – DCA)] x (NF/OH)

where:

(a) TBEC : Total building energy consumption (kWh/year)
(b) DCEC : Data centre energy consumption (kWh/year)
(c) GFA : Gross floor area (for info, carpark areas not included) (m^2)
(d) DCA : Data centre areas (m^2)
(e) NF : Normalising factor based on typical weekly operating hours that is 55 hrs/week
(f) OH : Weighted weekly operating hours (hrs/week)

Reference : [1] NUS Centre for Total Building Performance:
http://www.bdg.nus.edu.sg/buildingenergy/e_energy/audit_results.html

E5 Documentation Requirements

E5.1 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. Whilst the energy modeling specialist shall certify and be responsible for the correctness of the modeling included proper usage of the relevant software.

E5.2 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 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 Table E5.2-1(a) and Table E5.2-2(a)

(e) List of data such as

(i) 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)

(ii) Schedules for each individual operating zone (eg. lighting, occupants, mechanical fans, AHUs, other mechanical and electrical equipment, etc.)

(iii) Executable input data files used in the generation of the energy estimates for the Proposed and Reference Models

(iv) Output data on the monthly energy consumption by mechanical and electrical system components (eg. Air-conditioned systems, Lighting Systems, Receptacle Equipment, Lifts, Escalators etc)

(v) One year simulated hourly cooling load data in the form of the Frequency vs Cooling Load (RT) plot.

(f) Detailed computation of the ETTV for both Reference and Proposed Models

(g) Comparison of Reference Model versus Proposed Model as in Table E5.2-1(b)

(h) Summary of Energy of End Use including Efficiency Indicators for both Reference and Proposed Models as in Table E5.2-1(c) and Table E5.2-2(b).

(i) Summary printouts of energy modeling software for the Reference Model including summary of weather data results

(j) Monthly energy consumption of mechanical and electrical system components such as air-conditioned system, lighting systems, receptacle equipments, lift and escalator etc.

E5.3 Similar documentation requirements as above will also be required to reflect the as-built condition upon project completion for validation.

Table E5.2-1(a) Summary of Space and ETTV of the Building Envelope

(A) Space Summary			
Building Use	Air-Conditioned Area (m^2)	Non Air-Conditioned Area (m^2)	Total Area (m^2)
1. Office			
2. Toilets			
3. Storage			
4. Corridor			
5. Atrium			
6. Foodcourt			
7. Mechanical / Electrical			
8. Staircase			
9. Conference			
10.Retail Outlets			
11.Carpark			
12. Others			
Total			
Note: The building use floor areas for both the Reference and Proposed Models must be the same.			

(B) Building Envelope Summary – ETTV			
Orientation of Façade	Gross Area of External Walls (m^2)	Reference Model ETTV (W/m^2)	Proposed Model ETTV (W/m^2)
North			
North-East			
East			
South-East			
South			
South-West			
West			
North-West			
Average ETTV of the Building Envelope (W/m^2)		50 W/m^2	

Table E5.2-1(b) Comparison of Reference Model versus Proposed Model

BUILDING ELEMENT	REFERENCE MODEL	PROPOSED MODEL
BUILDING ENVELOPE		
Wall Construction		
Opaque Doors		
Windows		
Floor		
Roof		
Window to Wall Ratio (WWR)		
Others		
ELECTRICAL SYSTEMS		
Lighting Power Density (W/m^2)		
Lighting Occupant Sensor Controls		
Lighting Daylighting Controls		
Receptacle Power (W/m^2)		
Lifts & Escalators		
Others		
Note: The Receptacle Loads for both the Reference and Proposed Models must be the same.		
RENEWABLE ENERGY SYSTEMS		
Photovoltaics		
Note: To include a description of renewable energy systems used to reduce Proposed Model energy consumption.		

BUILDING ELEMENT	REFERENCE MODEL	PROPOSED MODEL
SCHEDULES		
Occupancy, Lighting & Equipment		
HVAC		
Note: The Occupancy Rates and Operating Schedules for both the Reference and Proposed Models must be the same.		
MECHANICAL & PLUMBING SYSTEMS		
HVAC System Type		
AHU Fan Properties		
Boiler Efficiency		
Central Plant Efficiency		
Note: Central plant efficiencies and capacities for chillers and cooling towers shall be listed whenever the central plant is included as part of the energy model.		
HVAC Circulation Loop Properties		
Domestic Water System		
Mechanical Ventilation Fans		
OTHERS		

Description of differences between the Reference Model and Proposed Model not documented on other forms:

□□Not Applicable □ Attached

Table E5.2-1(c) : Summary of Energy by End Use including Efficiency Indicators

End Use	Reference Model Energy Consumption (kWh)	Proposed Building Energy Consumption (kWh)	Energy Consumption Savings (%)
Lighting – (Air-Conditioned Space)			
Lighting- (Non Air-Conditioned Space)			
[3]Air-Conditioned Plant			
[4]Air System Fans			
Mechanical Ventilation Fans			
Lifts			
Escalators			
Receptacle Equipment			
Domestic Water Systems			
Others			
Total Building Energy Consumption			

Note : The stipulated energy savings required to attain the Green Mark Gold^{Plus} and Platinum rating to be based on the savings derived from energy efficiency measures and improvements over its reference model as listed above.

Renewable Energy Sources

End Use	Energy Produced (kWh)	Reference Model Energy Consumption (kWh)	Proposed Building Energy Consumption (kWh)	Energy Consumption Savings (%)
Photovoltaics		Not Applicable		
Others				
Total Building Energy Consumption including Renewable Energy Sources				

Efficiency Indicators

Efficiency Indicators	Reference Model	Proposed Model
Energy Efficiency Index, EEI (kWh/m^2/yr)		
System Efficiency of Air-Conditioned Plant (ikW/kW)		

[3] Chilled Water System (chillers, water pumps and cooling towers)
[4] Chilled Water Air Handling and Fan Coil Units

Table E5.2-2(a) : Summary of Space and ETTV of the Building Envelope

(required if there is a change)

(A) Space Summary			
Building Use	Air-Conditioned Area (m^2)	Non Air-Conditioned Area (m^2)	Total Area (m^2)
1. Office			
2. Toilets			
3. Storage			
4. Corridor			
5. Atrium			
6. Foodcourt			
7. Mechanical / Electrical			
8. Staircase			
9. Conference			
10.Retail Outlets			
11.Carpark			
12. Others			
Total			
Note: The building use floor areas for both the Reference and Actual Models must be the same.			

(B) Building Envelope Summary – ETTV			
Orientation of Façade	Gross Area of External Walls (m^2)	Reference Model ETTV (W/m^2)	Actual Model ETTV (W/m^2)
North			
North-East			
East			
South-East			
South			
South-West			
West			
North-West			
Average ETTV of the Building Envelope (W/m^2)		50 W/m^2	

Table E5.2-2(b) : Summary of Actual Energy by End Use including Efficiency Indicators

End Use	Reference Model Energy Consumption (kWh)	Actual Building Energy Consumption (kWh)	Energy Consumption Savings (%)
Lighting – (Air-Conditioned Space)			
Lighting- (Non Air-Conditioned Space)			
[5]Air-Conditioned Plant			
[6]Air System Fans			
Mechanical Ventilation Fans			
Lifts			
Escalators			
Receptacle Equipment			
Domestic Water Systems			
Others			
Total Building Energy Consumption			

Note : The stipulated energy savings required to attain the Green Mark Gold^{Plus} and Platinum rating to be based on the savings derived from energy efficiency measures and improvements over its reference model as listed above.

Renewable Energy Sources

End Use	Energy Produced (kWh)	Reference Model Energy Consumption (kWh)	Actual Building Energy Consumption (kWh)	Energy Consumption Savings (%)
Photovoltaics		Not Applicable		
Others				
Total Building Energy Consumption including Renewable Energy Sources				

Efficiency Indicators

Efficiency Indicators	Reference Model	Actual Building Model
Energy Efficiency Index, EEI (kWh/m^2/yr)		
System Efficiency of Air-Conditioned Plant (ikW/kW)		

[5] Chilled Water System (chillers, water pumps and cooling towers)
[6] Chilled Water Air Handling and Fan Coil Units