Green Mark International

BSR

Base Sustainability Requirements of Buildings

(New Developments and Existing Buildings)

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BASE SUSTAINABILITY REQUIREMENTS OF BUILDINGS

Contents

INTRODUCTION

The intent of this Base Sustainability Requirements of Buildings for GREEN MARK INTERNATIONAL (referred to as “this Minimum Requirements”) is to establish environmentally friendly practices on the planning, design and construction of buildings, which would help to mitigate the environmental impact of built structures.

This Base Requirements sets out the guidance and details in respect of the minimum environmental sustainability standard for buildings defined in GM International and the administrative requirements.

1 SCOPE

Base Sustainability Requirements for of Buildings GREEN MARK INTERNATIONAL (referred to as “this Minimum Requirements”) is to establish environmentally friendly practices on the planning, design, construction and operation of buildings, which would help to mitigate the environmental impact of built structures.

The provisions of this Base Requirements shall apply to:

1. New Developments: Base Sustainability Requirements (ND) for New Non-Residential buildings, New Residential buildings.

2. Existing Buildings: Base Sustainability Requirements (EB) for Existing Buildings applying for first Green Mark certification and Existing buildings with major energy-use change (which includes the installation, substantial alteration or replacement of the cooling system).

3. Existing buildings which previously held a Green Mark certificate and have not undergone major energy-use change (installation and replacement of the cooling system), will be assessed under Green Mark International In-Operation.

4. Exception: Air-Cooled Chilled-Water System can only be adopted if the peak building cooling load of not more than 500 RT and the building works involves major retrofitting or additions and alterations to an existing building.

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

2 DEFINITIONS

For the purpose of this Base Requirements, the following definitions shall apply:

Dwelling Unit	A unit within residential development that provides complete, independent living facilities for one or more persons.
Gross Floor Area (GFA)	The "gross floor area" has the same meaning as "floor area" in the Planning (Development Charges).
Major Retrofitting	The provision, extension or substantial alteration of the building envelope and building services in or in connection with an existing building.
Chilled Water Plant	A building's centralised air conditioning system that makes use of chilled water as the medium for removing the heat from the buildings. This includes the chillers and its ancillary equipment, including pumps and cooling towers where applicable.
Unitary Air Conditioning System	One or more factory-made assemblies that normally include an evaporator or cooling coil and a compressor combination. Units that perform a heating function area are also included.
Total System Efficiency (TSE)	The combined system efficiency of the water-side component and air-side component of the building cooling system. It is a measure of how efficiently the building cooling system would operate to meet the operating condition and requirements in providing an acceptable indoor thermal environment.
Operating System Efficiency (OSE)	The measured system efficiency of the building's chilled water plant during its normal operating hours.

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

3 REQUIREMENTS

3.1 Reference Codes and Standards

The following codes and standards have relevance:

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 591: Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency

f. AHRI Standard 550/590 - Performance Rating of Water Chilling and Heat Pump Water-Heating Packages using the Vapour Compression Cycle

g. SS 554: Code of Practice for Indoor Air Quality for Air-Conditioning Buildings

h. ANSI/ASHRAE/IES Standard 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings

i. BCA – FAQs on Instrumentation for Permanent M&V for Chilled-Water Plant System

3.2 New Developments – Base Environmental Sustainability Requirements

3.2.1 The Base Environmental Sustainability Requirements of building works shall have a level of environmental performance that meets all relevant Base Requirements and incorporates the number of appropriate sustainability indicators under Carbon Reduction Measures as specified in Table 3.2, Section 4.1 and 4.2.

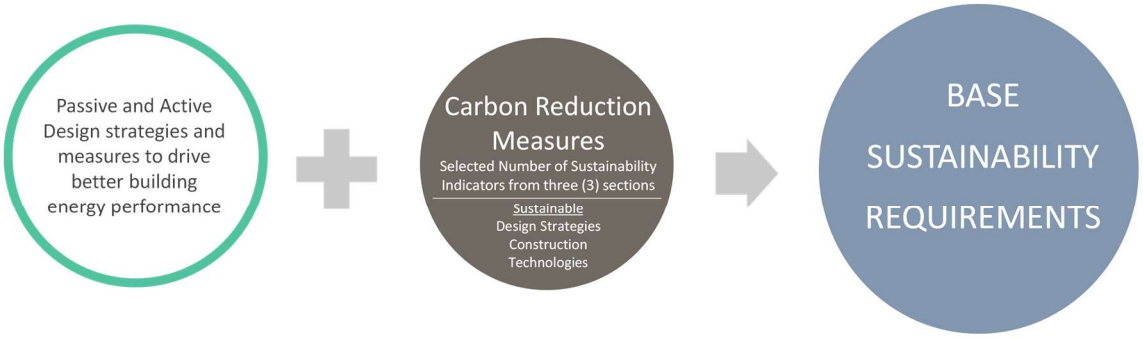

Figure 3.1 – Overview of Compliance Framework

3.2.2 The level of environmental performance required based on the building categories are as stipulated in the following Table 3.2.

Table 3.2 – Base Sustainability Requirements Compliance Methodology and Required Level of Environmental Performance

Residential Buildings	Non-Residential Buildings
▪ All listed in Table 4.1(a), where applicable. ▪ A selection of **four (4) Carbon Reduction Measures** in total as listed in Table 4.2(a) including a **minimum of two (2) measures from Section 2 - Sustainable Construction**.	▪ All listed in Table 4.1(b), where applicable. ▪ A selection of **four (4) Carbon Reduction Measures** in total as listed in Table 4.2(b) including a **minimum of two (2) measures from Section 2 - Sustainable Construction.**

Mixed-Use Building Developments

For mixed-use building developments consisting of residential and non-residential buildings/ components, the minimum environmental sustainability standards for both residential and non-residential buildings/components are to be complied with. If the GFA of any building works relating to the residential building/component or to the non-residential building/component is less than 2000 m^2, the Base Sustainability Requirements standard shall apply to the larger part of the building works based on the requirements under the respective building categories and as summarised below.

Project Type	Total New GFA Residential (m^2)	Total New GFA Non-Residential (m^2)	Residential Applicable	Non-Residential Applicable
Mixed-Use Building Developments	≥ 2000	≥ 2000	Yes	Yes
	≥ 2000	< 2000	Yes	No
	< 2000	≥ 2000	No	Yes

3.3 Existing Buildings - Base Environmental Sustainability Requirements

The Base Environmental Sustainability Requirements of the Existing Building shall have a level of environmental performance that meets all relevant Base Requirements and incorporates the number of appropriate sustainability indicators provided under the Carbon Reduction Measures as specified in Section 5.1 and 5.2.

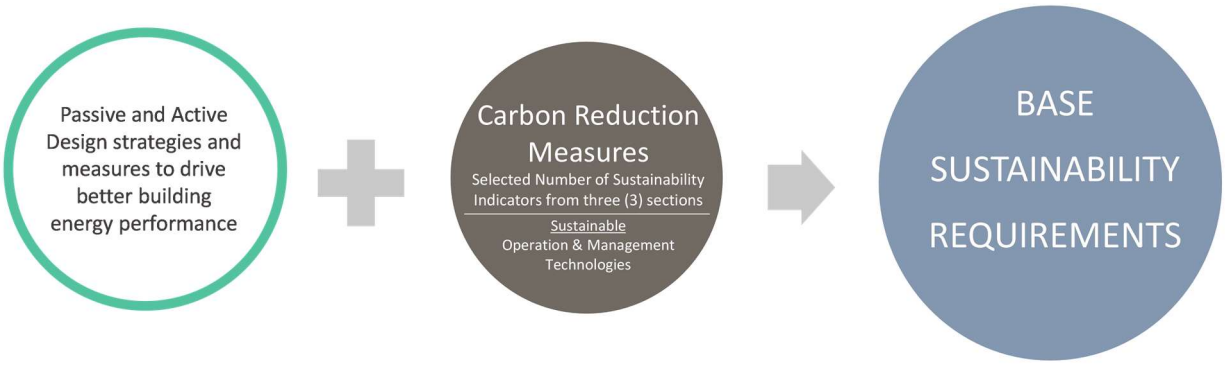

Figure 3.2 – Overview of Compliance Framework for Existing Buildings

There are a total of 6 mandatory base requirements in Section 5.1 and 3 groups of 9 sustainability indicators for Carbon Measures stated in Section 5.2

To comply with the overall Base Sustainability Requirements, the Existing Buildings must meet the 6 mandatory requirements in Section 5.1 and choose 3 indicators for the Carbon Measures in Section 5.2 with one of them must be from section on Sustainable Operation and Management.

4 COMPLIANCE METHODOLOGY FOR NEW DEVELOPEMENTS

4.1 Passive and Active Design Strategies for New Developments

The Passive and Active Design Strategies essentially are environmental sustainability attributes that have a direct impact on the building energy performance and are to be complied with, where applicable. The details are provided in the following Table 4.1(a) and Table 4.1(b) for the respective building categories.

Table 4.1(a) – Base Requirements for Residential Buildings

ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
RB01 Envelope and Roof Thermal Transfer	
A building shall be designed and constructed with good thermal performance to reduce solar heat gain through the building envelope and roof.	Thermal performance of building envelope and roof
RB01-1 Building Envelope	
Reduce heat gain through the building envelope to enhance thermal comfort and reduce the energy needed to condition the indoor environment, when required. (a) The building envelope is to be designed with Residential Envelope Transmittance Value (RETV) requirements in GM International - Energy Efficiency based on the methodology stated in the Code on Envelope Thermal Performance for Buildings; (b) The building envelope design to meet RETV 22W/m^2 is deemed to have satisfied the performance requirements if it meets the following criteria.	Building envelope design
RB01-2 Roof	
The average thermal transmittance (U-Value) of roof shall not exceed the prescribed limits as stated below:	Roof design
RB02 Building Energy Performance	
A building shall be designed and constructed with energy efficiency measures to reduce the energy consumption of building energy systems and meet the requirements in GM International - Energy Efficiency.	Energy performance of building energy systems

Window to Wall Ratio (WWR)	Shading Coefficients of Glass (SC_{glass})
< 0.30	≤ 0.67
0.30 to < 0.35	≤ 0.59
0.35 to < 0.40	≤ 0.52
0.40 to < 0.45	≤ 0.48
0.45 to ≤ 0.50	≤ 0.43

Roof Weight Group	Weight Range (kg/m^2)	Maximum U- value (W/m^2K)
Light	<50	0.8
Medium	50 to 230	1.1
Heavy	>230	1.5

Table 4.1(a) – Base Requirements for Residential Buildings	
Environmental Sustainability Attributes	Applicability & Scope
RB02-1 Air-Conditioning System	
Reduce energy required for space cooling by providing energy-efficient air-conditioning systems that could meet the GM International - Energy Efficiency - Residential (International) in (Pathway 2 – Fixed Metrics. Note (1) – Other systems such as centralised cooling systems (CCS) provided are to be designed to meet the minimum energy performance standard of 0.67 kW/RT.	Gold^{PLUS} and Platinum: Applicable to all dwelling units and common facilities. Certified and Gold Rating: Applicable to at least 80% of the total number of dwelling units and common facilities.
RB02-2 Lighting System for Common Facilities and Areas	
Reduce energy required to illuminate spaces in common facilities and areas with proper lighting levels. The lighting provision shall meet the energy efficient requirements GM International - Energy Efficiency. Lighting control for artificial lighting shall also be provided in accordance with SS 530, where applicable.	Lighting system for common facilities and areas
RB02-3 Mechanical Ventilation System for Car Parks	
Reduce energy required by regulating the demand for mechanical ventilation in car parks by way of Carbon Monoxide (CO) detection sensor controls with Variable Speed Drives (VSDs).	Mechanical ventilation system for car parks
RB02-4 Vertical Transportation System	
Reduce energy consumption by providing energy-efficient vertical transportation systems that are equipped with variable voltage variable frequency (VVVF) drives and sleep mode features.	Lift systems that serve four (4) floors or more

Table 4.1(b) – Base Requirements for Non-Residential Buildings

NRB01 Envelope and Roof Thermal Transfer

A building shall be designed and constructed with good thermal performance to reduce solar heat gain through the building envelope and roof.	Thermal performance of building envelope and roof

NRB01-1 Building Envelope

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

The building envelope is to be designed with Envelope Thermal Transfer Value (ETTV) requirements in GM International - Energy Efficiency. Projects using ***Pathway 1, 2 and 3***, based on the methodology stated in the Code on Envelope Thermal Performance for Buildings;

(a) The building envelope design 45 W/m^2 is deemed to have satisfied the performance requirements if it meets the following criteria.

Window to Wall Ratio (WWR)	Shading Coefficients of Glass (SC_{glass})
< 0.20	≤ 0.51
0.20 to < 0.25	≤ 0.41
0.25 to < 0.30	≤ 0.35
0.30 to < 0.35	≤ 0.30
0.35 to < 0.40	≤ 0.27
0.40 to ≤ 0.50	≤ 0.22
Note: Window to Wall Ratio (WWR) refers to fenestration areas/gross area of the exterior wall.	

Building envelope design

Buildings with an air-conditioning area

NRB01-2 Roof

Reduce heat gain through the roof to reduce the energy needed to condition the indoor environment.

(a) The roof with skylights is to be designed with Roof Thermal Transfer Value (RTTV) of not more than 50 W/m^2 based on the methodology stated in the Code on Envelope Thermal Performance for Buildings.

(b) For roof without skylights, the average thermal transmittance (U-Value) of roof shall not exceed the prescribed limits as stated below:

Roof Weight Group	Weight Range (kg/m^2)	Maximum U- value (W/m^{2}K)
Light	<50	0.5
Medium	50 to 230	0.8
Heavy	>230	1.2

Roof design with and without skylights

NRB02 Air-Tightness and Leakage

A building shall be designed and constructed with energy conservation measures to reduce air leakage through doors, windows and other openings on the building envelope comply to code requirement by the local authorities	Measures to minimise air infiltration or exfiltration

NRB02-1 Windows and Curtain Walls

Minimise air leakage through building envelope by way of effective means of weather-stripping of windows and curtain walls copy to the requirements by local authority.	Windows and curtain walls

Table 4.1(b) – Base Requirements for Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
NRB02-2 Openings between Conditioned and Non-Conditioned Spaces	
Conditioned air is to be well confined to minimise heat gain to the building due to air leakage with appropriate mitigation measures. Building entrances and door openings* to building exterior or non-air-conditioned spaces and the like, shall (a) be provided with doors that are equipped with automated technology or self-closing devices. Where door opening of any commercial units are located along the perimeter of the building envelope, that unit shall be equipped with the addition of pressure independent control valve and energy meter to measure the consumption of fan coiled units (FCUs) within the unit; and (b) be equipped with enclosed vestibules** or other appropriate measures for the doorway with high pedestrian traffic flow*. In the case of vestibules, the interior door and exterior door must have a minimum distance of not less than 2.5 m apart and should be interlocked to avoid being opened at the same time. ** Doorway with high pedestrian traffic flow refers to main entrances and those leading to transport nodes or other commercial buildings.* *** Other than the provision of vestibule as a means to reduce energy losses from air infiltration/exfiltration, appropriate measures could be considered in instances where doors are required to stay open for operational purposes. For example, the use of a highly efficient air-curtain system with its performance tested in accordance with ANSI/AMCA Standard 220 to ensure a minimum of 2.0 m/s airstream velocity at the floor. Other design approaches such as using temperature stratification concept with justification by way of Computer Fluid Dynamics (CFD) simulation along with appropriate placement of diffusers are possible alternatives to minimise air leakage.* As this requirement is intended for normal building operation, there could be a need to consider the provision of sufficient ventilation openings and effective air extraction/exhaust to cater for specific operational requirements, when needed.	Building entrances and door openings to building exterior or non-air-conditioned spaces
NRB03 Building Energy Performance	
A building shall be designed and constructed with energy performance that meets the minimum energy efficiency improvements requirements in GM International - Energy Efficiency.	Energy performance of building energy systems
NRB03-1 Whole Building Approach via Energy Modeling	
Facilitate integrated design process and energy use reduction by the way of energy modelling to meet the minimum energy efficiency improvement required in Pathway 3.	Building energy system that are stated in the energy modelling methodology and requirements
NRB03-2 System Level Approach via Enhanced Energy Performance Standards	
Facilitate energy use reduction in meeting the minimum energy efficiency improvements required with the provision of energy-efficient building systems that could meet the enhanced energy performance standard set out in the following sub-sections.	Key building systems stated in the sub-sections

Table 4.1(b) – Base Requirements for Non-Residential Buildings	
Environmental Sustainability Attributes	Applicability & Scope
NRB03-2(a) Air-Conditioning System	
educe energy required to provide and distribute conditioned air within the space through the use of energy-efficient air-conditioning system. (i) Water-Cooled Building Cooling System comprises the following systems and components, where relevant. • Water-Cooled Chiller • Water-Cooled Direct-Expansion (DX) System • Chilled Water Pump • Condenser Water Pump • Cooling Tower • Air Distribution System Total System Efficiency (TSE) refers to the combined system efficiency of the chiller plant and air distribution systems. The Total System Efficiency (TSE) of the building cooling system shall meet the required TSE mentioned in Pathway 1, Pathway 2 or Pathway 3. TSE refers to the combined system efficiency of the chilled water plant and air distribution systems. Additional requirement for new commercial buildings, the water-side component system efficiency shall not exceed 0.63 kW/RT. *Exception: For buildings with cooling provisions from the District Cooling System (DCS), the TSE requirement does not apply but the air-side component system efficiency standard shall meet the requirements in GM International - Energy Efficiency.* (ii) Air-Cooled Building Cooling System comprises the following systems and components, where relevant. • Unitary Air-Conditioners (Single or combination of systems) ○ Variable Refrigerant Flow (VRF) system ○ Single-Split Units ○ Multi-Split Units ○ Air Distribution System • Air-Cooled Chilled-Water System can only be adopted for existing building developments with inherent constraints and with peak building cooling load of not more than 500 RT ○ Air-Cooled Chiller ○ Chilled Water Pump ○ Air Distribution System GM International - Energy Efficiency (Pathway 1, Pathway 2 or Pathway 3): All projects are required to meet the Total System Efficiency (TSE) and Airside efficiency (air distribution) for buildings, where TSE refers to the combined system efficiency of the condenser units/ air-cooled chilled water plant and air distribution systems. Note(1) – The air-side component efficiency of the fan systems can be adjusted to allow for pressure drop adjustments where there is a need for more allowance due to functionality and activities as per recommended in SS 553 : Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings – Table 2b.	Building cooling system that serves air-conditioning area District Cooling system and existing air-conditioning system that serve new buildings or floor areas

Table 4.1(b) – Base Requirements for Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
NRB03-2(a) Air-Conditioning System – *Cont'd*	
Note(2) – Where there is a combination of water-cooled and air-cooled building cooling systems adopted, the respective TSEs are to be complied with. For new development, TSE is based on the expected part-load condition over the simulated average annual total cooling load profile for chilled-water systems, and total weighted system efficiency for unitary systems. For existing building, TSE should be based on the average annual total cooling load profile.	Building cooling system that serves an air-conditioning area District Cooling system and existing air-conditioning system that serve new buildings or floor areas
NRB03-2(b) Lighting System	
Reduce energy required to illuminate interior spaces with proper lighting levels. The lighting provision shall meet the requirements in GM International – Energy Efficiency Lighting control for artificial lighting shall also be provided in accordance with SS 530, where applicable.	Lighting systems for interior spaces
NRB03-2© Mechanical Ventilation System	
Reduce energy required to supply and distribute fresh air within the space using energy-efficient mechanical ventilation systems and controls. (i) Mechanical ventilation systems for normally occupied spaces shall be designed to be at least 10% more energy efficient than the prescribed standard stated in SS 553; and (ii) Provision of Carbon Monoxide (CO) detection sensor control with Variable Speed Drives (VSDs) to regulate demand for mechanical ventilation in car parks.	Mechanical ventilation systems for normally occupied spaces and car parks
NRB03-2(d) Vertical Transportation System	
Reduce energy consumption needed for vertical transportation with the provision of lifts and escalators that are equipped with variable voltage variable frequency (VVVF) drives and sleep mode features. In the case of escalators, the provision of occupancy sensors, standby speed and/or standby stop features will be required, where relevant. Note: Other than the provision of vertical transportation systems that come with VVVF and sleep mode features, there are other energy-efficient technologies such as regenerative drive or deployment of advanced dispatching software that could reduce occupant wait time while reducing energy use by up to 50% compared to traditional systems.	Lifts and escalators

Table 4.1(b) – Base Requirements for Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
NRB04 Measurement and Verification (M & V) Instrumentation	
A building shall be designed and equipped with means to facilitate monitoring and improvement in the efficiency of building cooling systems	Building cooling system efficiency
NRB04-1 Instrumentation for Central Chilled Water System	
Provision of permanent measuring instruments to monitor the energy performance of the water-cooled and air-cooled central chilled water plants and air distribution systems. The installed instrumentation must have the capability to calculate the resultant system efficiency within 5% of its true value in accordance with SS 591 – Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency. Each measurement system shall include sensors, any signal conditioning, the data acquisition system and the wiring connecting these components. The permanent measuring instruments and devices are to be accessible (*See Note (1) below)* and must not be located directly above the chillers, to facilitate verification and maintenance. They must be installed according to manufacturers' recommendations and SS 591. The measurement systems provided shall also comply with the following requirements: (a) All data logging devices are to be equipped with the capability to trend at a 1-minute sampling time interval, and recorded to the 3rd decimal digit; (b) Building management system (BMS), standalone energy management system (EMS) or local sequential controller (LSC) shall have the capability to compute and display the total system energy efficiency and its component (water-side and air-side efficiency) as well as the calculated heat balance of the chilled water system; (c) Magnetic in-line flow meter, with 1% uncertainty and capable of electronic in-situ verification to within ±2% of its original factory calibration. If the installation of magnetic in-line meters is not possible, ultrasonic flow meters or other flow meters that can meet the indicated performance may be used; (d) Temperature sensors are to be provided for chilled water and condenser water loop and shall have a measurement uncertainty within ±0.05°C over the entire measurement range. Each temperature measurement location shall have test plugs or additional thermowells located before and after each temperature sensor along the chilled water and condenser water lines for verification of measurement accuracy. All thermowells shall be installed in a manner that would allow the sensors to be in direct contact with the fluid flow; and (e) Dedicated power meters (of IEC Class 1 or better) and metering current transformers (of Class 1 or better) are to be provided for each of the following groups of equipment, where applicable: chillers, chilled water pumps, condenser water pumps, cooling towers, air distribution sub-system (i.e. AHUs, PAHUs). The same should be provided for FCUs, where possible. Note(1) – The temperature sensors are best placed in an accessible location with a mounting height of not more than 3 m, where possible. Otherwise, there should be evidence of provision for access by way of mobile access platforms or other suitable forms.	Instrumentation for water-cooled and air-cooled chilled water plants and air distribution systems

<table>
<tr><th colspan="2">Table 4.1(b) – Base Requirements for Non-Residential Buildings</th></tr>
<tr><th>ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES</th><th>APPLICABILITY & SCOPE</th></tr>
<tr><td colspan="2">NRB04-2 Instrumentation for Variable Refrigerant Flow (VRF) System</td></tr>
<tr><td>Provision of permanent measuring instruments to monitor the energy performance of the Variable Refrigerant Flow (VRF) condensing units and air distribution systems.

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

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

(a) All data logging devices with the capability to trend at a 5-minute sampling time interval, and preferably recorded to the 3rd decimal digit;
(b) Building management system (BMS), standalone energy management system (EMS) or other suitable systems shall have the capability to compute and display the total system energy efficiency and its component (condensing unit and air distribution system efficiency) and to facilitate data extraction for verification purpose; and

Dedicated power meters (of IEC Class 1 or better) and metering current transformers (of Class 1 or better) are to be provided for all condensing units of the VRF system and air distribution sub-systems (i.e. AHUs, PAHUs), where applicable. The same should be provided for FCUs, where possible.</td><td>Gold^{PLUS} and Platinum projects shall provide instrumentation for all VRF systems and air distribution systems.

Certified and Gold shall provide instrumentation for VRF systems and air distribution systems that serve an aggregate conditioned floor area of 2000 m^2 or more.</td></tr>
<tr><td colspan="2">NRB05 Electrical Submetering</td></tr>
<tr><td>A building shall be designed and equipped with means to facilitate measurement and monitoring of major energy end uses for energy management and audit. Separate sub-meters shall be provided and linked to a monitoring system that can measure and trend energy consumption data of the following systems:

<table>
<tr><th colspan="2">Sub-System for Metering</th></tr>
<tr><td>Lifts and escalators</td><td>More than 5 numbers or sets or with a sum of all feeders > 50 kVA.</td></tr>
<tr><td>Mechanical ventilation systems</td><td>Total subsystem’s load > 15 kW
Sub-metering applicable to individual fan system motors that are more than 1.5 kW in the following areas
• Normally Occupied Spaces
• Mechanical and Electrical Plant Rooms
• Car Parks</td></tr>
<tr><td>Centralised hot water supply system</td><td>> 50 kW thermal heating capacity</td></tr>
<tr><td>General power supply and lighting systems for tenancy areas and owners’ premises*</td><td>Sub-metering for tenancy areas and owners’ premises are to be separated. The sub-circuits serving these areas can be provided based on a sub-system basis and /or per floor level.</td></tr>
</table>

Note(1): Sub-metering provision for chilled water plant, variable refrigerant flow (VRF) systems and air distribution systems are covered under NRB04.

Note (2): If there is a need to cater to high plug loads or process loads exceeding 50 kVA, please provide separate sub-metering for these specific loads or areas to better manage the energy consumption.</td><td>Submetering for monitoring of major energy end uses and energy audit</td></tr>
</table>

Table 4.1(b) – Base Requirements for Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
NRB06 Maintenance of Building Cooling System Performance	
A building shall be designed and constructed with access space provisions to ensure the building cooling system performance can be maintained during operation as designed. The access space provisions for the following equipment shall comply with either the service clearances as per manufacturers' specification or the specifications set out in NRB06-1 to NRB06-4, whichever governs.	New building developments with water-cooled and air-cooled chilled water systems, and air distribution systems
NRB06-1 Chillers	
Access space provisions shall be as follows: (a) Clearance of 2.0 m or more at the front of chiller unit piping section for tube maintenance and cleaning, repair and replacement of bigger components; (b) Clearance of 1.2 m or more between the chillers measured from plinth to plinth for regular maintenance; and (c) Clearance of 1.5 m or more above the chiller to facilitate maintenance, overhaul or replacement.	Chillers
NRB06-2 Pump Systems	
Access space provisions shall be as follows: (a) Except for the areas where the pipes are connected, clearance of 0.6 m or more is to be provided around the pump for regular maintenance; and (b) Clear headroom of 1.0 m or more above the pump and motor to facilitate maintenance, overhaul or replacement.	Chilled water pumps (CHWP) and condensers water pumps (CWP)
NRB06-3 Cooling Towers	
Maintenance provisions shall be as follows: (a) Provision of maintenance platform, stairs and catwalks of 600 mm width or more with handrails around the cooling towers and access to the level for periodic maintenance and inspection of the water basin and fill media; and (b) Clear distance of 2.0 m or more from the top of cooling towers to the location of the trellis, where applicable.	Cooling towers

Table 4.1(b) – Base Requirements for Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
NRB06-4 Air Distribution Systems	
Maintenance provisions shall be as follows: (a) Air handling units (AHUs) of cooling capacity greater than 35 kW shall be floor mounted as stipulated in SS 553; and (b) For AHUs that are floor mounted, the access space provisions are as follows: (i) AHU access – Provide minimum 1.0 m clearance from the AHU room door entrance to the AHU for general maintenance; (ii) Cooling coil pipe and filter access – Provide minimum 800 mm clearance after pipe connection to facilitate cooling coil cleaning and filter access; (iii) Fan access – Provide minimum 800 mm clearance for fan/motor access and maintenance (if the access is not from the cooling coil connection side); and (iv) AHU side and back clearance – Provide minimum 600 mm clear width for general access and maintenance.	Floor mounted air handling units

4.2 Carbon Reduction Measures for New Developments

4.2.1 A suite of environmental sustainability indicators in relation to energy and carbon emission reduction measures is provided and classified in the following three (3) sections.

Sustainable Design Strategies

optimise the use of passive design strategies in response to local climate and site conditions to improve indoor environmental quality while minimising energy use.

Sustainable Construction

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

Sustainable Technologies

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

4.2.2 A selection of **four (4) carbon reduction measures** appropriate for the building development from the suite of environmental sustainability indicators provided in Table 4.2(a) and Table 4.2(b) will be required. In addition, there must be **two (2) measures from Section 2 - Sustainable Construction as part of the requirements to meet the minimum environmental sustainability standard.**

Table 4.2(a) – Carbon Reduction Measures for Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
SECTION 1 - SUSTAINABLE DESIGN STRATEGIES	
RBE01-1 Enhanced Building Envelope Performance	
Enhance building envelope performance to minimise heat gain to internal spaces for better indoor thermal comfort with any of the following provisions: (a) Façade design with Residential Envelope Transmittance Value (RETV) of not more than 20 W/m^2. (b) Application of cool materials that are certified by an approved local product certification body for 80% of all external wall areas of residential blocks or applicable roof areas. (c) Provision of innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, parametric façade and so on for at least 20% of the fenestration areas.	Building envelope and roof
RBE01-2 Naturally Ventilated Building Design	
Enhance indoor thermal comfort through the provision of building and unit layout design which facilitates good natural ventilation. (a) Building layout design comprises 30% of all units with window openings facing prevailing wind directions. (b) Dwelling unit design comprises 25% of living rooms and bedrooms designed with effective inlet and outlet openings to facilitate good cross ventilation. (c) Passive design considerations for dwelling unit indoor comfort and design for natural ventilation with minimum coverage of 80% in at least two(2) of the following areas: • Toilets/bathrooms of dwelling units • Lift lobbies and corridors • Staircases • Car parks • Common facilities	Dwelling units and common facilities and areas
RBE01-3 Effective Daylighting	
Encourage design that optimises the use of effective natural lighting for better visual comfort. (a) Habitable Spaces - Daylighting provision for 25% of the total number of dwelling units that meet the desired lighting level of $DA_{200lx,50\%}$ in 60% of applicable areas (namely living rooms and bedrooms) based on daylight availability table provided in Appendix E of this Code. (b) Non-Habitable Spaces - Provision of daylighting with minimum coverage of 80% in at least two (2) of the following areas: • Toilets/bathrooms of dwelling units • Lift lobbies and corridors • Staircases • Car parks • Common facilities	Dwelling units and common facilities and areas

<table>
<tr><th colspan="2">Table 4.2(a) – Carbon Reduction Measures for Residential Buildings</th></tr>
<tr><td>SUSTAINABILITY INDICATORS</td><td>APPLICABILITY & SCOPE</td></tr>
<tr><td colspan="2">SECTION 2 - SUSTAINABLE CONSTRUCTION</td></tr>
<tr><td colspan="2">RBE02-1 Resource Efficiency Measures</td></tr>
<tr><td>Encourage building design and practices that facilitate efficient use of resources in building construction.

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

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

(c) Embodied carbon reporting to account for the upfront carbon emissions of three (3) key construction materials namely, concrete, steel, and glass used in building developments.</td><td>Building design and construction</td></tr>
<tr><td colspan="2">RBE02-2 Low Carbon Concrete</td></tr>
<tr><td>Enhance carbon reduction with the use of sustainable materials in building construction.

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

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

<table><tr><th colspan="2">Minimum Usage Requirements</th></tr><tr><td>Recycled Concrete Aggregate (RCA)</td><td>1.50% X GFA</td></tr><tr><td>Granite fines</td><td>1.50% x GFA</td></tr><tr><td>Washed Copper Slag (WCS)</td><td>0.75% x GFA</td></tr><tr><td colspan="2">Note: GFA refers to Approved Gross Floor Areas of the building</td></tr></table>
(c) Alternative construction materials that can be used as a replacement for standard building materials for non-structural application.</td><td>Concrete building elements and construction materials</td></tr>
<tr><td colspan="2">RBE02-3 Sustainable Products</td></tr>
<tr><td>Encourage the specification and use of environmentally friendly products that are certified with Environmental Product Declaration (EPD) requirements or two-tick rated by an approved local certification body.

The provision shall include at least three (3) products for 80% of applicable areas or building components in relation to dwelling units.</td><td>Building products/ M & E products that are applicable to dwelling units</td></tr>
</table>

Table 4.2(a) – Carbon Reduction Measures for Residential Buildings	
Sustainability Indicators	APPLICABILITY & SCOPE
SECTION 3 - SUSTAINABLE TECHNOLOGIES	
RBE03-1 Renewable Energy System	
Encourage the use of on-site renewable energy system with a minimum capacity installation that would take up 15% of the roof areas of residential blocks within the development. The provision must come with suitable means to record and monitor the energy generated from the system.	Solar photovoltaic (PV) system
RBE03-2 Smart Technology Solutions	
Encourage the adoption of smart solutions and technologies which help facilitate resource usage monitoring and reduce overall energy consumption. Examples of solutions or technologies that can be considered are as follows: • Energy dashboard, web-based or mobile application or equivalent to provide useful and timely information on utility consumption and breakdown for homeowners and/or facility manager • Energy recovery system • Lifts with regenerative function • Occupancy sensors/controls for lighting in private lift lobbies, staircases or common facilities • Others (to be evaluated on a case-to-case basis)	Building/sensor-related technologies and energy usage monitoring apps/ system

Table 4.2(b) – Carbon Reduction Measures for Non-Residential Buildings	
Sustainability Indicators	APPLICABILITY & SCOPE
SECTION 1 - SUSTAINABLE DESIGN STRATEGIES	
NRBE01-1 Enhanced Building Envelope Performance	
Enhance building envelope performance to minimise heat gain to internal spaces for better indoor thermal comfort with any of the following provisions: (a) Façade design with Envelope Thermal Transfer Value (ETTV) of not more than 40 W/m^2 or enhanced with the provision of good thermal break/insulating profile framing. (b) Application of cool materials that are certified by an approved local product certification body for 80% of all external walls of the building development or applicable roof areas. (c) Provision of innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, parametric façade and so on for at least 20% of the fenestration areas.	Building envelope and roof
NRBE01-2 Naturally Ventilated Building Design	
Enhance indoor thermal comfort through the provision of building layout design which facilitates good natural ventilation. (a) Building layout design comprises 20% of all normally occupied spaces with openings facing prevailing wind directions. (b) Design for natural ventilation with minimum coverage of 80% in at least two (2) of the following areas: • Lift lobbies • Corridors • Staircases • Car parks • Atriums • Toilets	Normally occupied spaces and common areas
NRBE01-3 Effective Daylighting	
Encourage the provision of natural lighting to improve visual comfort and reduce energy use associated with artificial lighting. (a) Normally occupied spaces: Daylighting provision with the integration of daylighting controls or other suitable means for minimum coverage of 15% of the total normally occupied spaces. The extent of daylight provision shall be determined based on the Daylight Availability Tables and Methodology, details in technical guide and shall meet the desired lighting level and specific Daylight Autonomy (DA) requirements as listed below:	Normally occupied spaces and common areas

Table 4.2(b) – Carbon Reduction Measures for Non-Residential Buildings	
Sustainability Indicators	Applicability & Scope
NRBE01-3 Effective Daylighting (continued)	
<table><tr><th>S/N</th><th>Minimum Lighting Level Based on Space Occupancy Type</th><th>Daylight Autonomy requirement per unit area of space</th></tr><tr><td>1</td><td>Office, Institutional spaces where lux requirement is 500 lux</td><td>$DA_{500lx,50\%}$</td></tr><tr><td>2</td><td>Industrial, sports facilities, retail areas where lux requirement is 300 lux</td><td>$DA_{300lx,50\%}$</td></tr><tr><td>3</td><td>Hotel, resort-like and service apartment where lux requirement is 200 lux</td><td>$DA_{200lx,50\%}$</td></tr></table> (b) Common areas: Daylighting provision with the integration of daylight controls for minimum coverage of 80% in at least two (2) of the following areas: • Lift lobbies • Corridors • Staircases • Car parks • Atriums • Toilets (c) Provision of daylight redirecting technologies such as light shelves or tubular daylight/sun pipes to enhance lighting level.	Normally occupied spaces and common areas
SECTION 2 - SUSTAINABLE CONSTRUCTION	
NRBE02-1 Resource Efficiency Measures	
Encourage building design and practices that facilitate efficient use of resources in building construction. (a) Existing building structures with more than 50% of the floor and/or wall areas are conserved for adaptive reuse. (b) Design with Concrete Usage Index (CUI) of not more than 0.50. (c) Embodied carbon reporting to account for the upfront carbon emissions of three (3) key construction materials namely, concrete, steel, and glass used in building developments.	Building design and construction
NRBE02-2 Low Carbon Concrete	
Enhance carbon reduction with the use of sustainable materials in building construction. (a) Use of concrete with eco-friendly cementitious materials that are classified under CEM II to V types for at least 80% of the super-structural works by volume. (b) Use of recycled concrete aggregate (RCA), washed copper slag (WCS) and/or granite fines from approved sources and meet the minimum usage requirement as stipulated in the following table.	Concrete building elements and construction materials

Table 4.2(b) – Carbon Reduction Measures for Non-Residential Buildings	
Minimum Usage Requirements	
Recycled Concrete Aggregate (RCA)	1.50% X GFA
Granite fines	1.50% x GFA
Washed Copper Slag (WCS)	0.75% x GFA
Note: GFA refers to Approved Gross Floor Areas of the building	

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

NRBE02-3 Sustainable Products	
Encourage the specification and use of environmentally friendly products that are certified with Environmental Product Declaration (EPD) requirements or two-tick rated by an approved local certification body. The provision shall include at least three (3) products for 80% of applicable areas or building components in relation to functional spaces.	Building products/ M & E products that are applicable for functional spaces
SECTION 3 - SUSTAINABLE TECHNOLOGIES	
NRBE03-1 Renewable Energy System	
Encourage the use of on-site renewable energy sources to reduce the use of electricity by at least 1% of the expected total building electricity consumption.	Solar photovoltaic (PV) system
NRBE03-2 Smart Building Solutions	
Encourage the provision of a minimum of two (2) smart building solutions to facilitate automation and controls over building systems for better energy management and thermal comfort. Examples of building solutions that can be considered are listed below: • Use of BACnet, Modbus or any other open protocol as the network backbone of the building management system where data points can be used to facilitate communication and integration with other building systems. • Energy portal and dashboard that helps building owners and/or tenants to better manage their energy consumption in an intuitive manner. • Real-time remote monitoring of chiller plant system operation such as BCA Chiller Efficiency Smart Portal. • Demand controlled ventilation systems such as carbon dioxide sensors or devices to regulate the fresh air intake and ventilation based on occupants' need. • Timer sensors/controls for lighting and/or ventilation systems in common areas and facilities. • Smart building sensors that are equipped with sensing capability, microprocessors and communication technology that can help facilitate some form of monitoring or automation. • Differential pressure switches for Air Handling Units (AHUs) that are linked to a building management system (BMS) or suitable means that can monitor the air filter condition. • Others (to be evaluated on a case-to-case basis).	Building solutions that facilitate energy management and controls

Table 4.2(b) – Carbon Reduction Measures for Non-Residential Buildings	
NRBE03-3 Green Building Technologies	
Encourage the adoption of low-carbon solutions and technologies which help reduce energy consumption. Examples of the systems that can be considered are as follows: • Energy recovery system • Lifts with regenerative function • Passive displacement ventilation system • Hybrid cooling system • Smart sensor and control technologies • Dedicated outdoor air system • Others (to be evaluated on a case-to-case basis)	Building/sensor-related technologies

4.3 Documentation Requirements

The Responsible Persons for Application Submission shall ensure that the documentation requirements stated in GM International documents are available as evidence to demonstrate compliance with the environmental sustainability standard set under Base Sustainability Requirements. In general, the documentation can come in the following forms:

- Extracts of the tender specifications and other forms of documentary proof showing the pertinent details of the proposed green practices or features adopted;
- Relevant plan layouts, elevations and sectional drawings showing the applicable areas, locations or types of green features adopted;
- Summary sheets listing the detailed breakdown and the extent of implementation; and
- Calculations, worksheets or other data in the prescribed format as required.

5 COMPLIANCE METHODOLOGY FOR EXISTING BUILDINGS

5.1 Base Sustainability Requirements for Existing Buildings

The Base Requirements essentially are environmental sustainability attributes that have a direct impact on the building energy performance and are to be complied with, where applicable. The details are provided in the following Table 5.1.

Table 5.1 – Base Requirements for Existing Non-Residential Buildings

ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
ENRB01 Building Energy Performance	
The building energy performance shall be optimized to meet the requirements in GM International - Energy Efficiency (Pathway 1, Pathway 2 or Pathway 3) The compliance with this requirement shall be demonstrated either by way of energy audit methodology as mentioned in ENRB01-1 or by meeting the respective performance standards set for key energy systems set out in ENRB01-2.	Energy performance of building energy systems
ENRB01-1 Whole Building Approach via Energy Audit	
Two criteria shall be complied with to meet the minimum building energy performance. (1) The Energy Usage Intensity (EUI) of the building shall not exceed the benchmark set for the various building categories stipulated in the GM International Energy Efficiency Technical Guide, Table 1B Pathway 1 for Energy Use Intensity (EUI). (2) The Total System Efficiency (TSE) of the building cooling system shall meet the required TSE mentioned in Pathway 1, Pathway 2, or Pathway 3. TSE refers to the combined system efficiency of the chilled water plant and air distribution systems. The TSE shall not exceed the following limits:- **Total System Efficiency (TSE) of Building Cooling System** Water-cooled: 0.9 kW/RT; Air-cooled: 1.0 kW/RT In addition, the building must also comply with the minimum requirement on the chilled water plant system efficiency (that is the water-side component) and shall not exceed 0.65 kW/RT.	Air-conditioning system and lighting provision Other energy systems, where relevant.
ENRB01-2 System Level Approach via Enhanced Energy Performance Standards	
Facilitate energy load reduction with the provision of enhanced energy-efficient building systems and equipment that could contribute towards meeting the minimum energy efficiency set out in the following sub-sections.	Key building systems stated in the sub-sections.
ENRB01-2(a) Air-Conditioning System	
Reduce energy required to provide and distribute conditioned air within the space using energy-efficient air-conditioning system. (i) Water-Cooled Building Cooling System comprises the following systems and components, where relevant. • Water-Cooled Chiller • Water-Cooled Direct-Expansion (DX) System • Chilled Water Pump • Condenser Water Pump • Cooling Tower • Air-Distribution System	Water-cooled and air-cooled building cooling system, and air-distribution system

<table>
<tr><th colspan="2">Table 5.1 – Base Requirements for Existing Non-Residential Buildings</th></tr>
<tr><th>ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES</th><th>APPLICABILITY & SCOPE</th></tr>
<tr><td>The Total System Efficiency (TSE) of the building cooling system shall meet the required TSE mentioned in Pathway 1, Pathway 2 or Pathway 3.
In addition, the chilled water plant system efficiency (that is the water-side component) shall not exceed 0.65 kW/RT.</td><td></td></tr>
<tr><td>(ii) Air-Cooled Building Cooling System comprises the following systems and components, where relevant
• Unitary Air-Conditioners (Single or combination of systems)
o Variable Refrigerant Flow (VRF) system
o Single-Split Units
o Multi-Split Units
o Air-Distribution System

• Air-Cooled Chilled-Water System can only be adopted for existing building with inherent constraints and with peak building cooling load of not more than 500 RT
o Air-Cooled Chiller
o Chilled Water Pump
o Air-Distribution System

For Air-cooled building cooling system, the Total System Efficiency (TSE) shall not exceed required TSE mentioned in Pathway 1, Pathway 2, or Pathway 3. The TSE refers to the combined system efficiency of the condenser units/air-cooled chilled water plant and air distribution systems.

<table><tr><th>Total System Efficiency (TSE) for Air-Cooled Building Cooling System</th></tr><tr><td>1.0 kW/RT</td></tr></table>
In addition, the building must also comply with the minimum requirement of the water-side component efficiencies of the condensing units / air-cooled chilled water plant, as stated in the following table:

<table><tr><th colspan="2">Minimum Air-Conditioning Component Efficiency</th></tr><tr><td>Unitary System (Outdoor Condenser Units)</td><td>Air-Cooled Chilled Water Plant (Peak cooling load ≤ 500 RT)</td></tr><tr><td>0.78 kW/RT</td><td>0.86 kW/RT</td></tr></table>
Note(1) – The air-side component efficiency of the fan systems can be adjusted to allow for pressure drop adjustments where there is a need for more allowance due to functionality and activities as per recommended in SS 553 : Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings – Table 2b.

Note(2) – Where there is a combination of water-cooled and air-cooled building cooling systems adopted, the respective TSEs are to be complied with.</td><td>Water-cooled and air-cooled building cooling system, and air-distribution system</td></tr>
<tr><td colspan="2">ENRB01-2(b) Lighting System</td></tr>
<tr><td>Reduce energy required to illuminate interior spaces with proper lighting levels. The lighting provision shall meet the requirements in GM International - Energy Efficiency Technical guide on Lighting Power Budget and the lighting level shall be provided in accordance with SS 530, where applicable.</td><td>Lighting systems for all spaces (excluding tenanted areas)</td></tr>
<tr><td colspan="2">ENRB01-2(c) Mechanical Ventilation System</td></tr>
</table>

Table 5.1 – Base Requirements for Existing Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
Reduce energy required to supply and distribute fresh air within the space using energy-efficient mechanical ventilation systems and controls. (a) Mechanical ventilation systems for normally occupied spaces shall be designed to be at least 10% more energy efficient than the prescribed standard stated in SS 553; and (b) Provision of Carbon Monoxide (CO) detection sensor control with Variable Speed Drive (VSD) to regulate demand for mechanical ventilation in car parks.	Mechanical ventilation systems for normally occupied spaces and carparks .
ENRB01-2(d) Vertical Transportation System	
Reduce energy consumption needed for vertical transportation with the provision of lifts and escalators that are equipped with variable voltage variable frequency (VVVF) drives and sleep mode features and/or standby speed/stop features, where relevant. Note: Other than the provision of vertical transportation systems that come with VVVF and sleep mode features, there are other energy-efficient technologies such as regenerative drive or deployment of advanced dispatching software that could reduce occupant wait time while reducing energy use by up to 50% compared to traditional systems.	Lifts and/or escalators
ENRB02 Measurement and Verification (M & V) Instrumentation	
Facilitate energy management and monitoring of air-conditioning system operating efficiency with the provision of permanent measuring instrumentation.	Energy measurement and management of air-conditioning systems
ENRB02-1 Instrumentation for Chilled Water System	
Provision of permanent measuring instruments to monitor the energy performance of the chilled water plants and air distribution systems. The installed instrumentation must have the capability to calculate the resultant system efficiency within 5% of its true value in accordance with SS 591 – Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency. Each measurement system shall include sensors, any signal conditioning, the data acquisition system and the wiring connecting these components. The permanent measuring instruments and devices are to be accessible (See Note(1)) and must not be located directly above the chillers, to facilitate verification and maintenance. They must be installed according to the manufacturers' recommendations and SS 591. The measurement systems provided shall also comply with the following requirement: (a) All data logging devices are to be equipped with the capability to trend at a 1-minute sampling time interval, and recorded to the 3rd decimal digit; (b) Building management system (BMS) or standalone energy monitoring system (EMS) shall have the capability to compute and display the total system energy efficiency and its component (water-side and air-side system efficiency) as well as the calculated heat balance of the chilled water system; (c) Magnetic in-line flow meter, with 1% uncertainty and capable of electronic in-situ verification to within ±2% of its original factory	Instrumentation for Water-cooled and air-cooled chilled water plants and air distribution systems

Table 5.1 – Base Requirements for Existing Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
calibration. If the installation of magnetic in-line meters is not possible, ultrasonic flow meters or other flow meters that can meet the indicated performance may be used; (d) Temperature sensors are to be provided for chilled water and condenser water loop and shall have a measurement uncertainly within ±0.05°C over the entire measurement range. Each temperature measurement location shall have test plugs or additional thermowells located before and after each temperature sensor along the chilled water and condenser water lines for verification of measurement accuracy. All thermo-wells shall be installed in a manner that would allow the sensors to be in direct contact with the fluid flow; (e) Dedicated power meters (of IEC Class 1 or better) and metering current transformers (of Class 1 or better) are to be provided for each of the following groups of equipment, where applicable: chillers, chilled water pumps, condenser water pumps, cooling towers, air-distribution sub-system (i.e. AHUs, PAHUs). The same should be provided for FCUs, where possible; and (f) A heat balance substantiating test for the chilled water system is to be computed in accordance with SS 591 for verification of the accuracy of the M & V instrumentation. To meet the accuracy requirement, more than 80% of the heat balance (%) derived over the entire normal operating hours is to be within 5% for a period of one (1) week. Note (1) – The temperature sensors are best placed in an accessible location with a mounting height of not more than 3 m, where possible. Otherwise, there should be evidence of provision for access by way of mobile access platforms or other suitable forms.	
ENRB02-2 Instrumentation for Variable Refrigerant Flow (VRF) System	
Provision of permanent measuring instruments for monitoring of the energy performance of the Variable Refrigerant Flow (VRF) condensing units and air distribution systems. The installed instrumentation must have the capability to calculate the resultant system efficiency within 10% uncertainty. Each measurement system shall include sensors, any signal conditioning, the data acquisition system and the wiring connecting these components. The measurement systems provided shall also comply with the following requirement: (a) All data logging devices are to be equipped with the capability to trend at a 5-minute sampling time interval, and preferably recorded to the 3rd decimal digit; (b) Building management system (BMS), standalone energy monitoring system (EMS) or other suitable systems shall have the capability to compute and display the total system energy efficiency and its component (condensing unit and air distribution system efficiency) and to facilitate data extraction for verification purposes; and (c) Dedicated power meters (of IEC Class 1 or better) and metering current transformers (of Class 1 or better) are to be provided for all condensing units of the VRF system and air distribution sub-systems (i.e. AHUs,	Gold^{PLUS} and Platinum projects shall provide instrumentation for all VRF systems and air distribution systems. Certified and Gold shall provide instrumentation for VRF systems and air distribution systems that serve an aggregate conditioned floor area of 2000 m^2 or more.

Table 5.1 – Base Requirements for Existing Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
PAHUs*)*, where applicable*.* The same should be provided for FCUs, where possible.	
ENRB03 Real-Time Remote Monitoring of Chiller Plant System Operation	
Facilitate real-time diagnostic and monitoring of chiller plant system operation with the provision of web-based control system with remote access functionality.	Energy measurement and management
ENRB04 Energy Utilisation Reporting	
Encourage monitoring of the building energy consumption trend over time and review of energy efficiency measures and improvement plan.	Energy use trending and improvement
ENRB05 Indoor Temperature	
Minimise incidences of overcooling and energy wastage by ensuring that the normal dry-bulb temperature for indoor spaces is maintained at 23^{o}C and above.	Indoor air temperature
ENRB06 Indoor Air Quality (IAQ) Audit	
Facilitate improvement on indoor environmental quality by way of a post-retrofit IAQ audit. The audit shall be conducted by an accredited laboratory under Singapore Accreditation Council or by the local IAQ consultants or certified laboratory operating in the country in which the building is being assessed. The IAQ shall be based on the parameters and method of measurement, stated in with respect to the recommended IAQ parameters and acceptable limits stated in Table 1 of SS554 : 2016 Code of Practice for Indoor Air Quality for Air-Conditioned Buildings.	Indoor air quality

5.2 Carbon Reduction Measures for Existing Buildings

5.2.1 A suite of environmental sustainability indicators in relation to energy and carbon emission reduction measures is provided and classified in the following three (3) sections.

Sustainable Features

encourages incorporation of cost effective green features and passive strategies when building upgrade so as to minimise the overall building energy consumption and to improve on indoor thermal comfort.

Sustainable Operation and Management

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

Sustainable Technologies

encourages the provision of green technology that is oriented towards establishing low energy building consumption and smart control systems that could adapt to the users' needs and facilitate better building performance management.

5.2.2 A selection of **three (3) carbon reduction measures** appropriate for the building development from the suite of environmental sustainability indicators provided in Table 5.2 will be required. In addition, there must be **one (1) measure from Section 2 - Sustainable Operation and Management** as part of the requirements to meet the minimum environmental sustainability standard.

5.2.3 Alternative solutions which could meet the sustainability objectives under these sections can be considered on a case-to-case basis.

<table>
<tr><th colspan="2">Table 5.2 – Carbon Reduction Measures for Existing Non-Residential Buildings</th></tr>
<tr><th>SUSTAINABILITY INDICATORS</th><th>APPLICABILITY & SCOPE</th></tr>
<tr><td colspan="2">SECTION 1 - SUSTAINABLE FEATURES</td></tr>
<tr><td colspan="2">ENRBE01-1 Building Envelope Enhancement</td></tr>
<tr><td>Enhance building envelope performance to minimise heat gain to internal spaces for better indoor thermal comfort with any of the following provisions:

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

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

(c) Provision of innovative façade technology or solutions such as the use of electrochromic glass, integration of photovoltaic modules, film technology, parametric façade and so on for at least 20% of the fenestration areas.</td><td>Building envelope and roof</td></tr>
<tr><td colspan="2">ENRBE01-2 Naturally Ventilated Building Design</td></tr>
<tr><td>Reduce energy demand for cooling and ventilation by enhancing the space layout design with added provision of naturally ventilated spaces by at least 5% of the applicable areas.</td><td>Applicable areas</td></tr>
<tr><td colspan="2">ENRBE01-3 Sustainable Products</td></tr>
<tr><td>Encourage the specification and use of environmentally friendly products that are certified with Environmental Product Declaration (EPD) requirements or two-ticks rating by an approved local certification body.

The provision shall include at least two (2) products for 80% of applicable areas or building components.</td><td>Building products mechanical and electrical products</td></tr>
<tr><td colspan="2">SECTION 2 – SUSTAINABLE OPERATION AND MANAGEMENT</td></tr>
<tr><td colspan="2">ENRBE02-1 Electrical Submetering</td></tr>
<tr><td>Facilitate measurement and monitoring of major energy end uses for energy management and audit. Separate sub-meters shall be provided and linked to a monitoring system that can measure and trend energy consumption data of any of the following systems when upgrade:

<table>
<tr><th colspan="2">Sub-System for Metering</th></tr>
<tr><td>Lifts and escalators</td><td>More than 5 numbers or sets or with a sum of all feeders > 50 kVA.</td></tr>
<tr><td>Mechanical ventilation systems</td><td>Total subsystem’s load > 15 kW
Sub-metering applicable to individual fan system motors that are more than 1.5 kW in the following areas
• Normally Occupied Spaces
• Mechanical and Electrical Plant Rooms
• Car Parks</td></tr>
<tr><td>Centralised hot water supply system</td><td>> 50 kW thermal heating capacity</td></tr>
<tr><td>General power supply and lighting systems for tenancy areas and owners’ premises*</td><td>Sub-metering for tenancy areas and owners’ premises are to be separated. The sub-circuits serving these areas can be provided based on a sub-system basis and /or per floor level.</td></tr>
</table>
</td><td>Submetering for monitoring of major energy end uses and energy audit</td></tr>
</table>

Table5.2 – Carbon Reduction Measures for Existing Non-Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
SECTION 2 – SUSTAINABLE OPERATION AND MANAGEMENT	
ENRBE02-1 Electrical Submetering (Continued)	
Note(1): Sub-metering provision for chilled water plant, variable refrigerant flow (VRF) systems and air distribution systems are covered under ENRB02. Note (2): If there is a need to cater to high plug loads or process loads exceeding 50 kVA, please provide separate sub-metering for these specific loads or areas to better manage the energy consumption.	Submetering for monitoring of major energy end uses and energy audit
ENRBE02-2 Maintenance of Building Cooling System Performance	
Ensure adequate service clearances so that the building cooling system performance can be maintained during operation as designed. The access space provisions for the following equipment are to comply with either the service clearances as per manufacturers' specification or the specifications set out in ENRBE02-2(a) to ENRBE02-2(d), whichever governs.	Space requirement for water-cooled and air-cooled chilled water systems, and air distribution systems
ENRBE02-2(a) Chillers	
Access space provisions are as follows: (a) Clearance of 2.0 m or more at the front of chiller unit piping section for tube maintenance and cleaning, repair and replacement of bigger components; (b) Clearance of 1.2 m or more between the chillers measured from plinth to plinth for regular maintenance; and (c) Clearance of 1.5 m or more above the chiller for maintenance, overhaul or replacement.	Chillers
ENRBE02-2(b) Pump Systems	
Access space provisions are as follows: (a) Except for the areas where the pipes are connected, clearance of 0.6 m or more is to be provided around the pump for regular maintenance; and (b) Clear head room of 1.0 m or more above the pump and motor to facilitate maintenance, overhaul or replacement.	Chilled water pumps (CHWP) and condensers water pumps (CWP)
ENRBE02-2(c) Cooling Towers	
Maintenance provisions are as follows: (a) Provision of maintenance platform, stairs and catwalks of 600 mm width or more with handrails around the cooling towers and access to the level for periodic maintenance and the inspection of the water basin and fill media; and (b) Clear distance of 2.0 m or more from the top of cooling towers to the location of the trellis, where applicable.	Cooling towers

Table5.2 – Carbon Reduction Measures for Existing Non-Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
ENRBE02-2(d) Air-Distribution Systems	
Maintenance provisions are as follows: (a) Air handling units (AHUs) of cooling capacity greater than 35 kW shall be floor mounted as stipulated in SS 553. (b) For AHUs that are floor mounted, the access space provisions are as follows: (i) AHU access – Provide minimum 1.0 m clearance from the AHU room door entrance to the AHU for general maintenance; (ii) Cooling coil pipe and filter access – Provide minimum 800 mm clearance after pipe connection to facilitate cooling coil cleaning and filter access; (iii) Fan access – Provide minimum 800 mm clearance for fan/motor access and maintenance (if the access is not from the cooling coil connection side); and (iv) AHU side and back clearance – Provide minimum 600 mm clear width for general access and maintenance.	Floor mounted air handling units
ENRBE02-3 User Engagement Plan	
Encourage the provision of user engagement plans and strategies that facilitate users' involvement and contribution in reducing the overall carbon footprint. It should have a minimum of two (2) strategic approaches such as sustainability-related activities, educational programmes, green fit-out guidelines, green lease or incentives for tenants meeting measurable outcomes.	Approaches adopted must have users' involvement
SECTION 3 – SUSTAINABLE TECHNOLOGIES	
ENRBE03-1 Renewable Energy System	
Encourage the use of on-site renewable energy sources to reduce the use of electricity by at least 1% of the expected total building electricity consumption.	Solar photovoltaic system
ENRBE03-2 Smart Building Solutions	
Encourage the provision of a minimum of two (2) building solutions which facilitate automation and controls over building systems for better energy management and thermal comfort as listed below: • Use of BACnet, Modbus or any other open protocol as the network backbone of the building management system where data points can be used to facilitate communication and integration with other building systems. • Energy portal and dashboard that helps building owners and/or tenants to better manage their energy consumption in an intuitive manner. • Demand controlled ventilation systems such as carbon dioxide sensors or devices to regulate the fresh air intake and ventilation based on occupants' need. • Timer sensors/controls for lighting and/or ventilation systems in common areas and facilities.	Building solutions that facilitate energy management and controls

Table5.2 – Carbon Reduction Measures for Existing Non-Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
• Smart building sensors that are equipped with sensing capability, microprocessors and communication technology that can help facilitate some form of monitoring or automation. • Differential pressure switches for Air Handling Units (AHUs) that are linked to a building management system (BMS) or suitable means that can monitor the air filter condition. • Others (to be evaluated on a case-to-case basis).	
ENRBE03-3 Green Building Technologies	
Encourage the adoption of low-carbon solutions and technologies which help minimise energy consumption. Examples of the systems that can be considered are as follows: • Energy recovery system • Lifts with regenerative function • Passive displacement ventilation system • Hybrid cooling system • Smart sensor and control technologies • Dedicated outdoor air system • Others (to be evaluated on a case-to-case basis)	Building and sensor-related technologies

5.3 Documentation Requirements

The building owner and his consultants shall ensure that the relevant documentation (as stated in GM International documents) are available and provided as evidence to demonstrate compliance with the environmental sustainability standard set under Base Sustainability Requirements and selected Carbon Reduction Measures.

Submittal of other documents may be required and shall be provided in such forms as requested by the Green Mark assessors.