CODE ON

ENVIRONMENTAL SUSTAINABILITY MEASURES

FOR EXISTING BUILDINGS

Edition 3.0

Building and Construction Authority

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CODE ON ENVIRONMENTAL SUSTAINABILITY MEASURES FOR EXISTING BUILDINGS (EDITION 3.0)

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INTRODUCTION

The intent of this Code for Environmental Sustainability Measures for Existing Buildings (referred to as "this Code") is to establish environmentally friendly practices in the operation and retrofitting of existing buildings.

This Code sets out the guidance and details in respect of the minimum environmental sustainability standard for existing buildings defined in the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 and the administrative requirements.

This Code 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 Code and such other laws affecting the design and construction of the building, the laws shall take precedence.

If you need clarification on any aspect of this Code, please contact the Building and Construction Authority, Singapore (BCA).

1 SCOPE

This Code sets out the minimum environmental sustainability standard for existing buildings and the administrative requirements in complying with the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013. It includes the compliance method for determining the level of environmental sustainability of an existing building.

The Code shall apply to all prescribed buildings with Gross Floor Areas (GFA) of 5000 m^2 or more for which a major energy-use change is proposed (that is the installation, substantial alteration or replacement of the prescribed cooling system), except for the following Type A and Type B buildings.

Type A
- (a) Data centres;
- (b) Religious buildings;
- (c) Residential buildings (other than serviced apartments); or
- (d) Utility buildings;

Type B
- (a) Industrial buildings;
- (b) Railway premises;
- (c) Port services and facilities; or
- (d) Airport services and facilities.

For more details on the applicable building types and mixed-use development, please refer to the Building Control (Environmental Sustainability Measures for Existing Building) (Amendment) Regulations 2016.

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

2 DEFINITIONS

For the purpose of this Code, the following definitions shall apply:

As-built Submission	The submitted as-built score for a prescribed building that has completed the major energy-use change.
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.
Design Submission	The submitted design score for a prescribed building undergoing a major energy-use change.
Gross Floor Area (GFA)	The "gross floor area" has the same meaning as "floor area" in the Planning (Development Charges) Rules (Cap.232, R 5).
Minimum Green Mark Score	The score that would meet the minimum level of environmental performance required for existing buildings.
Operating System Efficiency (OSE)	The measured system efficiency of the building's chilled water plant during its normal operating hours.

PE(Mechanical)	A person who is registered under the Professional Engineers Act (Cap. 253) in the mechanical engineering discipline and who has in force a practicing certificate issued under that Act authorizing him to engage in mechanical engineering.
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.
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.

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

3 STATUTORY REQUIREMENTS

3.1 Act and Regulations

The following Act and Regulations have relevance:

a. The Building Control Act

b. The Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 (referred to as "the Regulations" in this Code)

c. The Building Control (Environmental Sustainability Measures for Existing Building) (Amendment) Regulations 2016

3.2 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 554 : Code of Practice for Indoor Air Quality for Air-Conditioning Buildings

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

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

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

3.3 Responsibility

The building owner shall appoint a Professional Engineer (Mechanical), in short PE (Mech) before the commencement of the proposed major energy-use change to the building. The PE (Mech) shall assess the design of the retrofitting works involving the installation/replacement of the cooling system, prepare the Design Submission, and provide the documentation of the design submissions that meets the minimum environmental sustainability standard and such other documents required in the Regulations.

The building owner shall submit the Design Submission and supporting documents prepared by his PE(Mech) for approval before work commencement and to complete the works not later than the period prescribed in the Regulations.

Upon work completion, the PE (Mech) shall assess and prepare the As-built Submission that meets the minimum environmental sustainability standard and provide to the building owner the documentation of the As-built Submission, completion certificate and such other documents required in the Regulations.

The building owner shall submit the As-built Submission, the declaration by PE(Mech) and supporting documents to BCA for approval not later than the period prescribed in the Regulations.

3.4 Minimum Environmental Sustainability Standard

The minimum environmental sustainability standard of the 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 4.1 and 4.2 in order to meet the minimum Green Mark score of 50 points.

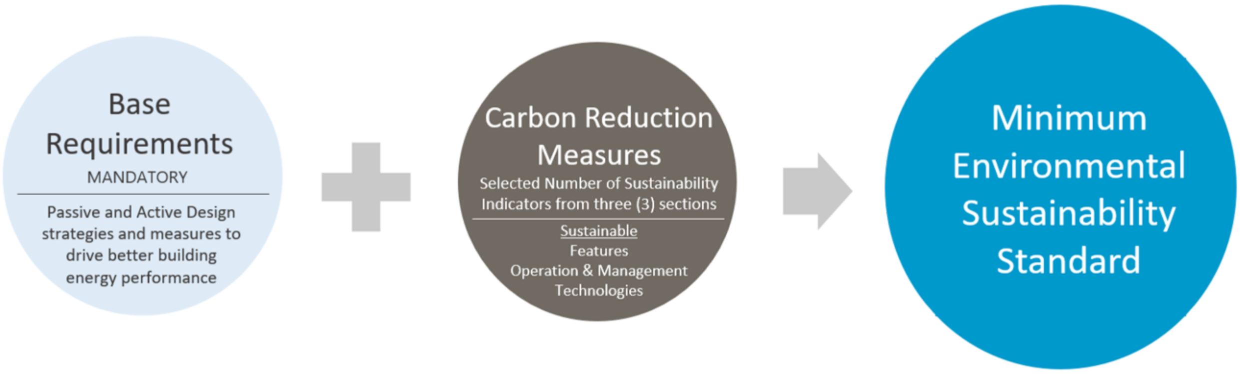


Figure 3.4 – Overview of Compliance Framework

4 COMPLIANCE METHODOLOGY

4.1 BASE REQUIREMENTS

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 4.1.

Table 4.1 – Base Requirements for Existing Non-Residential Buildings

ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
ENRB01 Building Energy Performance	
The building energy performance shall be optimised to meet the minimum energy improvements of 40% over the 2005 baseline when retrofit. This can be translated to 20% energy savings over the current Singapore Standard and baseline. The compliance with this requirement shall be demonstrated either by way of energy audit methodology or by meeting the respective performance standards set for key energy systems set out in the following sections ENRB01-1 and ENRB01-2.	Energy performance of building energy systems
ENRB01-1 Whole Building Approach via Energy Audit	
Facilitate energy efficiency improvement of 40% over the 2005 baseline by optimising the energy saving potential from system upgrades and retrofits. The Energy Usage Intensity (EUI) of the building shall not exceed the benchmark set for the respective building categories shown in the following table:	Air-conditioning system and lighting provision Other energy systems, where relevant.

Energy Use Intensity (EUI) for Different Building Categories ($kWh/m^2.yr$)			
Commercial		**Healthcare**	
Office Buildings (Large)	155	Hospitals	375
Office Buildings (Small)	135	Community Hospitals	230
Hotels (Large)	230	Polyclinic	150
Hotels (Small)	185	Nursing/ Youth Homes	90
Retail Malls	240	-	-
Educational		**Others**	
Institutions of Higher Learning (University, Polytechnics, ITE)	130	Sport and Recreation Centres	110
Private Schools and Colleges	110	Community Centres	150
Junior Colleges	60	Cultural Institution	180
Public Schools	40	Civic Buildings	80
Mixed developments (by GFA mix)			
Source: GM 2021 Framework			

The demonstration of the energy savings requirement shall be conducted using the energy audit approach based on the methodology and requirements stipulated in Appendix A.

The Total System Efficiency (TSE) of the building cooling system provided shall not exceed the following limits

Total System Efficiency (TSE) of Building Cooling System	
Water-cooled	Air-Cooled
0.9 kW/RT	1.0 kW/RT

Table 4.1 – Base Requirements for Existing Non-Residential Buildings

ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
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 improvements of 40% over the 2005 baseline.	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 through the use of energy-efficient air-conditioning system.	Water-cooled and air-cooled building cooling 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) for Water-Cooled Building Cooling System
Existing Buildings with Major Energy-Use Change
0.9 kW/RT

where TSE refers to the combined system efficiency of the chilled water plant and air distribution systems.

The minimum requirement on the chilled water plant system efficiency (that is the water-side component) will be based on the chilled water supply temperature and as follows:

Minimum Water-Cooled Chilled Water Plant Efficiency η_c						
Chilled Water Supply Temp (°C)	6	7	8	9	10	For chilled water supply temp above 10°C, the threshold will be adjusted from 0.64 kW/RT by 0.01 kW/RT for every 1 °C increase in chilled water supply temperature
Water-Cooled Chiller System Efficiency (kW/RT)	0.68	0.67	0.66	0.65	0.64	

(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 development with inherent constraints and with peak building cooling load of not more than 500 RT
  - Air-Cooled Chiller
  - Chilled Water Pump
  - Air-Distribution System

<table>
<tr><th colspan="2">Table 4.1 – Base Requirements for Existing Non-Residential Buildings</th></tr>
<tr><th>ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES</th><th>APPLICABILITY & SCOPE</th></tr>
<tr><td>
<table>
<tr><th>Total System Efficiency (TSE)
for Air-Cooled Building Cooling System</th></tr>
<tr><td>Existing Buildings with Major Energy-Use Change</td></tr>
<tr><td>1.0 kW/RT</td></tr>
</table>
where TSE refers to the combined system efficiency of the condenser units/air-cooled chilled water plant and air distribution systems.
The minimum water-side component efficiencies for different systems are as stated in the following table.
<table>
<tr><th colspan="2">Minimum Air-Conditioning Component Efficiency η_c</th></tr>
<tr><td>Unitary System
(Outdoor Condenser Units)</td><td>Air-Cooled Chilled Water Plant
(Peak cooling load $\leq$ 500RT)</td></tr>
<tr><td>0.78 kW/RT
(inclusive of site derating factor)</td><td>0.85 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</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 be at least 40% more energy efficient than the prescribed lighting power budget stated in SS 530 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment.</td><td>Lighting systems for all spaces (excluding tenanted areas)</td></tr>
<tr><td colspan="2">ENRB01-2(c) Mechanical Ventilation System</td></tr>
<tr><td>Reduce energy required to supply and distribute fresh air within the space through the use of energy-efficient mechanical ventilation systems and controls.

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

(ii) Provision of Carbon Monoxide (CO) detection sensor control with Variable Speed Drive (VSD) to regulate demand for mechanical ventilation in car parks.</td><td>Mechanical ventilation systems for normally occupied spaces and carparks if there is a replacement</td></tr>
<tr><td colspan="2">ENRB01-2(d) Vertical Transportation System</td></tr>
<tr><td>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.</td><td>Lifts and/or escalators if there is a replacement</td></tr>
</table>

<table>
<tr><th colspan="2">Table 4.1 – Base Requirements for Existing Non-Residential Buildings</th></tr>
<tr><th>ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES</th><th>APPLICABILITY & SCOPE</th></tr>
<tr><td colspan="2">ENRB02 Measurement and Verification (M & V) Instrumentation</td></tr>
<tr><td>Facilitate energy management and monitoring of air-conditioning system operating efficiency with the provision of permanent measuring instrumentation.</td><td>Energy measurement and management of air-conditioning systems</td></tr>
<tr><td colspan="2">ENRB02-1 Instrumentation for Chilled Water System</td></tr>
<tr><td>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 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</td><td>Instrumentation for Water-cooled and air-cooled chilled water plants and air distribution systems</td></tr>
</table>

Table 4.1 – Base Requirements for Existing Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
(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, PAHUs), where applicable. The same should be provided for FCUs, where possible.	Instrumentation for VRF systems and air distribution systems that serve an aggregate conditioned floor area of 2000 m^2 or more.
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 such as BCA Chiller Efficiency Smart Portal.	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

Table 4.1 – Base Requirements for Existing Non-Residential Buildings	
ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES	APPLICABILITY & SCOPE
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°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 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

4.2 CARBON REDUCTION MEASURES

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.

1

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.

2

Sustainable Operation and Management

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

3

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.

4.2.2 A selection of three (3) carbon reduction measures appropriate for the building development from the suite of environmental sustainability indicators provided in Table 4.2 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.

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

Table 4.2 – Carbon Reduction Measures for Existing Non-Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
SECTION 1 - SUSTAINABLE FEATURES	
ENRBE01-1 Building Envelope Enhancement	
Enhance building envelope performance to minimise heat gain to internal spaces for better indoor thermal comfort with any of the following provisions: (a) Façade design with Envelope Thermal Transmittance Value (ETTV) of not more than 45 W/m^2. (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.	Building envelope and roof
ENRBE01-2 Naturally Ventilated Building Design	
Reduce energy demand for cooling and ventilation by enhancing the space layout design with added provision of naturally ventilated spaces by at least 5% of the applicable areas.	Applicable areas
ENRBE01-3 Sustainable Products	
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.	Building products mechanical and electrical products

<table>
<tr><th colspan="2">Table 4.2 – 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 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>
<tr><td colspan="2">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.</td></tr>
</table>
</td><td>Submetering for monitoring of major energy end uses and energy audit</td></tr>
<tr><td colspan="2">ENRBE02-2 Maintenance of Building Cooling System Performance</td></tr>
<tr><td>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.</td><td>Space requirement for water-cooled and air-cooled chilled water systems, and air distribution systems</td></tr>
<tr><td colspan="2">ENRBE02-2(a) Chillers</td></tr>
<tr><td>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.</td><td>Chillers</td></tr>
</table>

Table 4.2 – Carbon Reduction Measures for Existing Non-Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
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
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

Table 4.2 – Carbon Reduction Measures for Existing Non-Residential Buildings	
SUSTAINABILITY INDICATORS	APPLICABILITY & SCOPE
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. • 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
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 SUBMISSION PROCEDURES

5.1 General

Compliance with the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 is required before any commencement of retrofitting works for which a major energy-use change is proposed The design submission of the proposed major energy-use change are to be submitted by the PE (Mech) appointed by the building owner at the following stages:

- Before the commencement of retrofitting works
- After the completion of retrofitting works and system commissioning

5.2 Submission before the commencement of retrofitting works

The appointed PE (Mech) shall assess and design the proposed major energy-use change to the building and prepare the Design Submission and prescribed form/ documents before any work commencement. The following forms/documents are to be e-signed and submitted to BCA electronically via CORENET e-submission system for approval.

(A) Form BCA-EB-NAPPPE01	Notification of Appointment / Authorisation of Mechanical Engineer
(B) Form BCA-EB-RWAPPV01	Application for Approval of Design Score – Environmental Sustainability Measures for Existing Buildings
(C) Supporting Document to Form BCA-EB-RWAPPV01	

- Audit report on the current air-conditioning system before retrofitting works
- Cooling load calculations (if there is a change in cooling load or unitary air-conditioning systems installed)
- Design schematic drawing of proposed air-conditioning system (water-side & air-side)
- Chiller plant room layout drawing including the location of M&V instruments using symbol and color scheme as well as the access provision and service clearances of major equipment (i.e. chillers, chilled water and condenser water pumps, cooling towers, AHUs)
- Chiller part-load performance datasheet from the equipment supplier
- Chilled water pump selection datasheet and pump curves showing design flow and head, pump hydraulic efficiency, motor absorbed power and efficiency
- Condenser water pump selection datasheet and pump curves showing design flow and head, pump hydraulic efficiency, motor absorbed power and efficiency
- Cooling tower selection datasheet and location plans
- Project schedule for retrofitting works is attached
- Worksheet for chiller plant efficiency and air-side efficiency computation
- Worksheet for the lighting power budget computation
- The building's past three years Energy Use Intensity (EUI) and projected post-retrofit EUI

A Notice of Approval will be issued to the building owner if the submission is in order.

5.3 Submission after completion of the retrofitting works

Upon completion of the retrofits and system commissioning, the PE(Mech) shall assess and prepare the As-built Submission, e-signed and submit the following forms/documents to BCA electronically via CORENET e-submission system:

List of Submission Documentation	
(A) Form BCA-EB-NAPPPE01	Notification of Appointment / Authorisation of Mechanical Engineer
(B) Form BCA-EB-RWCW01	Application for Approval of Completion of Major Energy- Use Change & Submission of As-Built Score
(C) Supporting documents listed in Form BCA-EB-RWCW01	
• As-built schematic drawing of air-conditioning system (water-side & air-side) • As-built chiller plant room layout drawing indicating the location of M&V instruments using symbol and color scheme as well as the access provision and service clearances of major equipment (i.e. chillers, chilled water and condenser water pumps, cooling towers, AHUs) • As-built chiller part-load performance datasheet from the equipment supplier • As-built chilled water pump selection datasheet and pump curves showing design flow and head, pump hydraulic efficiency, motor absorbed power and efficiency • As-built condenser water pump selection datasheet and pump curves showing design flow and head, pump hydraulic efficiency, motor absorbed power and efficiency • As-built cooling tower selection datasheet and location plans • As-built air-distribution system selection datasheet and relevant details • Instruments' calibration certificates from an accredited laboratory (temperature sensors) and batch calibration certificates from manufacturers (other M&V instruments) • Construction drawings of the instruments showing the details of installation • 2-week raw data of the following data points in excel format (.xls) with the date and time stamp: chilled water supply temperature (°C); chilled water return temperature (°C); condenser water supply temperature (°C); condenser water return temperature (°C); chilled water flow rate (l/s); condenser water flow rate (l/s); electrical power of chiller(s), chilled water pump(s), condenser water pump(s) & cooling tower(s) (kW). The excel file should include all the chart plots specified in Annex B of the Code on Periodic Energy Audit of Building Cooling Systems • Energy Audit report (format in accordance to Annex B of "Code on Periodic Energy Audit of Building Cooling Systems") • As-built lighting power budget computation • The building's post retrofitted Energy Use Intensity (EUI) • A post-retrofit IAQ surveillance audit based on the indicative methods according to SS 554 - Code of Practice for Indoor Air Quality for Air-Conditioned Buildings.	

A Notice of Approval for completion of the retrofitting works will be given if the works are successfully commissioned and the submissions are in order. Site audit may be carried out and corrective actions would have to be taken to ensure compliance.

5.4 Documentation Requirements

5.4.1 Other than the submission forms, the building owner and PE (Mech) shall ensure that relevant documentation can be provided to demonstrate compliance with the environmental sustainability standard set under Base Requirements and selected Carbon Reduction Measures. Details of the documentation required can be found in Appendix A for compliance.

5.4.2 Submittal of other documents may be required and shall be made in such manner and be in such form as the Commissioner of Building Control requires upon request.

Appendix A

Compliance Requirements & Documentation

Existing Non-Residential Buildings

BASE REQUIREMENTS

For Existing Non-Residential Buildings

Strategic improvement measures and practices that have a direct influence on building energy performance and operating carbon and are to be complied with, where relevant.

ENRB01 Building Energy Performance

ENRB02 Measurement and Verification (M & V) Instrumentation

ENRB03 Real-Time Remote Monitoring of Chiller Plant System Operation

ENRB04 Energy Utilisation Reporting

ENRB05 Indoor Temperature

ENRB06 Indoor Air Quality (IAQ) Audit

ENRB01 Building Energy Performance

Intent

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

Applicability & Scope

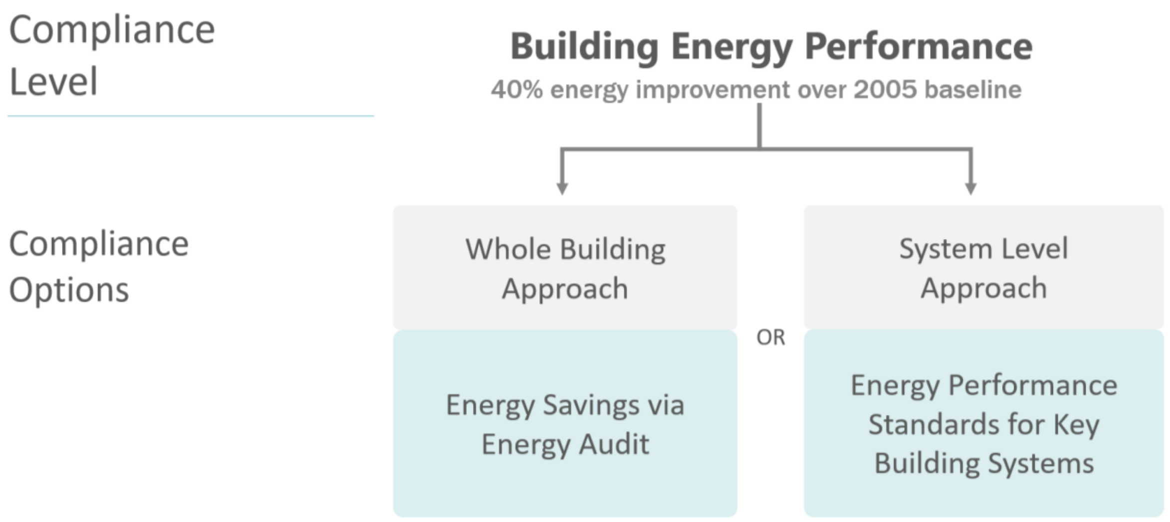
Applicable to buildings with mechanical and/or electrical equipment and systems. This section specifies the minimum energy efficiency requirements for the following systems.

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

Base Requirement

The building energy performance shall be optimised to meet the minimum energy improvements of 40% over the 2005 baseline when retrofit.

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



ENRB01-1 Whole Building Approach via Energy Audit

The Whole Building Approach via Energy Audit that could better identify the potential areas for energy use reduction shall be used to meet the minimum energy efficiency improvements of 40% over the 2005 baseline. In addition, the Total System Efficiency (TSE) of the building cooling system must also be within the stipulated limit set in Table A1 below.

The methodology in determining the compliance is as follows:

- Collate and compute the building's total yearly electricity consumption and its average over the past three (3) years based on the actual utility bills and the monthly electricity consumption in the prescribed tabulated format given in the worked example ENRB01-1. The breakdown of the electricity consumption of various key energy systems derived from energy profile distribution from Building Management System (BMS) system and existing equipment/system technical information should also be provided.

- Estimate the potential energy savings from the retrofitting works and derive the expected yearly energy consumption of the building after work completion.

- Determine the expected energy use intensity (in kWh/m^2.year) of the building. To meet the requirement, it must not be more than the prescribed Energy Use Intensity (EUI) based on the building categories as listed in Table A2 below.

- Check that the Total System Efficiency (TSE) of the building cooling system does not exceed the limits set in Table A1.

Table A1 – Total System Efficiency (TSE) of Building Cooling System	
Water-cooled	Air-Cooled
0.9 kW/RT	1.0 kW/RT

Table A2 – Energy Use Intensity (EUI) for Different Building Categories (kWh/m^2.yr)			
Commercial		**Healthcare**	
Office Buildings (Large)	155	Hospitals	375
Office Buildings (Small)	135	Community Hospitals	230
Hotels (Large)	230	Polyclinic	150
Hotels (Small)	185	Nursing/ Youth Homes	90
Retail Malls	240	-	-
Educational		**Others**	
Institutions of Higher Learning (University, Polytechnics, ITE)	130	Sport and Recreation Centres	110
Private Schools and Colleges	110	Community Centres	150
Junior Colleges	60	Cultural Institution	180
Public Schools	40	Civic Buildings	80
Mixed developments (by GFA mix)			
Source: GM 2021 Framework			

Worked Example ENRB01-1

An office building with 3000RT cooling load with planned upgrade and replacement of its chilled water system together with other energy systems including lighting to landlord areas, mechanical ventilation for car parks, efficient lift and escalator systems.

The yearly energy consumption from the actual utility bills and monthly electricity consumption of the past three (3) years as tabulated below.

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

Based on the proposed retrofitting works, estimate the potential energy savings and derive the expected yearly energy consumption of the building after work completion.

For air-conditioning systems, it can be estimated based on the energy efficiency standard of the existing system versus that of the new replacement or enhancement.

System	Energy Efficiency Standard		Annual Energy Savings*
	Existing system	New system	
Chilled Water System	1.1KW/RT	0.60kW/RT	(1.1-0.6)*3000RT*10hrs*365 days = 5,475,000 kWh
Air Distribution System	0.4kW/RT	0.25kW/RT	(0.4-0.25)*3000RT*10hrs*365 days = 1,642,500 kWh

For other systems, the energy savings can be estimated based on operational hours and usage patterns or apportionment based on the available data of the energy consumption breakdown.

In this example, the expected energy savings from the enhancement or replacement of key energy systems were estimated to be as follows:

System/ Equipment	Expected Energy Savings (KWh)/year
Lighting	1618215
Air-Conditioned Plant	5475000
Air System Fans	1642500
Mechanical Ventilation Fans	107881
Lifts	539405
Escalators	107881
Total Expected Energy Savings:	**9490882**

Expected Total Building Electricity Consumption, TBEC = Average TBEC – Expected Energy Savings
= 24,767,114 – 9490882
= 15,276,232

Building's Energy Use Intensity (EUI) = Expected TBEC / GFA
= 15,276,232/ 120,000
= 128 kWh/m2/year ok (< 155 kWh/m^2/year for large office building)

Refer to the methodology to check on the Total System Efficiency of the Building Cooling System

Documentation Requirements

Design Submission Stage

- Detailed calculation of the Energy Use Intensity (EUI) as shown in the worked example ENRB01-1;
- Other supporting documents for the water-cooled chilled water system are stated in Section 5.2; and
- For unitary air-conditioning system, to provide the technical specification and product information.

As-Built Submission Stage

- Updated calculation of the EUI if there are major changes; and
- Other supporting documents for water-cooled chilled water system are stated in Section 5.3.

ENRB01-2 System Level Approach via Enhanced Energy Performance Standards

Alternatively, the System Level Approach shall be adopted where all enhanced energy performance standards set for the key building systems are to be complied with, in order to meet the minimum energy efficiency improvements of 40% over the 2005 baseline.

ENRB01-2(a) Air-Conditioning System

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

The Total System Efficiency (TSE) which is the combined system efficiency of the chilled water plant or condenser unit and air distribution systems shall not exceed the limits set in respective Table A3 and A5 during the building operating hours as defined below.

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

The minimum threshold set on the component system efficiency of chilled water plant or condenser units stipulated in Table A4 and A6 are required to be complied with.

(i) Water-Cooled Building Cooling system comprises a combination of the following components:

- Water-Cooled Chiller
- Water-Cooled Direct-Expansion (DX) System
- Chilled Water Pump
- Condenser Water Pump
- Cooling Tower
- Air Distribution System

The limits set for Total System Efficiency set for water-cooled building cooling system is as shown in the following Table A3.

Table A3 – Total System Efficiency (TSE) for Water-Cooled Building Cooling System
Existing Buildings with Major Energy-Use Change
0.9 kW/RT

where TSE refers to combined system efficiency of the chiller plant and air distribution systems and the minimum requirement on water-side component efficiency will be based on the chilled water supply temperature and as follows :

Table A4 – Minimum Water-Cooled Chilled Water Plant Efficiency η_c

Chilled Water Supply Temp (°C)	6	7	8	9	10	For chilled water supply temp above 10°C, the threshold will be adjusted from 0.64 kW/RT by 0.01 kW/RT for every 1 °C increase in chilled water supply temperature
Water-Cooled Chiller System Efficiency (kW/RT)	0.68	0.67	0.66	0.65	0.64	

(ii) Air-Cooled Building Cooling System comprises the following systems and components :

- 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 development with inherent constraints and with peak building cooling load of not more than 500 RT
  - Air-Cooled Chiller
  - Chilled Water Pump
  - Air Distribution System

The limits set for Total System Efficiency set for air-cooled building cooling system is as shown in the following Table A5.

Table A5 – Total System Efficiency (TSE) for Air-Cooled Building Cooling System
Existing Buildings with Major Energy-Use Change
1.0 kW/RT

where the minimum water-side component efficiencies for different systems are as stated in Table A6.

Table A6 – Minimum Air-Conditioning Component Efficiency η_c

Unitary System (Outdoor Condenser Units)	**Air-Cooled Chilled Water Plant**
0.78 kW/RT (inclusive of site derating factor)	0.85 kW/RT

Important Notes:

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

(2) The air-conditioning systems designed should be rightly sized with good configuration to cater to a wider range of operating cooling load conditions during operation. This helps ensure that these systems could be operated at optimal energy efficiency level and comfort most of the time. There should be considerations to cater for load conditions that are not within the building operating hours specified such as night load for better building energy effectiveness and performance.

Guidance Notes

(1) Building Cooling System with Chilled Water Plant

The total system efficiency of the building cooling system is to be derived considering the building operation at part-load conditions. It is computed based on the annual energy consumption (kWh) of the system over the annual cooling consumption in RTh. The units used in kW/RT. The simplified methodology in determining the TSE can be adopted and as follows :

- Determine the building load profile from audit measurements and identify the cooling load requirements over the building operating hours defined for a day in RTh.
- Propose air-conditioning plant configuration and derive the respective power inputs of various plant equipment selected over the operating range of cooling load conditions. The minimum frequency set point for the Variable Speed Drives (VSDs) used for regulating the speed of chilled-water pumps, condenser water pumps or cooling tower fans are to be considered to ensure that chilled-water flow can be effectively distributed.
- Propose air distribution system and derive the respective power inputs over the operating range of cooling load conditions with due consideration for the minimum airflow rate requirement.
- Derive the Total System Efficiency (TSE) of the proposed building cooling system (in kW/RT) based on total power input of the air-conditioning plant (kWh) and air distribution system required over the total average cooling load requirement in RTh during building operating hours.
- The air-side component efficiency can be adjusted to allow for pressure drop adjustments for fan system where there is a need for more allowance due to functionality and activities as recommended in SS 553: Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings – Table 2b

Worked Example ENRB01-2(a)(i)

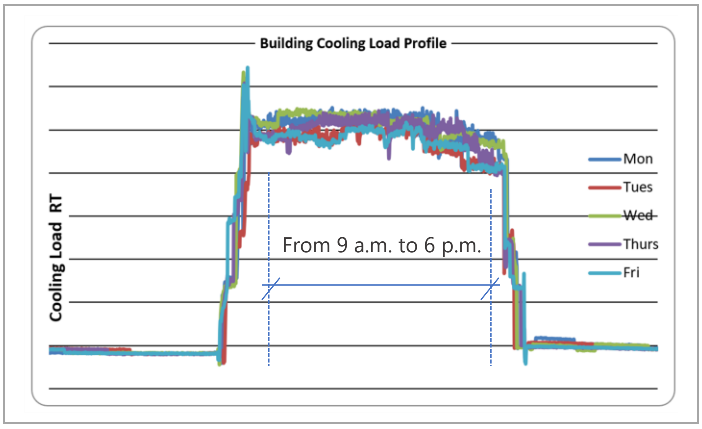
Computation of the Total System Efficiency (TSE) of a Water-Cooled Chilled-Water Plant with Primary Chilled-Water System

An office building has an air-conditioned floor area of 70,000 m^2 with cooling provision served by a chilled water plant. Variable-speed drives are designed to control the speed of the chilled-water pumps, condenser water pumps and cooling tower fans. For office buildings, the building operating hours is defined to be 9 a.m. to 6 p.m from Monday to Friday.

Step 1 – Building cooling load profile based on audit measurements

From the energy audit, the building cooling load is as follows :

Time	Average Cooling Load (RT)
0.00	190
1.00	190
2.00	190
3.00	190
4.00	190
5.00	190
6.00	190
7.00	1,400
8:00	1,200
9:00	1,190
10:00	1,260
11:00	1,260
12:00	1,260
13:00	1,260
14:00	1,260
15:00	1,260
16:00	1,190
17:00	1,190
18:00	1,190
19.00	980
20:00	190
21:00	190
22:00	190
23:00	190
24:00	190



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

The chiller plant system efficiency will be computed based on the following cooling loads measured during the specified operating hours i.e. 0900 to 1800 hrs (office building):

(a) 0900 to 1600 hrs : 1200 RT

(b) 1600 to 1800 hrs : 1150 RT

Step 2: Proposed Chiller Plant Equipment Configuration

Proposed chiller plant equipment configuration:

Equipment	Office hours (0900 to 1800 hrs)	After Office hours (1800 to 0900 hrs)
Chillers	3 nos. x 700 RT (2 in operation & 1 stand-by)	2 nos. x 200 RT (1 in operation & 1 stand-by)
Chilled Water Pumps	3 nos. x 45 kW (2 in operation & 1 stand-by)	2 nos. x 15 kW (1 in operation & 1 stand-by)
Condenser Water Pumps	3 nos. x 55 kW (2 in operation & 1 stand-by)	2 nos. x 18.5 kW (1 in operation & 1 stand-by)
Cooling Towers	3 nos. x 900 RT, each having 3 fans x 7.5 kW	

Step 3: Water-Cooled Chillers' Performance

Chillers in operation are 2 nos. x 700 RT during office hours and 1 no. x 200 RT for after office hour operation. Performance data for selected chillers (700 RT) as given by chiller suppliers is shown below:

% Load	Capacity (RT)	Chiller Input Power (kW)	Chiller Efficiency kW/RT	Evaporator		Condenser	
				CHWST (°C)	CHWRT (°C)	CWRT (°C)	CWST (°C)
100	700	363	0.519	6.67	12.31	34.80	29.68
90	630	329	0.522	6.67	12.31	34.29	29.68
80	560	291	0.520	6.67	12.31	33.78	29.68
70	490	260	0.533	6.67	12.31	33.28	29.68
60	420	227	0.543	6.67	12.31	32.77	29.68
50	350	195	0.563	6.67	12.31	32.27	29.68
40	280	165	0.596	6.67	12.31	31.76	29.68
30	210	135	0.652	6.67	12.04	31.25	29.68
20	140	104	0.750	6.67	10.27	30.75	29.68
15	105.3	87	0.836	6.67	9.39	30.50	29.68

Cooling load (RT)	No. of Chillers in operation	% Load	kW/RT	Total Chiller Power (kW)
A	B	C	D	E = A x D
1200 RT	2 nos. x 700RT	85.7%	0.521	625.2
1150 RT	2 nos. x 700RT	82.1%	0.520	598.0

Step 4: Chilled Water (CHW) Pumps' Performance

(i) 2 nos. x 45 kW pumps will be in operation during office hours and are installed with Variable Speed Drives (VSDs)

(ii) Operating pump head = 28 m (from energy audit)

(iii) Pump efficiency = 86.8 % at design operation condition

(iv) Motor efficiency = 94.2 % at design operation condition

(v) Motor absorbed power (kW) is calculated from = $\dfrac{(Q)(\rho)(g)(h)}{(10^6)(\eta_p)(\eta_m)}$

where

Q=water flow rate in L/s
ρ=density of water = 1000 kg/m^3
g=gravitational acceleration = 9.81 m/s^2
h=static pressure head m
η_p= pump efficiency
η_m=motor efficiency

Chilled Water Pump 1 & 2 (45 kW)					
% Load	A	B	C	D	E = (A x 1000 x 9.81 x B) / (10^6 x C x D)
	Rated Flow (l/s)	Rated Head (m)	Motor Efficiency (%)	Pump Efficiency (%)	Pump input power (kW)
100	106.1	28	94.2	86.8	35.64
90	95.49	22.68	94.2	84.2	26.76
85.7	90.9	20.56	94.2	84	23.17
82.1	87.1	18.87	94.2	83.7	20.45
80	84.88	17.92	94.2	83.3	19.00
70	74.27	13.72	94.2	79.9	13.27
60	63.66	10.08	94.2	77.3	8.64

For the total cooling requirement of 1200 RT, the 2 nos. CHW pumps will operate at part-load i.e. 1200RT / 1400RT i.e. 85.7%.

Cooling load (RT)	No. of CHW pumps in operation	% Load	Pump input power (kW)	Total CHW Pump Power (kW)
A	B	C	D	E = B x D
1200	2 nos.	85.7%	23.17	46.34
1150	2 nos.	82.1%	20.45	40.9

Note: It is recommended to limit the speed of the pump to a minimum of 60% of the load.

Step 5: Condenser Water (CW) Pumps' Performance

(i) 2 nos. x 55 kW will be in operation during office hours and all pumps are installed with Variable Speed Drives (VSDs)

(ii) Operating pump head = 32 m (from energy audit)

(iii) Pump efficiency = 88.5 % at design operation condition

(iv) Motor efficiency = 94.7 % at design operation condition

Condenser Water Pump 1 & 2 (55 kW)					
% Load	A	B	C	D	E = (A x 1000 x 9.81 x B) / (10^6 x C x D)
	Rated Flow (L/s)	Rated Head (m)	Motor Efficiency (%)	Pump Efficiency (%)	Pump input power (kW)
100	132.51	32	94.7	88.5	49.63
90	119.26	25.92	94.7	85.9	37.28
85.7	113.56	23.5	94.7	85.5	32.33
82.1	108.8	21.57	94.7	85.2	28.53
80	106.01	20.48	94.7	85.0	26.46
70	92.76	15.68	94.7	81.4	18.51
60	79.51	11.52	94.7	78.8	12.04

For the total cooling requirement of 1200 RT, the 2 nos. CW pumps will operate at part-load i.e. at 1200 /1400 RT i.e. 85.7%.

Cooling load (RT)	No. of CW pumps in operation	% Load	Pump input power (kW)	Total CW Pump Power (kW)
A	B	C	D	E = B x D
1200	2 nos.	85.7%	32.33	64.66
1150	2 nos.	82.1%	28.53	57.06

Note: It is recommended to limit the speed of the pump to a minimum 60% of the rated capacity.

Step 6: Operating Efficiency for Cooling Towers (CT)

(i) 2 nos. cooling towers will be in operation with Variable Speed Drives (VSDs)

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

(iii) Total heat rejection for 2 nos. cooling towers = 900 RT x 2 = 1800 RT

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

(v) Fan Motor efficiency = 92 %

(vi) Fan motor input power for each tower = (7.5 kW x 3 fans.) / 92% = 24.46 kW

(vii) Total power for 2 nos. cooling towers = 24.46 kW x 2 = 48.92 kW

Cooling load (RT)	Chiller Input Power (kW)	Required Heat Rejection (RT)
A	B	C = A + (B / 3.517)
1200	625.2	1377.77
1150	598	1320.03

Cooling load (RT)	No. of CT in operation	Total CT Heat Rejection Capacity (RT)	Percentage Loading for Required & Available Heat Rejection (RT)
A	B	D	E = C / D
1200	2	1800	76.5 %
1150	2	1800	73.3 %

At full speed (100%), total cooling tower (2 nos.) power consumption = 24.46 x 2 = 48.92 kW

Based on the fan law,

$$\frac{\text{Fans Power}_{@\ 76.6\%}}{\text{Fans Power}_{@\ 100\%}} = \left(\frac{\text{Fans Speed}_{@\ 76.6\%}}{\text{Fans Speed}_{@\ 100\%}}\right)^3$$

At 76.6% speed (via VSDs), total cooling towers' fans power = 48.92 x $(0.765)^3$ = **21.90 kW**

Similarly, at 73.4% speed, total cooling towers' fans power = 48.92 x $(0.733)^3$ = **19.27 kW**

Cooling Load (RT)	Required Part Load % for CT	Total Fan Motor Power at Required Part Load (kW)
1200 RT	76.5%	21.90
1150 RT	73.3%	19.27

Step 7: System Efficiency of the Chiller Plant

The chiller plant system efficiency at various cooling loads is tabulated below.

Time	Average Cooling Load (RT)	Chillers Power Input (KW)	CHW Pumps Power (kW)	CW Pumps Power (kW)	CT power (kW)	Total Power Input (kW)
9:00	1200	625.2	46.34	64.66	21.90	758.1
10:00	1200	625.2	46.34	64.66	21.90	758.1
11:00	1200	625.2	46.34	64.66	21.90	758.1
12:00	1200	625.2	46.34	64.66	21.90	758.1
13:00	1200	625.2	46.34	64.66	21.90	758.1
14:00	1200	625.2	46.34	64.66	21.90	758.1
15:00	1200	625.2	46.34	64.66	21.90	758.1
16:00	1150	598	40.9	57.06	19.27	715.23
17:00	1150	598	40.9	57.06	19.27	715.23
18:00	1150	598	40.9	57.06	19.27	715.23
Total (0900 to 1800)	$\sum CL_i$ = 11850	6170.4	447.08	623.8	211.11	$\sum TPL_i$ = 7452.39
Chilled Water Plant Efficiency (kW/RT)		**0.521**	**0.038**	**0.053**	**0.018**	**0.629**

Proposed chiller water plant efficiency = Total Power Input /Total Cooling Load
= 7,452.39/11850
= 0.629 kW/RT which is better than minimum threshold of 0.67 kW/RT at chilled water supply temperature 7°C, ok

Step 8: Air Distribution System Efficiency and Total System Efficiency

Hours	Daily Average Cooling Load (RT)	Total Power Input from Chilled Water Plant (kW)	Air Distribution System		Total System	
			Type	Air-Side (CF/VF) (kW)	Total Water + Air	
					kW	KW/RT
9:00	1200	758.1	AHU-VAV	262.84	1020.94	0.851
10:00	1200	758.1	AHU-VAV	253.91	1012.01	0.843
11:00	1200	758.1	AHU-VAV	298.58	1056.68	0.881
12:00	1200	758.1	AHU-VAV	302.31	1060.41	0.884
13:00	1200	758.1	AHU-VAV	295.60	1053.7	0.878
14:00	1200	758.1	AHU-VAV	297.84	1055.94	0.880
15:00	1200	758.1	AHU-VAV	294.86	1052.96	0.877
16:00	1150	715.23	AHU-VAV	289.65	1004.88	0.874
17:00	1150	715.23	AHU-VAV	271.78	987.01	0.858
18:00	1150	715.23	AHU-VAV	224.87	940.1	0.817
Total (0900 to 1800)	$\sum CL_i$ = 11850 RTh	7452.39 kWh	-	2792.23 kWh	10244.63 kWh	0.865

In summary,

Water-Side Component System Efficiency, kW/RT	0.629
Air-Side Component System Efficiency, kW/RT	0.236
Total System Efficiency (TSE), kW/RT	0.865 meets the limit 0f 0.90 kW/RT ok

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

Important note: For simplicity, the estimated operating pump and motor power of the various components at part-load condition as illustrated in Step 4 & Step 5 are based on the affinity laws assuming that the system curve remains unchanged.

For marginal cases, there would be a need to consider and account for the losses during actual operating conditions based on the pump part-load power curve, referenced from Appendix 5.7 of the *Non-Residential Alternative Calculation Method Reference Manual 2013* by the California Energy Commission (CEC) is to be used to estimate the pump power at the part-load conditions. In the case of the VAV fan system, ASHRAE 90.1, Table G3.1.3.15, Part-Load Performance for VAV Fan Systems, Method 2 – Part-Load Fan Power Equation can be used to derive the part-load fan power and as summarised in the following table.

Chilled Water Pump and Condenser Water Pump	Pump power ratio = $0.0205x + 0.4101x^2 + 0.5753x^3$ *where x is the part-load ratio.*
Cooling Tower	Fan power ratio = $0.331629 - 0.885676x + 0.605565x^2 + 0.948482x^3$ *where x is the part-load ratio.*
VAV Fan System	Fraction of full-load fan power = $0.0013 + 0.1470x + 0.9506x^2 - 0.0998x^3$ *where x is the part-load ratio (Ratio of current L/s against design L/s)*

(2) Unitary Air-Conditioning System

The total system efficiency (TSE) of the unitary air-conditioning system can be determined based on the concept of Integrated Energy Efficiency Ratio (IEER) which would take into consideration the different load capacities with due consideration for part-load conditions. The IEER is defined as

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

where

A = EER or COP at full load
B = EER or COP at 75% load
C = EER or COP at 50% load
D = EER or COP at 25% load

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

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

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

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

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

The methodology in determining the TSE is as follows:

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

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

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

Worked Example ENRB01-2(a)(ii)

Computation of the Total System Efficiency (TSE) of Variable Refrigerant Flow (VRF) Systems

An office building with a replacement of two VRF systems that serve an air-conditioned floor area of 4,250 m^2. The building operating hours is Monday to Friday from 9 a.m. to 6 p.m. Based on the cooling capacity requirement, the system and equipment schedule, the TSE can be determined to be as follows:

Step 1 – Determine the individual IEER of the condensing units based on the load conditions of 100%, 75%, 50% and 25% can be based on published technical specifications or verification testing results.

Outdoor Condenser Units / System	Zone	Location Served	Specification of VRF Outdoor Condensing Unit						IEERi (0.020 x A) + (0.617 x B) + (0.238 x C) + (0.125 x D)
			Full Installed Capacity (KW)	Designed Cooling Capacity (kW)	100% EER (A)	75% EER (B)	50% EER (C)	25% EER (D)	
VRF System 1	1	FCC Room Lift lobby Corridor Reception	22.4	14.18	4.1	5.5	7.3	7.6	6.16
VRF System 2	2	Office 1	44.8	28.36	3.90	5.20	7.10	7.90	5.96
	3	Office 2	44.8	28.36	3.90	5.20	7.10	7.90	5.96
	4	Office 3	44.8	28.36	3.90	5.20	7.10	7.90	5.96
Total cooling capacity:			156.8	99.26	-	-	-	-	-

Step 2 – Determine the overall weighted system efficiency of condensing units by proration.

Weighted Design System, Efficiency of outdoor condenser units

$$\eta_{c\,(overall)} \text{ (in kW/RT)} = 3.517 / \left[\frac{\sum (\text{Cooling capacity x IEER})_i}{\text{Total Cooling Capacity}_{\text{Overall}}} \right]$$

$$= 3.517 / \left[\frac{(14.18 \times 6.16) + (28.36 \times 5.96) \times 3}{99.26} \right]$$

$$= 0.608 \text{ kW/RT}$$

If site deration factor is about 10%, corrected $\eta_{c\,(overall)} = 0.608 \times 1.1 = 0.668$ kW/RT < 0.78 kW/RT ok

Note that the site derating factor would depend on design, site constraints and installation considerations such as losses due to piping, which would vary from project to project.

Step 3 – Determine the individual air distribution system efficiencies. For simplicity, the air-distribution system efficiency can be derived based on rated cooling capacity and nameplate motor power from the technical specification in particular for fans coil units with speed determined by the constant frequency of the power supply. The derivation of overall air distribution system efficiency is as follows:

Indoor Unit / System	Zone	Location Served	Specification of Air Distribution Units				Air Distribution System efficiency based on design cooling capacity η_a in kW/RT
			Unit Type	Installed Capacity (kW)	Design cooling Capacity (kW)	Nameplate Motor Power (kW)	
VRF System 1	1	FCC Room	Ceiling Cassette (FCUs)	4.2	2.67	0.043	0.0569
		Lift lobby Corridor	Ceiling Cassette (FCUs)	9.0	5.70	0.092	0.0568
		Reception	Ceiling Cassette (FCUs)	9.0	5.70	0.092	0.0568
VRF System 2	2	Office 1	Ducted FCUs	44.0	27.85	1.8	0.2273
	3	Office 2	Ducted FCUs	44.0	27.85	1.8	0.2273
	4	Office 3	VAV AHUs	44.8	28.36	5.2	0.6449
			Total:	155	98.13	9.027	–

Step 4 – Determine the overall weighted system efficiency of air distribution system by proration.

Weighted System Efficiency of air-distribution system $\eta_{a\,(overall)}$ (in kW/RT) will be as follows :

$$= \left[\frac{\sum (\text{Cooling capacity x } \eta_a)_i}{\text{Total Cooling Capacity}_{\text{Overall}}} \right]$$

$$= \left[\frac{(2.67 \text{ x } 0.0569) + 2 \text{ x } (5.70 \text{ x } 0.0568) + 2 \text{ x } (27.85 \text{ x} 0.227) + (28.36 \text{ x } 0.645)}{98.13} \right]$$

= 0.324 kW/RT

Step 5 – Derive the Total System Efficiency (TSE) of the proposed VRF system

Total system efficiency, TSE (in kW/RT) = $\eta_{c\,(overall)}$ + $\eta_{a\,(overall)}$

= 0.668 + 0.324 = 0.992 kW/RT < 1.0 kW/RT ok

Note that the system efficiency of the VAV-AHUs derived was based the full load condition similar to that for FCUs and the consideration for the part-load conditions can be found in the next section.

Consideration for Part-load Performance of VAV AHUs

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

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

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

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

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

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

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

where

A = EER or COP at full load
B = EER or COP at 75% load
C = EER or COP at 50% load
D = EER or COP at 25% load

In this instance,

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

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

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

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

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

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

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

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

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

System efficiency of VAV-AHU (in kW/RT) is as follows:
= 3.517/ (0.020 x 8.623) + (0.617 x 10.695) + (0.238 x 14.360) + (0.125 x 7.180)
= 0.317 kW/RT

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

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

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

= 0.229 kW/RT instead of 0.324 kW/RT derived using nameplate motor power as shown in Step 3

(3) Use of Existing Chilled-Water Plant and/or Air Distribution System

In the case where the cooling required are to be provided by both the new and existing chilled-water plants, the derivation of the Total System Efficiency (TSE) shall also consider the contribution from the existing chilled-water plant. The same will apply to the use of the existing air distribution system. Where needed, optimisation of existing chilled water plant and/or air distribution systems would have to be carried out to meet the minimum energy efficiency standard required.

(4) Verification of the Total System Efficiency of the Building Cooling System

Upon work completion, the total system efficiency of the building cooling system must be verified and the measurement records are to be included as part of the energy audit report requirement stated under Section 5.3 and in accordance with the guidelines given in the Code on Periodic Energy Audit of Building Cooling Systems.

For the measurement of the air distribution system efficiency, η_a at building level, the data on the power consumption can be obtained from the dedicated power meters that are linked to the Building Management System (BMS) or standalone energy management system (EMS) for a period of seven (7) days. In instances where there is no dedicated power meter for some air distribution systems, the following methodology shall be adopted to derive the air distribution system efficiency for consistency.

Measurement of Air-Distribution System Efficiency at Building Level				
Air-side Components:	**Measurement Method**	**Duration**	**Coverage**	**Total Power Consumption per Week**
(A) Air Handling Units (VAV-AHUs or CAV AHUs)	Trend data from BMS/EMS	1 week	All	kWhrs
	If there is no linkage with BMS/EMS		Sample 10% of total no. of AHUs Min 5 measurements (Cap at 10)	kW_{ave} x Number of Operating hrs per week x Number of AHUs = kWhrs
	• VAV-AHUs : Trend log input power using portable power meter/logger	Log for 1 day		
	• CAV – AHUs : Spot measurements using portable power meters	Take reading at 10 am or 3pm, where peak loads typically occurred		
(B) Fan Coil Units (FCUs)	Trend data from BMS/EMS	1 week	Sample 10 % of total no. of FCUs	kW_{ave} x Number of Operating hrs per week x Number of FCUs = kWhrs *Alternatively, the power consumption can be computed based on the Nameplate Motor Power of all FCUs instead of measurement.*
	Spot measurements using portable power meters	Take reading at 10 am or 3pm, where peak loads typically occurred		
(C) Building Cooling Load	Trend data from BMS/EMS	1 week	Chiller plant VRF system	Tonhrs kW
Air-side efficiency at building level, η_a (in kW/RT)				$\frac{\sum A + \sum B}{C}$

Documentation Requirements

Design Submission Stage

- Detailed calculations of the total system efficiency of air-conditioning system as shown in the worked example ENRB01-2(a)(i) and ENRB01-2(a)(ii) where relevant;
- Other supporting documents for the water-cooled chilled water system are stated in Section 5.2; and
- For unitary air-conditioning system, to provide the technical specification and product information.

As-Built Submission Stage

- Updated calculation of the total system efficiency of air-conditioning system if there are major changes;
- Measurement and verification details of the Total System Efficiency (TSE); and
- Other supporting documents are stated in Section 5.3.

ENRB01-2(b) Lighting System

To reduce energy required to illuminate interior spaces with proper lighting levels. The lighting provision shall be at least 40% more energy efficient than the prescribed lighting power budget stated in SS 530 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment. The lighting provision for the tenanted areas can be excluded.

Guidance Notes

In the selection of light fittings, due consideration should be given to account for future phase-out of inefficient lighting and ballasts in Singapore. Reference can be made to the Minimum Energy Performance Standard (MEPS) on lamp efficacies and ballast energy performance for lighting design under the Energy Conservation Act.

Other than the provision of energy-efficient lighting, it is important to ensure that proper lighting level is considered. For guidance on the illuminances recommended for different applications or spaces given, reference is to be made to Singapore Standard SS 531 – Code of practice for lighting of workplaces. Lighting control for artificial lighting should be provided in accordance with SS 530, where applicable.

Worked Example ENRB01-2(b)

The proposed and maximum lighting power budget for artificial lighting can be computed by determining the total power consumption and efficiency level based on the lighting layout design for each area and light fitting types used as illustrated in the following example.

Location	Areas (m^2)	Light Fitting Type	Power Consumption Per Fitting (W)	Ballast Loss	No. of Fittings	Total Power Consumption based on Fitting Type
	(A)	(B)	(C)	(D)	(E)	[(C+D) x E]
Common Areas						
Corridors Type 1	150	LED	12	0	40	480
Corridors Type 2	205	LED	12	0	40	480
		Surface downlight	70	3	10	730
Atrium	850	LED	24	0	174	4,176
		Surface downlight	150	3	10	1,530
Car Parks	7500	LED	12	0	870	10,440
Staircase Areas	300	LED	12	0	40	480
Toilets	100	LED	12	0	30	360
					Total:	18,676

Description	Area (m^2)	Design Data		SS 530 Requirements	
		Total Power Consumption (by area) (W)	Design Lighting Power Density (W/m^2)	Reference Lighting Power Density (W/m^2)	Reference Total Power Consumption (by area) (W)
	(A)	(F)	(F/A)	(H)	(H x A)
Common Areas					
Corridors Type 1	150	480	3.20	7	1050
Corridors Type 2	205	1210	5.90	7	1435
Atrium	850	5,706	6.71	10	8500
Car Parks	7500	10,440	1.39	3	22500
Staircase Areas	300	480	1.60	6	1800
Toilets	100	360	3.60	10	1000
Total	9105	18,676	2.05	3.99	36285

Reference with SS 530 - Total Power Consumption (W)	36,285
Proposed Design - Total Power Consumption (W)	18,676
% Improvement over reference standard	$= [\Sigma(HxA) - \Sigma(F)] / \Sigma(HxA) \times 100$ $= (36,285 - 18,676)/36,285 \times 100$ $= 48.5\% > 40\%$ ok

Documentation Requirements

Design Submission Stage

Generally, no supporting document requirement at this stage.

As-Built Submission Stage

- As-built lighting layout plan and schedules showing the numbers, location and types of luminaries used;
- Calculation of lighting power budget based on actual installation and the percentage improvement over prescribed lighting power budget; and
- Delivery orders and technical product information of the lighting luminaries used.

ENRB01-2(c) Mechanical Ventilation System

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

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

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

Guidance Notes

The energy efficiency improvement can be considered based on Option (1) Fan System Motor Nameplate Power or Option (2) Fan System Input in accordance with SS 553 and as stated in Table A6 below.

Table A6 – Baseline Standard for Mechanical Ventilation System for Normally Occupied Spaces
Fan Power Limitation for Constant Volume and Variable Volume
Option 1: Fan system motor nameplate ⟶ Allowable nameplate motor: 0.35 W/CMH
Option 2: Fan System Input ⟶ Allowable Fan System Input Power: ≤ 0.3 + A* W/CMH
*A is the sum of the pressure drop adjustments (in Pa) that can be considered according to the recommendation provided in Table 2b of SS 553 and are subject to BCA's evaluation

Worked Example ENRB01-2(c)

An example of an institutional development with six (6) technical workshop spaces with replacement of mechanical ventilation systems. The derivation of the energy efficiency improvements based on the given design parameters and fan schedules are as illustrated in the following computations.

Option 1 – Fan Motor Nameplate Power

MV Fan Schedule									
Work Shop	Fan Ref	Fan Type	Floor Areas (m^2)	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	Axial	650	10	6	39000	650	11	0.28
3	FAF 1-3	Axial	650	10	6	39000	650	11	0.28
4	FAF 1-4	Axial	500	8	6	24000	500	5.5	0.23
5	FAF 1-5	Axial	500	8	6	24000	500	5.5	0.23
6	FAF 1-6	Axial	500	8	6	24000	500	5.5	0.23
1	EAF 1-1	Axial	650	10	6	39000	650	11	0.28
2	EAF 1-2	Axial	650	10	6	39000	650	11	0.28
3	EAF 1-3	Axial	650	10	6	39000	650	11	0.28
4	EAF 1-4	Axial	500	8	6	24000	500	5.5	0.23
5	EAF 1-5	Axial	500	8	6	24000	500	5.5	0.23
6	EAF 1-6	Axial	500	8	6	24000	500	5.5	0.23

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

Option 2 – Fan Motor Input Power

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

Total Air-Flow Rate	378000 CMH
Total Fan Power (Design)	73.2 kW
Total Fan Power (Baseline)	378000 CMH x 0.30 W/CMH = 113.4 kW
% Improvement over Baseline	35 % over baseline > 10% ok

Documentation Requirements

Design Submission Stage

- Architectural plan layouts showing the mode of ventilation for various spaces;
- Mechanical ventilation design plan layouts;
- Computation of the fan static calculations, design air flow rate and energy efficiency improvement;
- MV fan equipment schedule; and
- Technical product information of all MV fans (to include fan curves).

As-Built Submission Stage

- As-built details are similar to design submission if there are major changes.

ENRB01-2(d) Vertical Transportation System

To reduce energy consumption from vertical transportation such as lifts and escalators by adopting energy-efficient technologies and control. The lift and escalator systems provided for the building developments are required to be equipped with Variable Voltage Variable Frequency (VVVF) and sleep mode features and/or standby speed and/or standby stop features, where relevant.

Guidance Notes

Other than the provision of vertical transportation systems that come with VVVF and sleep mode features, there are other energy-efficient technologies such as regenerative drive or deployment of advanced dispatching software that could reduce occupant wait time while reducing energy use by up to 50% compared to traditional systems. These technologies if adopted can be considered under ENRBE03-3.

Documentation Requirements

Extracts of specifications that indicate the types of lifts, escalators and related features.

References

(1) Mandatory Minimum Energy Performance Standards (MEPS) for Air-Conditioners and Minimum Energy Efficiency Standards (MEES) for Water-Cooled Chilled Water Systems in Industrial Facilities under the Energy Conservation Act can be found on the website of the National Environmental Agency (NEA)

(2) SS 530 – Code of Practice for Energy Efficiency Standard for Building Services and Equipment

(3) SS 553 – Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings

(4) Code on Periodic Energy Audit of Building Cooling System issued by the Building and Construction Authority (BCA)

(5) Mandatory Minimum Energy Performance Standards (MEPS) for Lamps and Ballasts can be found on the website of the National Environmental Agency (NEA)

(6) SS 531 – Code of Practice for Lighting of Work Places – Indoor – Part 1

Related Information

It is recommended to adopt chillers that use climate-friendly refrigerants with Global Warming Potential (GWP) of 15 or less, which will help reduce Singapore's greenhouse gas (GHG) emissions arising from the use of hydrofluorocarbons (HFCs). Note that the supply of water-cooled chillers that use refrigerants with GWP above 15 will be banned from Q4 2022 under the Energy Protection Management Act. Please refer to NEA's website for more details

ENRB02 Measurement and Verification (M&V) Instrumentation

Intent

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

Applicability & Scope

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

Base Requirement

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

ENRB02-1 Instrumentation for Chilled Water Air-Conditioning System

There shall be a 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. 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' recommendation 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 management system (EMS) 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 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 3m, where possible. Otherwise, there should be evidence of provision for access by way of mobile access platforms or other suitable forms.

Guidance Notes

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

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

$$Error_{rms} = \sqrt{\sum (U_N)^2}$$

where
U_N = Individual uncertainty of variable N (%)
N = Mass flow rate, electrical power input or delta T

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

Worked Example ENRB02-1

Computation of uncertainty of the overall measurement system

Item	Measurement System	Measurement Uncertainty (% of reading)
1	Temperature	$\frac{\sqrt{0.05^2 + 0.05^2}}{5.5} = 1.3$
2	Flow	1% see note(3) + 1% (i.e. 2%)
3	Power	$\sqrt{1^2+1^2} = 1.4\%$ see note(4)

Note(2) – Temperature measurement system shall have a 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.

Note(3) – An additional 1% to be included in the computation of measurement uncertainty for flow meter.

Note(4) – Uncertainty of power measurement system shall include that of the current transformer where applicable. It is recommended that 3rd party verified power meter be specified to ensure accuracy.

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

$$\begin{aligned} Error_{rms} &= \sqrt{(\sum (U_N)^2)} \\ &= \sqrt{(1.3^2 + 2^2 + 1.4^2)} \\ &= 2.8\ \% \end{aligned}$$

where U_N = individual uncertainty of variable N (%)

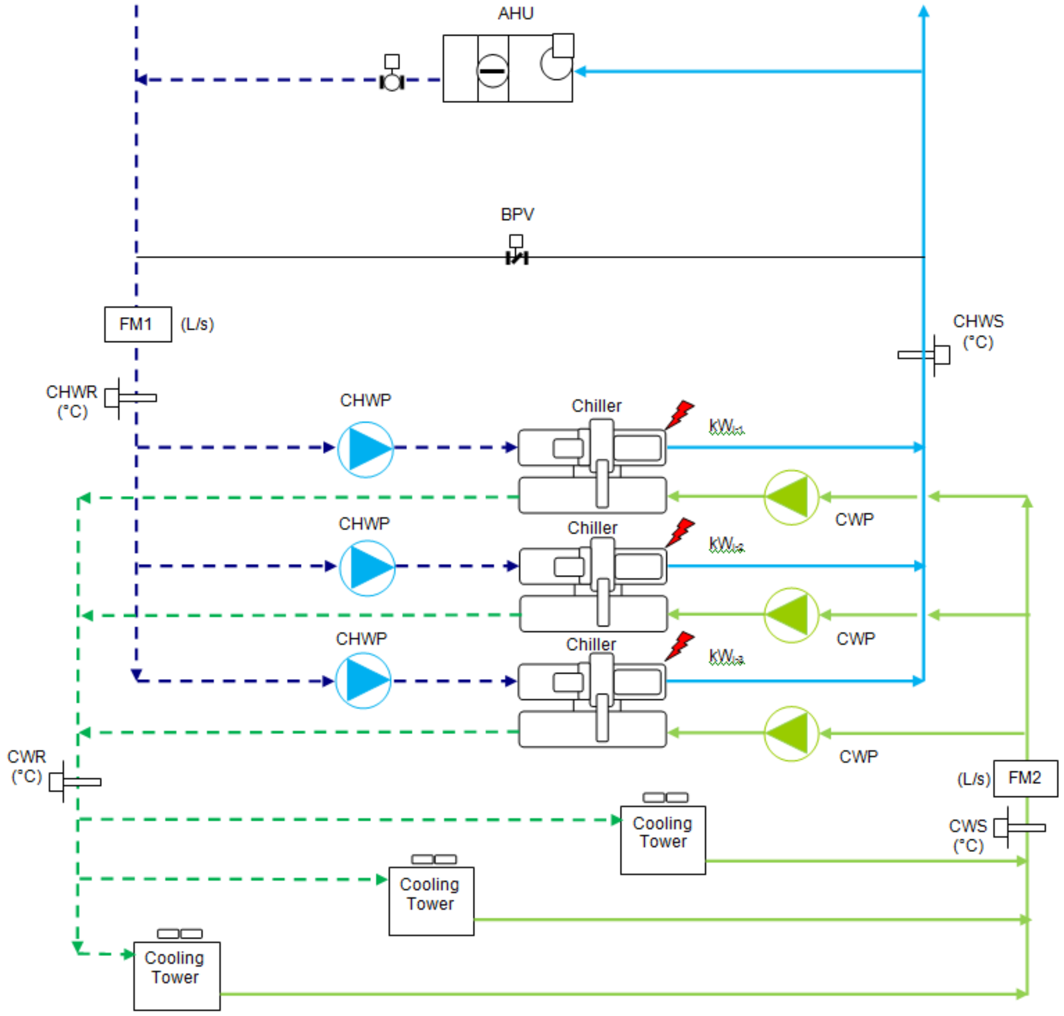
N = mass flow rate, electrical power input or delta T

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

It is important to ensure correct placement of the temperature sensors for proper measurement. A heat balance-substantiating test can be carried out to ascertain the overall accuracy of the measurement result of the permanent instrumentation provided for the central chilled water system. To meet the accuracy requirement, more than 80% of the heat balance (%) derived over the entire normal operating hours is to be within ± 5% for a period of one (1) week. Detailed guidelines on the placement of temperature sensors and heat balance-substantiating test can be found in SS 591 – Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency as well as the Code on Periodic Energy Audit of Building Cooling System.

Determining Heat Balance for Different Plant Configurations

Plant A – Constant Primary Chilled-Water System

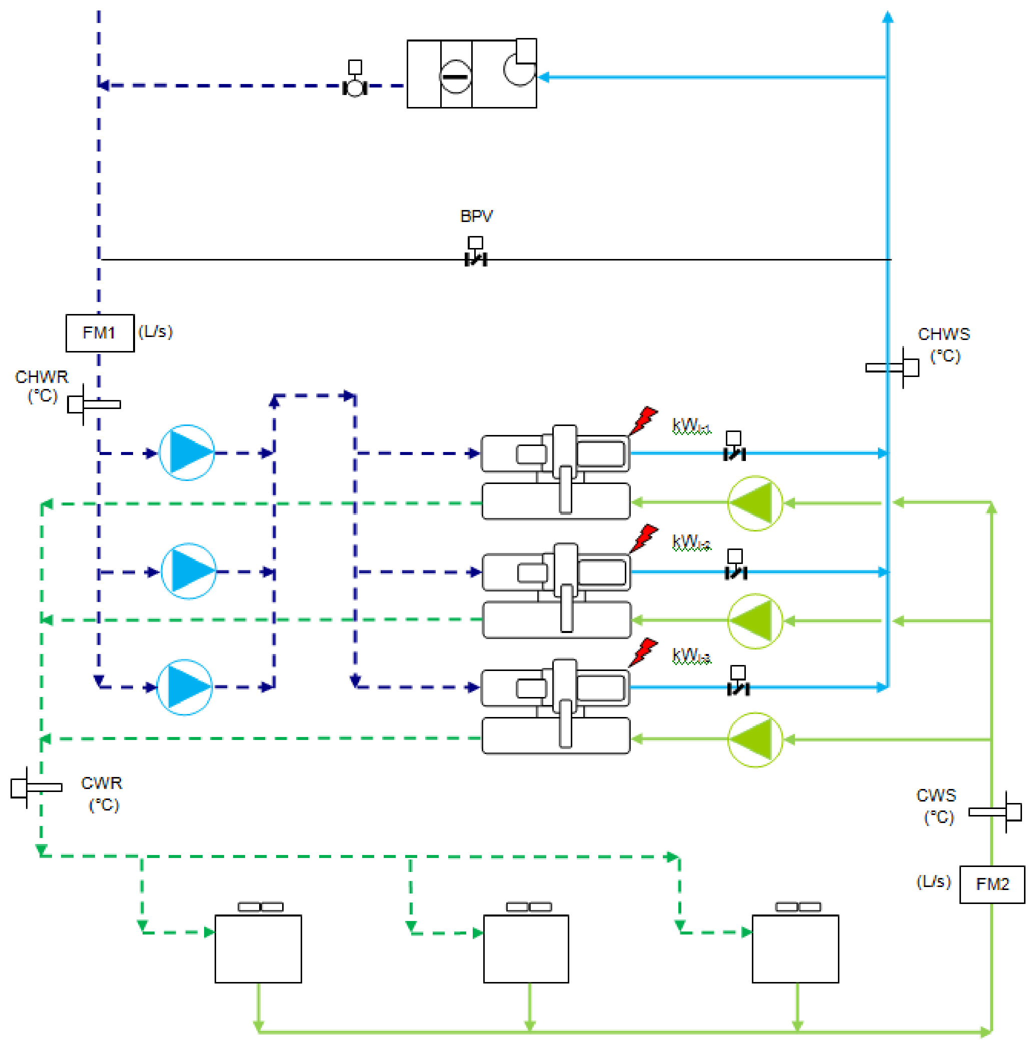


A: $q_{evaporator}$ = m x Cp x ΔT = FM1 x Cp x (CHWR - CHWS)
B: $q_{condenser}$ = m x Cp x ΔT = FM2 x Cp x (CWR - CWS)
C: W_{input} = kWi_{-1} + kWi_{-2} + kWi_{-3}

where Cp = 4.19 kJ/kg.°C & density of chilled 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, W_{input}/ $q_{condenser}$ may be adjusted to account for these additional heat gain. The value shall be determined from variable speed drive losses, motor efficiency and pump efficiency values certified by the manufacturer.

Plant B – Variable Primary Chilled-Water System

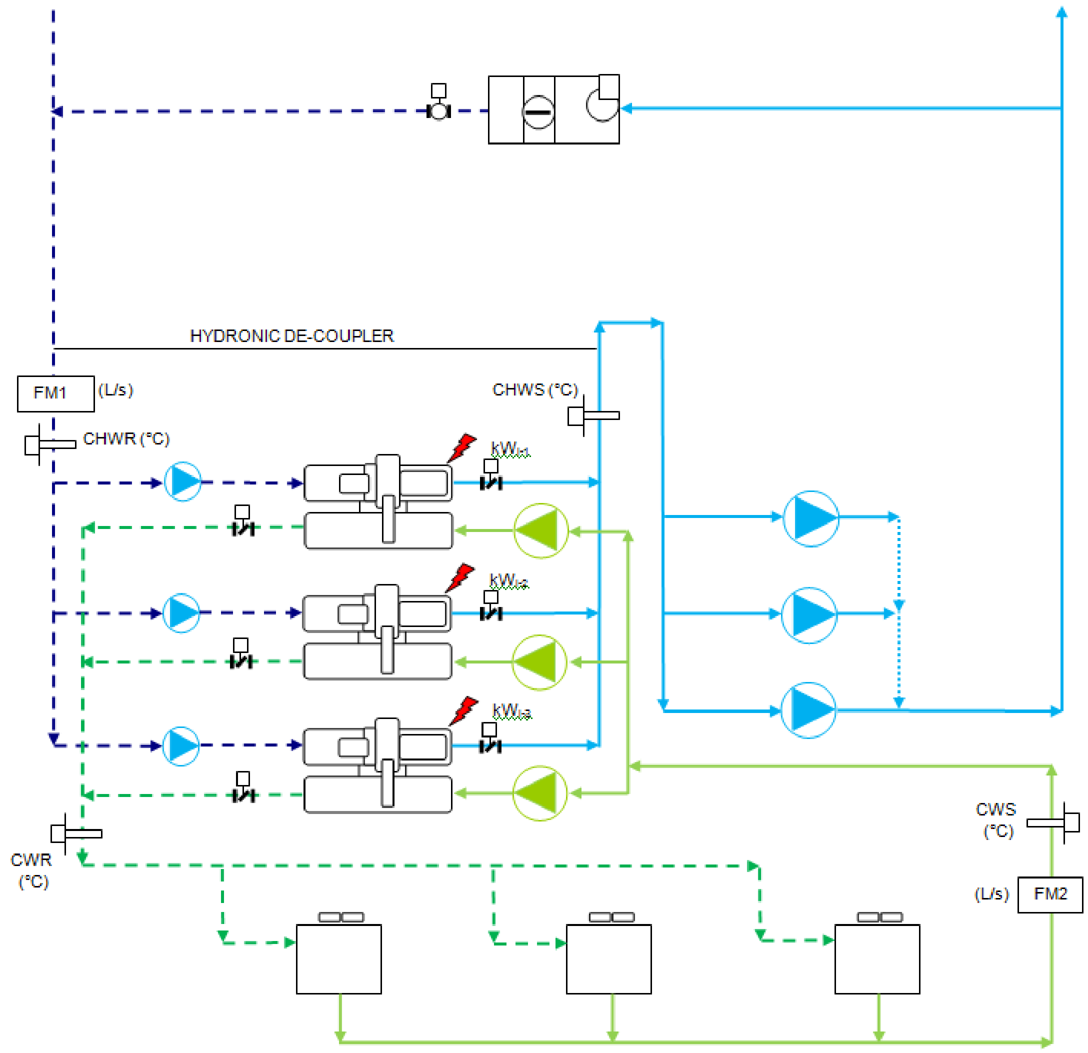


A: $q_{evaporator}$ = FM1 x Cp x (CHWR - CHWS)
B: $q_{condenser}$ = FM2 x Cp x (CWR - CWS)
C: W_{input} = kW_{i-1} + kWi_{-2} + kWi_{-3}

where Cp = 4.19 kJ/kg.°C & density of chilled 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, W_{input}/ $q_{condenser}$ may be adjusted to account for these additional heat gain. The value shall be determined from variable speed drive losses, motor efficiency and pump efficiency values certified by the manufacturer.

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



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

where Cp = 4.19 kJ/kg.°C & density of chilled 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 a substantial heat gain, W_{input}/ $q_{condenser}$ may be adjusted to account for these additional heat gain. The value shall be determined from variable speed drive losses, motor efficiency and pump efficiency values certified by the manufacturer.

Worked Example ENRB02-1(f)

An example to illustrate the Heat Balance calculation in deriving the percent heat balance based on the available data collated.

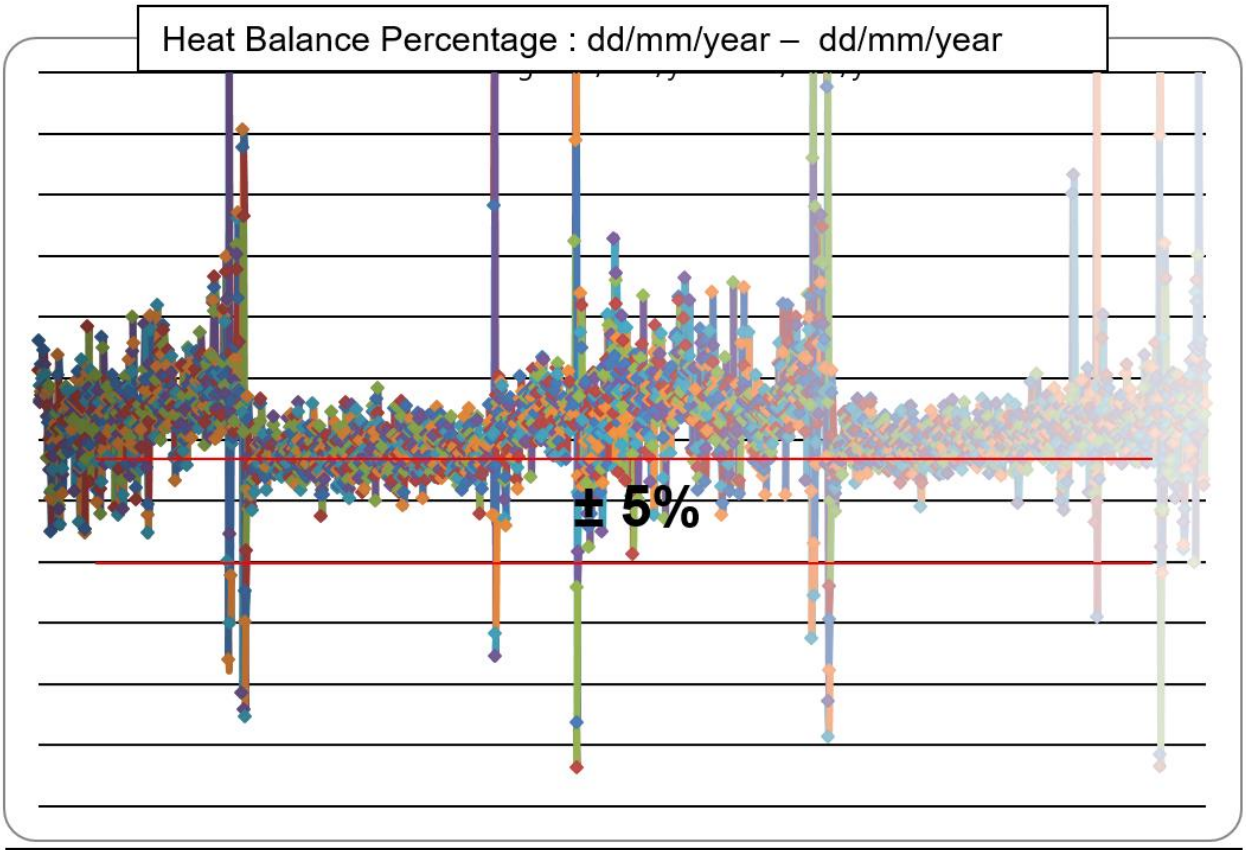
	(a) Chilled water supply temperature	(b) Chilled water return temperature	(c) Chilled water flow rate	(d) Condenser water supply temperature	(e) Condenser water return temperature	(f) Condenser water flow rate	(g) Chiller kWe	(h) Heat Gain	(i) Heat Rejected	(j) Percent Heat Balance
dd/mm/yyyy hh:mm	°C	°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.ºC x [(b) – (a)] / 3.517

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

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

System level heat balance plot from the data collated is as follows :



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 example, 82% of the heat balance calculation falls within ± 5% which fulfills the criterion of 80%.

Note: 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

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

Documentation Requirements

- Calculation of total uncertainty of resultant operating system efficiency using the following root sum square formula:

$$Error_{rms} = \sqrt{\sum (U_N)^2}$$

where
U_N =Individual uncertainty of variable N (%)
N = Mass flow rate, electrical power input or delta T
In deriving the measurement uncertainty contributed by the flow meter, an additional 1% is to be included in the computation.

- Detailed schematic drawings of the instruments and test plug locations;
- Technical specifications and/or sample data sheets/ product information for instruments and meters;
- Detailed drawings and schematics of the power measurement strategies for the air conditioning system;
- Purchase orders and delivery orders of the instrumentation and power meters installed;
- Instrumentation calibration certificates;
- BMS screenshots showing the relevant calibration inputs have been entered for temperature measurement; and
- *Site requirement*: To determine the chilled-water plant efficiency using the following operation data/ installations to demonstrate compliance with design specifications:

From Building Management System	From Operating Chiller Panel
▪ Chilled-water plant kW/RT ▪ Chilled water/ Condenser water supply & return temperatures of the header to be checked for consistency against the temperatures of individual chillers and/or individual branches. ▪ Chilled-water/ Condenser water header flow rate to be checked for consistency against the flow rate(s) of individual branches ▪ The accuracy of the programmed formula for the computation of kW/RT of the various parameters	▪ Chilled water/ Condenser water supply & return temperatures to be checked for consistency against the BMS data ▪ Approach of chilled water supply- refrigerant evaporating temperature ▪ Approach of chilled water return- refrigerant condensing temperature ▪ Location of the chilled-water flow meter(s) installed to comply with manufacturer's recommendations.

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

There shall be a provision of permanent measuring instruments for monitoring of the energy performance of the Variable Refrigerant Flow (VRF) system if it serves an aggregate conditioned floor area of 2000 m^2 or more.

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 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 monitoring system (EMS) or other suitable platforms 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, PAHUs), where applicable. The same should be provided for FCUs, where possible.

Documentation Requirements

- Detailed catalogue and evidence showing that overall uncertainty of measurement of the resultant system efficiency in kW/RT is within ± 10 %;
- Technical specifications and/or sample data sheets/product information for instruments and meters for data logging;
- As-built design schematics and single-line drawings showing the locations of the power meters and BMS system;
- Extract of data from logging system or other suitable platforms for verification of performance; and
- Screenshots from BMS or monitoring platform made available to building owners showing the display of key indicators including total system efficiency and its component system efficiencies (that is the condensing units and air-distribution system).

References

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

Related Information

Building owners may be issued a notice to conduct periodic energy audits at any time after 3 years from the approval of completion of the major energy-use change and subsequently at an interval of not less than 3 years after the date of last notice served. Please refer to the Code on Periodic Energy Audit of Building Cooling System which can be found on BCA’s website for more details.

ENRB03 Real-Time Remote Monitoring of Chiller Plant Operation

Intent

Facilitate real-time monitoring of chiller plan system operation.

Applicability & Scope

Buildings with chiller plant systems

Base Requirement

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

Documentation Requirements

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

ENRB04 Energy Utilisation Reporting

Intent

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

Applicability & Scope

Generally applicable

Base Requirement

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

Guidance Notes

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

Calculation of EUI = TBEC / GFA

where

TBEC : Total building energy consumption (kWh/year)
GFA : Gross floor area (exclude car park area) (m^2)

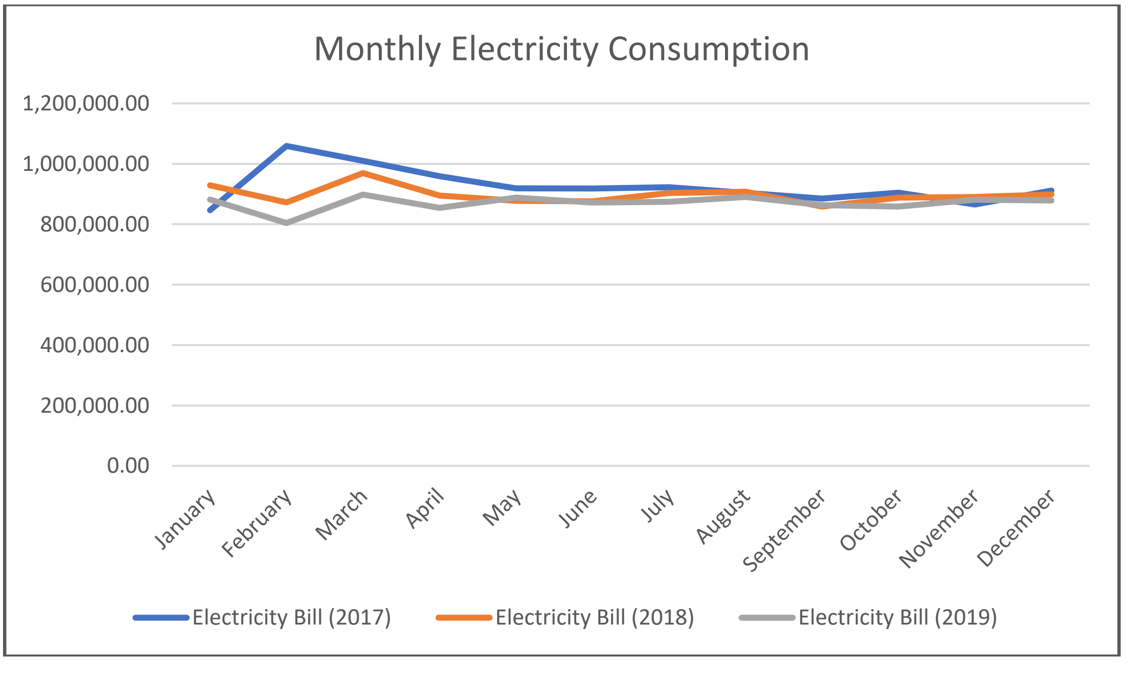
Worked Example ENRB04

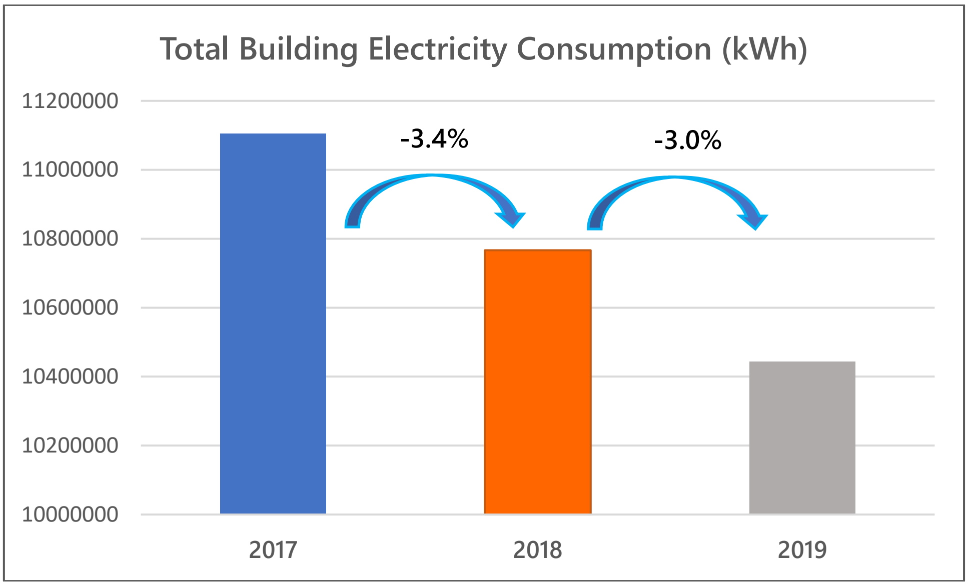
An existing building with GFA of 31,540 m^2 and the following energy consumption data.

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

EUI Calculation

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





Documentation Requirements

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

ENRB05 Indoor Temperature

Intent

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

Applicability & Scope

Generally applicable to air-conditioned spaces

Base Requirement

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

Documentation Requirements

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

Reference

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

ENRB06 Indoor Air Quality (IAQ) Surveillance Audit

Intent

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

Applicability & Scope

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

Base Requirement

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

Guidance Notes

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

Documentation Requirements

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

Reference

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

CARBON
REDUCTION MEASURES
For Existing Non-Residential Buildings

SECTION 1 – SUSTAINABLE FEATURES

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

ENRBE01-1 Building Envelope Enhancement
ENRBE01-2 Naturally Ventilation Strategies
ENRBE01-3 Sustainable Products

ENRBE01-1 Building Envelope Enhancement

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

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

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

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

Guidance Notes

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

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

Worked Example ENRBE01-1(b)

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

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

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

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

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

Worked Example ENRBE01-1(c)

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

<table>
<tr><th>Innovative Solutions</th><th>Areas of Application (m^2)</th><td rowspan="4">Total Fenestration Areas = 20500
Extent of coverage = 5000/20500 = 24% ok</td></tr>
<tr><td>Film Technology</td><td>2000</td></tr>
<tr><td>BIPV system</td><td>3000</td></tr>
<tr><td>Total areas of application</td><td>5000</td></tr>
</table>

Documentation Requirements

ENRBE01-1(a)

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

ENRBE01-1(b)

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

ENRBE01-1(c)

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

Related Information

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

ENRBE01-2 Naturally Ventilated Building Design

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

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

Guidance Notes

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

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

Documentation Requirements

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

Related Information

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

ENRBE01-3 Sustainable Products

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

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

Guidance Notes

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

Worked Example ENRBE01-3

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

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

Documentation Requirements

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

References

SS ISO 14205 : Environmental Labels and Declarations – Type III environmental declarations – Principles and procedures

EN 15804 : Sustainability of Construction Works – Environmental Product Declarations – Core Rules for the Product Category of Construction Products

CARBON

REDUCTION MEASURES

For Existing Non-Residential Buildings

SECTION 2 – SUSTAINABLE OPERATION AND MANAGEMENT

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

ENRBE02-1 Electrical Submetering

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

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

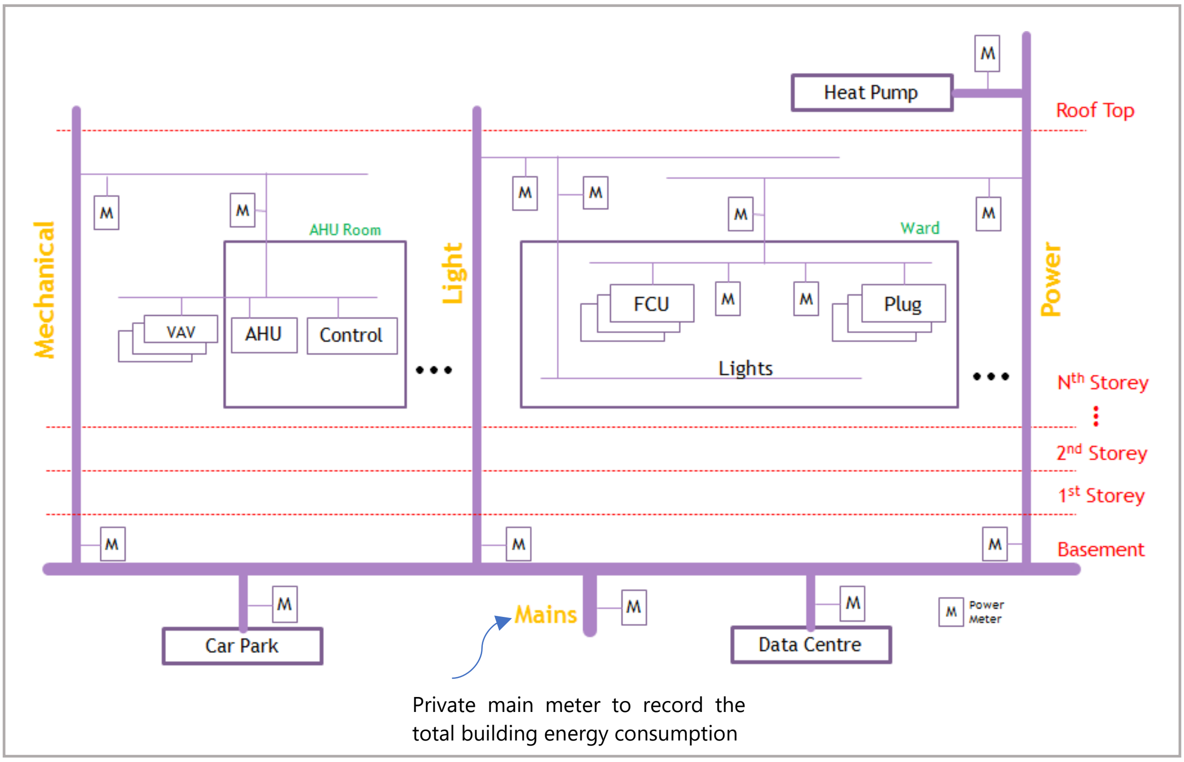
Note(1): Sub-metering provision for chilled water plant, variable refrigerant flow (VRF) systems and air distribution systems are covered under ENRB02.

Note(2): If there is a need to cater to high plug loads or process loads exceeding 50 kVA, please provide separate sub-metering for these specific areas to better manage and audit the building energy consumption.

Guidance Notes

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

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



Documentation Requirements

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

ENRBE02-2 Maintenance of Building Cooling System Performance

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

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

ENRBE02-2(a) Chillers

Access space provisions are as follows:

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

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

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

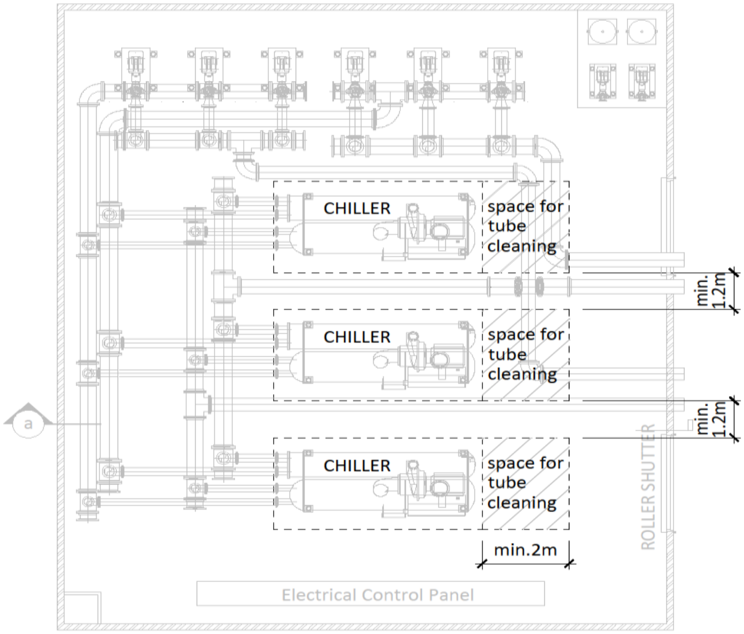


Figure A1 – Access space for the chillers

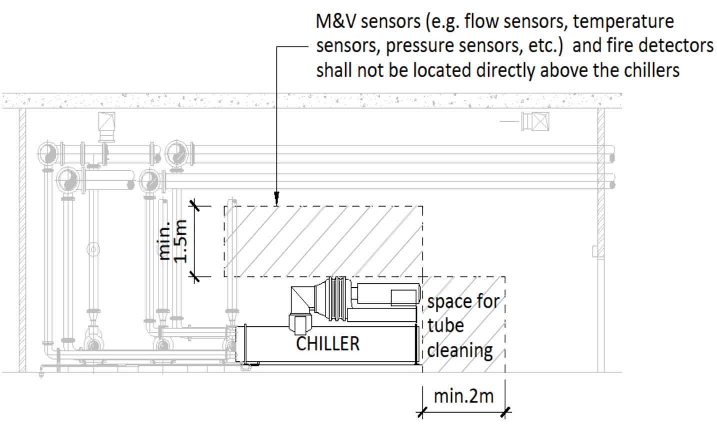


Figure A2 – Head room requirements for the chillers

Documentation Requirements

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

ENRBE02-2(b) Pump Systems

Access space provisions are as follows:

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

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

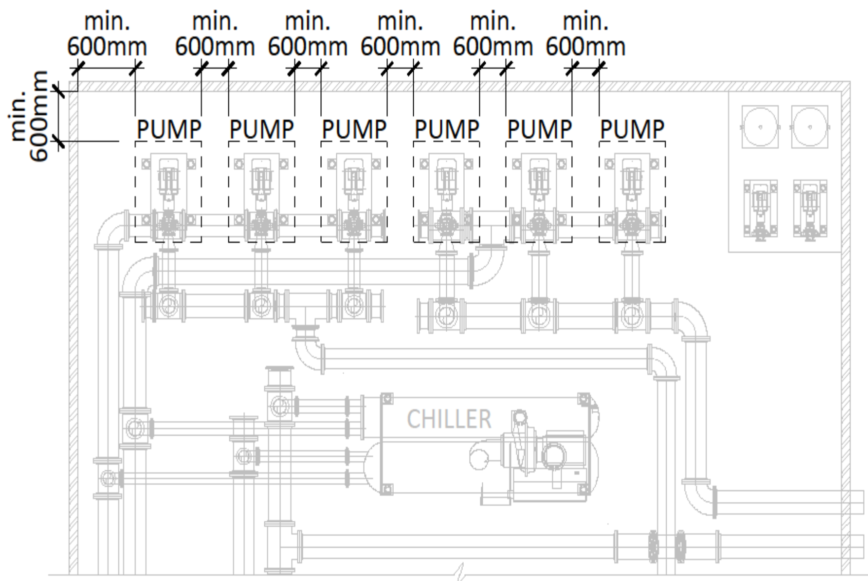


Figure A3 – Access space for the pump systems

Documentation Requirements

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

ENRBE02-2(c) Cooling Towers

Maintenance provisions are as follows:

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

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

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

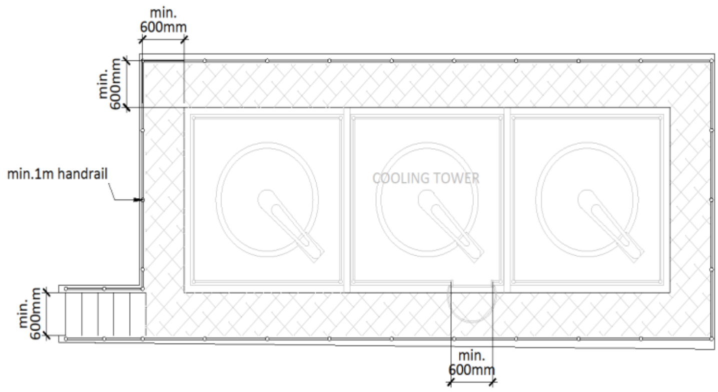


Figure A4 – Maintenance provisions for cooling towers

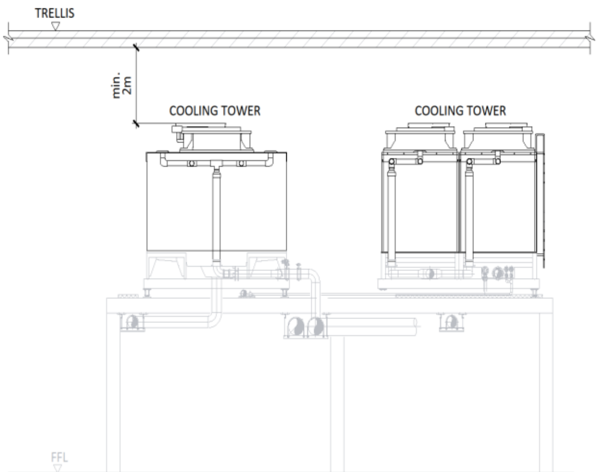


Figure A5 – Clear space requirement from top of cooling towers to location of trellis

Documentation Requirements

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

ENRBE02-2(d) Air Distribution Systems

Maintenance provisions are as follows:

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

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

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

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

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

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

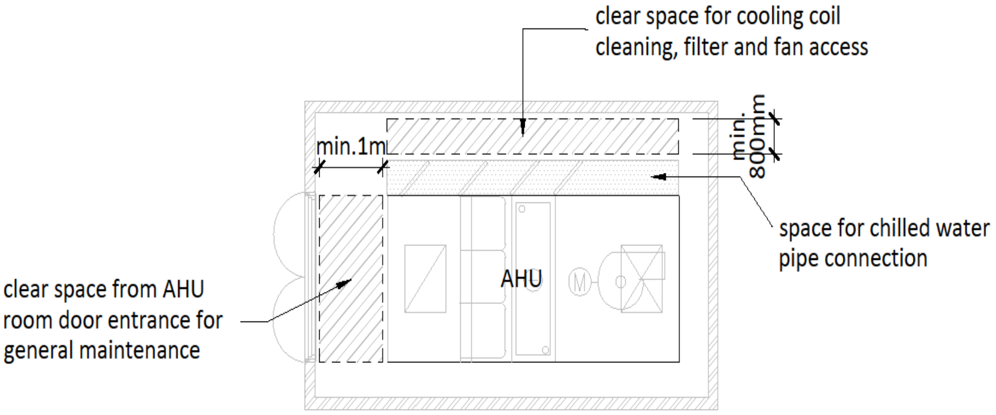


Figure A6 – Space provisions for Air Handling Units

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

Documentation Requirements

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

References

Design for Maintainability Guide on Non-Residential Buildings published by Building and Construction Authority

Maintainability Section under the Green Mark 2021 Framework

Related Information

There are considerations under the Workplace Safety and Health (Design for Safety) Regulations 2015 which can potentially affect the provision of access and space for mechanical and electrical services for safety purposes. Please ensure that the access space provisions meet the WSH guidelines published by the Ministry of Manpower (MOM) - Workplace Safety and Health Guidelines on Design for Safety (DfS), where relevant.

ENRBE02-3 User Engagement Plan

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

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

Guidance Notes

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

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

Documentation Requirements

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

CARBON
REDUCTION MEASURES
For Existing Non-Residential Buildings

SECTION 3 – SUSTAINABLE TECHNOLOGIES

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

ENRBE03-1 Renewable Energy System

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

Guidance Notes

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

Worked Example – ENRBE03-1

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

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

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

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

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

Documentation Requirements

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

ENRBE03-2 Smart Building Solutions

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

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

Documentation Requirements

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

ENRBE03-3 Green Building Technologies

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

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

Guidance Notes

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

Documentation Requirements

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