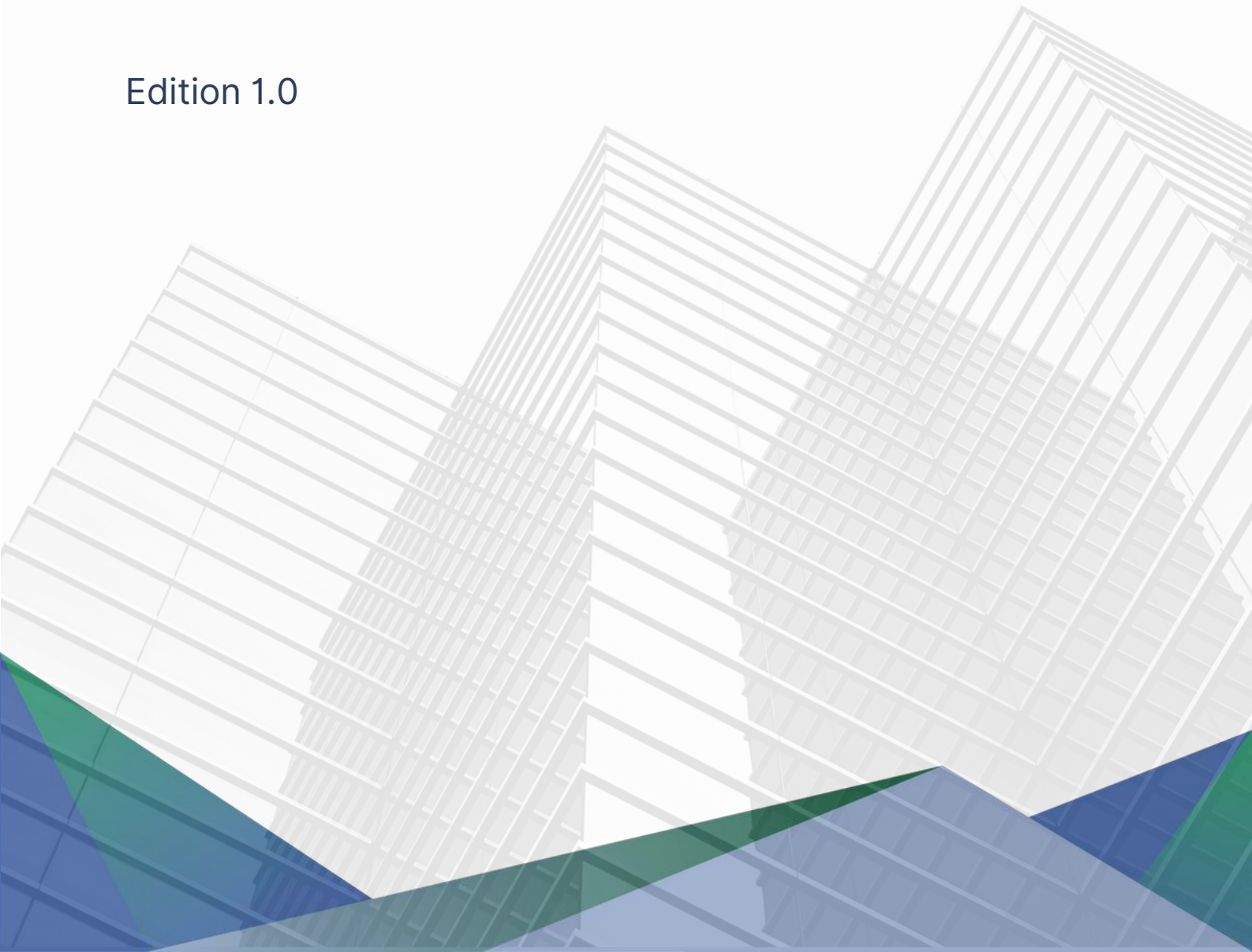
Building and Construction Authority

CODE ON

# MANDATORY ENERGY IMPROVEMENT

## FOR EXISTING BUILDINGS

Edition 1.0



The Code on Mandatory Energy Improvement for Existing Buildings, Edition 1.0
is electronically published by the Building and Construction Authority.



Building and Construction Authority

# CODE ON
# MANDATORY ENERGY IMPROVEMENT FOR EXISTING BUILDINGS

Edition 1.0

June 2025

# Revision Log

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# Contents

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# INTRODUCTION

Buildings account for over 20% of Singapore's carbon emissions, making them a key focus in our transition towards a low-carbon, climate-resilient built environment. Over the years, the approach to enhancing building energy performance has been centred on progressive performance-based standards, complemented by ongoing improvements in building system efficiency. Considerable adoption of energy-efficient systems and technologies has been achieved through this approach, particularly in new building developments and existing buildings undergoing major retrofits.

However, there is no requirement for owners to improve their building energy performance if they do not undertake any major retrofit or energy use changes. Given the urgency of climate change and Singapore's carbon reduction targets, a new regulatory framework known as the Mandatory Energy Improvement **("MEI")** Regime has been introduced through amendments to the Building Control Act ("**Act**") in Sep 2024. The MEI regime targets existing buildings that are energy intensive and imposes requirements to reduce energy consumption.

Under this regime, the owner of an energy-intensive building will be required to (i) engage a professional to carry out an energy audit of the building's energy-consuming system and submit an audit report and energy efficiency improvement plan (**"EEIP"**), (ii) implement energy efficiency improvement measures to reduce the building's energy usage intensity by 10% and (iii) maintain this improved energy performance for a period of one year. The detailed requirements can be found in Part 3B of the Act and the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 ("**ESM Regulations 2013**").

This Code titled 'Code on Mandatory Energy Improvement for Existing Buildings (referred to as "**MEI Code**")' is referenced in the ESM Regulations 2013 for compliance. It sets out the detailed requirements for building energy audits, with a focus on cooling and other high energy consumption systems. It also outlines the requirements for EEIP and defines the submission procedures.

This Code is not intended to address safety, health, environmental or related requirements contained in other applicable laws, codes or policies administered by relevant authorities.

If you need clarification on any aspect of this Code, please contact the BCA.

# 1 SCOPE

The MEI regime shall apply to an energy-intensive building with a gross floor area of at least 5000 $m^2$ and an energy use intensity ("**EUI**") that is above the prescribed EUI threshold for three consecutive years prior to the year of notice.

The regime does not apply to buildings that are solely used as data centres, railway premises, airport service and facilities, port services and facilities, general industrial buildings, light industrial buildings, religious buildings, residential building, special industrial buildings and utility buildings. For details, please refer to Regulation 2B of the ESM Regulations 2013.

This Code elaborates on the requirements in Part 3B of the Act and the ESM Regulations 2013. In particular, this Code :

(a) sets out the methodology for calculating the annual building energy consumption and energy use intensity ("**EUI**") of a building;

(b) stipulates the prescribed manner to carry out an audit on the energy use of buildings and systems;

(c) specifies the manner in which an energy audit is to be carried out to determine the energy efficiency standard of building's cooling system during operation; and

(d) spells out the submission procedures as well as the qualifications and experience required for registration or renewal of registration as an energy auditor.

# 2 DEFINITIONS

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

| | |
|---|---|
| Building Cooling System | A cooling system installed in a building to provide comfort cooling to the space, which may include chilled water systems with their associated air distribution systems (inclusive of air-handling systems), variable refrigerant flow (VRF) systems, split systems, packaged air-conditioning units, or other cooling technologies. |
| Chilled Water Plant/System | A centralised air conditioning system that makes use of chilled water as the medium for removing the heat from the buildings. It includes chillers and ancillary equipment such as pumps and cooling towers, where applicable. |
| Major energy use change | The installation, substantial alteration or replacement of building cooling system as defined in section 22FA of BC Act. |
| Operating System Efficiency (OSE) | The measured system efficiency of the chilled water plant or condenser unit and air distribution system. |
| Qualified Professional | A person who is registered under the Professional Engineers Act 1991 in the branch of mechanical engineering and who has in force a practicing certificate issued under that Act (referred to as PE (Mech), or a person registered with BCA as an energy auditor and who has in force a practicing certificate issued under the Act (referred to as EA). |

| | |
|---|---|
| Specified Individual | A qualified professional appointed to carry out an energy audit under section 22FL of the Building Control Act. |
| Total System Efficiency (TSE) | It is a measure of how efficiently the building cooling system would function to meet the operating condition and requirements in providing an acceptable indoor thermal environment. |
| Unitary Air Conditioning System | A factory-made assembly that typically comprising an evaporator or cooling coil and a compressor-condenser combination in a single package or split configuration, designed to condition and deliver air to the space being served. |

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) Building Control Act

(b) Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations

## 3.2 Reference Codes and Standards

The following codes and standards have relevance:

(a) Code on Environmental Sustainability Measures for Existing 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) ANSI/ASHRAE/ACCA Standard 211 : Standard for Commercial Building Energy Audits

(h) Mandatory Energy Labelling Scheme and Minimum Energy Performance Standards (MEPS) for Air-Conditioners under the Energy Conservation Act

## 3.3 Responsibility

### MEI Audit Notice Requirements

3.3.1 The building owner on whom an audit notice is served under section 22FL(1) of the Act must appoint a qualified professional to conduct an energy audit of the building and systems and prepare the energy efficiency improvement plan **("EEIP")**. The appointed qualified professional (known as **"specified individual"** in ESM Regulations 2013) is responsible for preparing and signing both the

audit report and the EEIP. These documents must be submitted within 1 year from the date that the MEI audit notice is issued to the owner or within the period specified in the MEI audit notice.

3.3.2 The specified individual must carry out an energy audit of the building and its systems in accordance with the prescribed manner in this Code. Based on the audit findings, the specified individual must provide:

(a) a recommendation on whether the building can meet the specified reduction in energy use intensity without undergoing a major energy use change;

(b) an audit report of the results of the energy audit and energy efficiency improvement plan must be prepared and signed in the form and manner specified on the BCA website; and

(c) an energy efficiency improvement plan outlining proposed measures to meet the specified reduction in the building's energy use intensity. This plan may include energy efficiency retrofits involving major energy use change, where relevant.

### Implementation of Energy Efficiency Improvement Measures

3.3.3. The building owner must implement the measures outlined in the EEIP within 3 years from the date of EEIP submission to the CBC. Upon completion, the building owner must submit a certificate of completion, prepared and signed by the specified individual confirming that all measures have been fully implemented according to the EEIP and the required reduction in energy use intensity has been achieved.

3.3.4 If any changes are made to the measures outlined in the submitted EEIP, the building owner must ensure that the specified individual amends the EEIP to indicate all departures and deviations and certifies that the amended EEIP will meet the required reduction in energy use intensity. The building owner must submit the amended EEIP within 60 days of initiating the changes, in the form and manner specified on the BCA website. For the avoidance of doubt, all measures, including any amendments, must be implemented within the 3-year period unless an extension is granted.

### Maintaining the Required Reduction in EUI

3.3.5 Following the implementation of energy efficiency improvement measures, the building owner must maintain the required reduction in EUI in relation to the building for a period of 1 year (**"maintenance period"**) after the date that the certificate of completion is submitted to the CBC.

3.3.6 A maintenance report prepared and signed by a specified individual must be submitted within 3 months after the last day of the maintenance period and in the form and manner specified on the BCA website.

3.3.7 The maintenance report must state the energy use intensity of the building during the maintenance period. If the required reduction in EUI is not maintained during such period, the report must contain additional measures to supplement the EEIP.

3.3.8 A written direction may be issued requiring the building owner to ensure that a specified individual prepares a supplemental report to the EEIP with additional measures to be implemented for the building. The building owner must implement these additional measures within the specified period. Following implementation, the building owner must submit a report, prepared and signed by the specified individual, confirming that the required reduction in EUI has been achieved and maintained.

## 3.4 Specified Reduction in Energy Use Intensity (EUI)

Under the MEI regime, the building owner is required to achieve a reduction of at least 10% in the building's Energy Use Intensity (EUI). This specified reduction is measured by comparing the building's EUI before and after implementation of energy efficiency improvement measures. For consistency, the building's EUI before implementation is taken as the average of its yearly EUI over the three-year period prior to the year of notice

# 4 EUI CALCULATION AND EUI THRESHOLD

## 4.1 Methodology in calculating the Building's Energy Use Intensity (EUI)

4.1.1 In the context of this regime, energy consumption calculations will focus on electricity, the primary energy source for most buildings. While buildings may use other energy sources, this framework is based on electrical energy use and the building's EUI will serve as the key energy performance indicator.

4.1.2 The annual energy consumption (in kWh/year) of a building is determined using energy use data from utility bills, energy management systems, and sub-metering over a typical 1-year period. It encompasses the total energy consumption from all activities and operations within the building, including tenant spaces and cooling provided by third-party cooling systems, without any normalisation.

4.1.3 The Gross Floor Area (GFA), a key parameter in calculating the EUI, is defined as the aggregate of the gross areas of all floor spaces that are prescribed in the Act and ESM Regulations 2013. It should be noted that this term holds the same meaning as 'floor area' in the Planning (Development Charges) Rules (Cap. 232).

4.1.4 The methodology in calculating the building's EUI is by dividing the annual energy consumption by the gross floor area, expressed in kilowatt-hours per square metre per year (kWh/$m^2$.yr). Building owners can use this metric to understand their building's energy performance relative to similar buildings, as published in the annual Building Energy Benchmarking Report (BEBR) on the BCA website and to track their building energy performance. The EUI value shows energy consumption per unit area. Buildings with higher EUI values compared to similar building types may have more opportunities for energy efficiency improvements. A higher EUI reflects greater energy use per unit area relative to other similar buildings, indicating potential opportunities for improving energy efficiency and reducing overall energy use.

## 4.2 Energy Use Intensity (EUI) Threshold

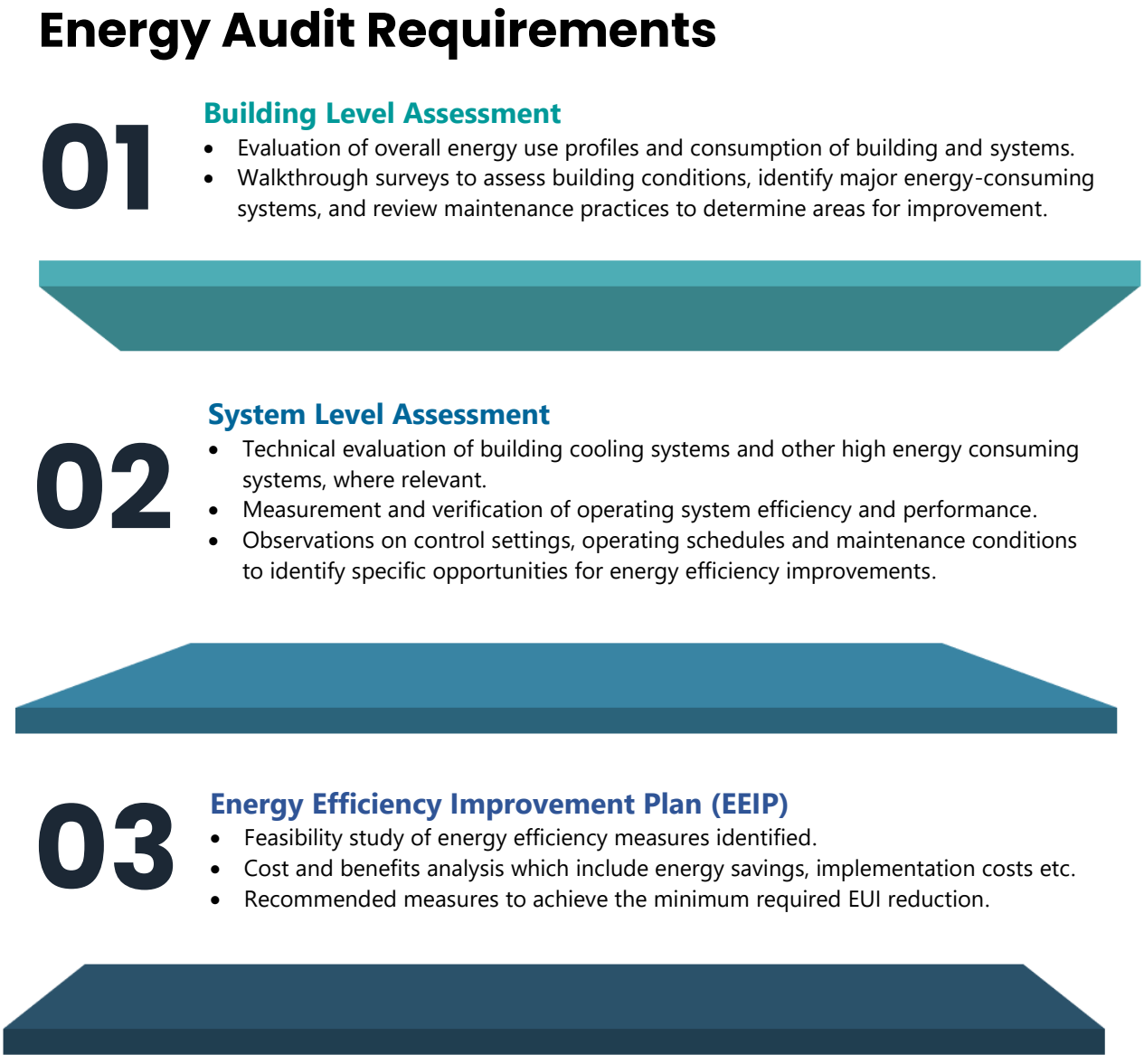
4.2.1 For the purpose of this regime, the threshold level of energy use intensity (**"EUI threshold"**) for different building uses have been established and specified in the First Schedule of ESM regulations 2013. These thresholds are subject to periodic review and adjustment to reduce carbon emissions in line with national commitments.

4.2.2 For buildings with inherently high energy uses, such as those housing data centres or laboratories, the EUI threshold can be adjusted to account for these exceptionally high energy demands. For mixed-use buildings, the EUI threshold will be calculated as a weighted average, pro-rated according to the gross floor area percentage of each building use category. (See Annex A for more details).

# 5 ENERGY AUDIT METHODOLOGY

## 5.1 General

5.1.1 This section sets out the energy audit methodology comprising building and system level assessments of energy use, cooling system efficiency, and other prescribed high energy consumption systems. These assessments identify opportunities for energy efficiency improvements and provide some basis for developing the EEIP, as summarised in the following chart.




5.1.2 While adherence to these requirements ensures a consistent approach to assessing building energy performance and identifying improvement measures, the specified individual may enhance the audit process and coverage beyond the minimum requirements stipulated in this Code. To achieve better energy performance outcomes, building owners should work with their appointed specified individual to establish additional audit assessment scope, where relevant.

## 5.2 Building Level Assessment

### Audit on Energy Use of Buildings and Systems

5.2.1 The objective of the audit on energy use of buildings and systems is to establish the energy profile and distribution, which is fundamental to identifying major energy uses and developing cost-effective measures to tackle areas of inefficiencies. To achieve this, the audit must include data collection and analysis to determine the building and system operational characteristics covering the following aspects, but not limited to:

(a) Building owner's operations and systems:
  (i) Owner/Landlord-operated systems and equipment and
  (ii) Central services and shared facilities related to building services and operation.

(b) Tenant operations:
  (i) Energy consumption within leased spaces and
  (ii) Where recommended, tenant-specific equipment and processes that are energy-intensive.

5.2.2 The scope of the audit must include the following areas, as applicable to the building:

(a) Review of the historical energy consumption data for 3 consecutive years prior to the year of notice, which include the energy bills.

(b) Walkthrough survey to visually inspect the building and major energy-consuming systems to identify areas of wastage and inefficiencies.

(c) Data collection of the electricity use which can include gathering sub-metering data for major building systems and obtaining energy bills and records from both landlord and key tenants, where applicable. Spot measurements using portable standard grade instrument may be used as a mean to ascertain the energy consumption of major building uses. The annual electricity consumption of the building may be sourced from energy use data published under the BCA Benchmarking Report (BEBR) on the BCA website, if available.

(d) Inventory of major energy-consuming systems and equipment which include types, quantities, age, rated capacities, rated power performance and control systems of various building services installation such as building cooling system and centralised hot water system, where relevant;

(e) Analysis of the collected data to identify the energy use profiles and peak demand period in relation to the building occupancy patterns and operational schedules of major energy-consuming systems and includes the following:

  (i) Breakdown of the annual electricity consumption by major energy uses, including but not limited to building cooling system, centralised hot water system and charging facility of electric vehicles, where relevant. Other building systems (such as lifts, escalators, and receptacle equipment load etc.) can be assessed collectively if individual data are not readily available. Energy profile and distribution charts that visually represents the proportion of total energy use attributed to each major system and end-use from the landlord and key tenants are to be provided.

  (ii) For each energy use, provide the measured energy consumption in absolute units (e.g., kWh) and as a percentage of the total annual energy consumption. Should

operation data or record be not fully available, reasonable estimates based on equipment ratings, operating hours, and standard engineering practices may be used, with the estimation methodology and assumptions clearly documented. The on-site energy generated by on-site Photovoltaic (PV) systems can be provided separately, if relevant.

## 5.3 System Level Assessment

### Audit on Energy Performance of Building Cooling Systems

5.3.1 At system level, the audit will cover the assessment of the energy performance of the building cooling systems. This includes the evaluation of the current operating energy efficiency of these systems as compared with their original design specifications and prevailing industry standards. Additionally, the assessment of control system, zoning strategies and maintenance practices that are relevant to identify potential energy efficiency improvements in system operation, maintenance, or controls.

5.3.2 The determination of the energy efficiency of the cooling system must be conducted under normal operating conditions with the indoor space conditions, maintained within the recommended limits stated in SS553 and SS554, where applicable.

### Chilled Water Plant

5.3.3 For chilled water plant, the energy performance data shall be obtained during the operating hours of the system and to be sampled and acquired simultaneously and continuously for a minimum of one (1) week at one (1) minute intervals, unless otherwise specified.

5.3.4 The energy performance of the system shall be evaluated based on the normal operating hours defined for each building type, to ensure consistent comparison with prevailing energy efficiency standards. However, it is recommended to consider the energy performance of the system during off-peak or night-time if the cooling demands are significant and present opportunities for energy savings.

5.3.5 If the permanent instrumentations and power meters are used, the accuracy of its permanent temperature sensors must be checked with a portable calibrated temperature sensor before extracting any data for the computation of performance data. Alternatively, the data may be obtained via external instrumentations that are calibrated with comparable accuracy.

5.3.6 The heat balance substantiating test is required for water-cooled chilled water plant to determine the quality of the measurements that is the uncertainty, installation and positioning of the instrumentations are within the prescribed tolerance for the purpose of deriving the Operating System Efficiency (OSE) of the water-cooled chilled water plant.

5.3.7 The OSE of the water-cooled chilled water plant must be verified and carried out by computing the system heat balance of the plant in accordance with the SS591- Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency, and to the extent as prescribed.

### Air Distribution System

5.3.8 For the measurement of the air distribution system efficiency, the data on the power consumption shall 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 1 week.

5.3.9 In instances, where there is no dedicated power meter for the air distribution systems, the measurement method, duration and coverage in deriving the power consumption from these systems as detailed in the following table are to be adopted for consistency.

<table>
<tr><th colspan="5">Measurement of Air Distribution System Efficiency</th></tr>
<tr><th>System Components</th><th>Measurement Method</th><th>Duration</th><th>Coverage</th><th>Total Power Consumption</th></tr>
<tr><td rowspan="4">(A) Air Handling Units (VAV-AHUs) (CAV-AHUs) excluding Pre-cooled AHUs</td><td>Trend data from BMS/EMS</td><td>Log for 1 week at 5-min interval</td><td>All</td><td>kWh</td></tr>
<tr><td colspan="4">If there is no linkage with BMS/EMS</td></tr>
<tr><td>VAV-AHUs: Trend log input power from VSD</td><td>Log for 1 day at 5-min interval</td><td rowspan="2">Minimum 10% of the total no. of AHUs or 5 no. of AHUs, whichever is higher<br><br>(Cap at 10 no.)</td><td rowspan="2">$kW_{avg}$ x Number of Operating hours per week x Number of AHUs = kWh</td></tr>
<tr><td>CAV-AHUs : Spot measurements using portable power meters with accuracy of IEC Class 1 or equivalent</td><td>Spot measurements during normal operating hours</td></tr>
<tr><td rowspan="4">(B) Fan Coil Units (FCUs)</td><td>Trend data from BMS/EMS</td><td>Log for 1 week at 5-min interval</td><td>All</td><td>kWh</td></tr>
<tr><td colspan="4">If there is no linkage with BMS/EMS</td></tr>
<tr><td>Spot measurements using portable power meters with accuracy of IEC Class 1 or equivalent</td><td>Spot measurements during normal operating hours</td><td>Minimum 10% of the total no. of FCUs</td><td>$kW_{avg}$ x Number of Operating hours per week x Number of FCUs = kWh</td></tr>
<tr><td colspan="4">Alternatively, the power consumption of FCUs can be computed based on the nameplate motor power of FCUs instead of measurement.</td></tr>
<tr><td colspan="5">Note: In addition to power consumption data, there are other pertinent data to be collected or recommended for collection such as supply air temperature (off-coil and on-coil), space air temperature, and relative humidity (RH%) etc. Please refer to the details provided in Annex B – Section (G) Energy Efficiency of Building Cooling System.</td></tr>
</table>

The efficiency of air distribution systems at building level, $\eta_a$ (in kW/RT) $= \frac{(\Sigma A + \Sigma B)}{C}$

where C is the total building cooling load based on trend data obtained from BMS/EMS for the same one (1) week as that for the measurement for the air distribution system.

### Unitary Air Conditioning System

5.3.10 The audit must include the assessment of the energy efficiency of unitary air conditioning systems which can be measured from the permanent measuring instruments, if available. Alternatively, the energy performance data published for air conditioners in the Mandatory Energy Labelling Scheme (MELS) or from the manufacturers' specification can be used as the basis to determine the energy efficiency of the unitary air conditioning system. The system energy efficiency

can be derived based on the concept of Integrated Energy Efficiency Ratio (IEER), which consider 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

5.3.11 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.

5.3.12 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.

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

*where*

*$COP_{100\%}$ is defined as the ratio of the cooling capacity to effective power input at full rated capacity*
*$COP_{50\%}$ is defined as the ratio of the cooling capacity to effective power input at 50% rated capacity*

5.3.13 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:

| | |
|---|---|
| **Energy efficiency of unitary air-conditioning system** | $$EE_{Weighted}\,(\text{in kW/RT}) = \frac{3.517/\sum(\text{Cooling Capacity} \times \text{IEER or } COP_{weighted})_i}{\text{Total Cooling Capacity}_{overall}}$$ |

5.3.14 Site derating factor could be included to account for the system efficiency of the condenser units to better reflect its expected operating performance when measured to consider possible efficiency losses due to site inherent constraints and considerations observed.

## 5.4 Audit Findings and Assessment

5.4.1 The detailed evaluation of building energy consumption profile, combined with the assessment of cooling system efficiency, provides critical insights for identifying potential energy-saving opportunities. These findings can form the basis for developing practical measures to reduce energy consumption and to meet the specified reduction in EUI.

5.4.2 Generally, energy improvement measures can come in many forms. Building owners can engage tenants and occupiers through green lease provisions with energy performance targets, cost-sharing mechanisms and rebate schemes. Beyond these engagement measures, technical and operational improvements can include adjusting system operations (such as AHU operating hours and space temperature settings), replacing equipment/components, adding energy-efficient

technologies, implementing energy recovery strategies, installing renewable energy systems, and enhancing operation and maintenance practices.

5.4.3 Building owners and their appointed specified individual should identify all potential energy efficiency improvement opportunities during the assessment. Priority should be given to immediate, low-cost measures requiring minimal investment - from optimising operating schedules and adjusting temperature set points, to fine-tuning control systems, improving maintenance practices, enhancing building management procedures, and conducting basic system balancing.

5.4.4 Additional opportunities may include medium-cost system modifications and major retrofit opportunities, such as system upgrades, equipment replacements, and significant redesign of building cooling systems. Building owners have the flexibility in planning their approach with various options to maximise the EUI reduction potential. However, to meet the required EUI reduction target, they may need to consider both immediate improvements and, if required, system enhancements.

## 5.5 Energy Efficiency Improvement Plan (EEIP)

5.5.1 Following the identification of potential energy efficiency improvement measures, the specified individual must work with the building owner to develop the EEIP. The measures selected are to collectively achieve the specified EUI reduction within the stipulated 3-year timeframe.

5.5.2 The building owner and specified individual can determine appropriate criteria for selecting the measures. While these typically include implementation cost and available budget, technical feasibility, complexity of solutions, and operational impacts, other relevant factors may also be considered. As part of this selection process, each measure's contribution to the overall energy reduction target should be clearly established, considering future maintenance and operational requirements.

5.5.3 The EEIP functions as a roadmap outlining the detailed descriptions of recommended measures, implementation timelines, expected energy savings, and implementation cost estimates. It also forms the basis for monitoring the building's progress towards the specified EUI reduction. Where necessary, building owners may be required through a written direction to provide progress updates to ensure implementation remains on track. Please refer to Annex B – Part 2 Energy Efficiency Improvement Plan on the detailed requirements.

# 6 SUBMISSION REQUIREMENTS AND PROCEDURES

## 6.1 General

Under the MEI regime, an owner to an energy-intensive building who receives an audit notice must, in accordance with the Act:

(a) Appoint a specified individual to carry out an energy audit (under sections 22FM and 22FN);
(b) Submit an audit report of the energy audit carried out and an energy efficiency improvement plan (under section 22FO);
(c) Ensure that the energy efficiency improvement plan is carried out (under section 22 FQ); and
(d) Ensure that the specified reduction or approved reduction in EUI is maintained for the maintenance period (under section 22FT).

## 6.2 Submission Process and Documentation

6.2.1 This section outlines the submission requirements that building owners and specified individuals must comply with to fulfill their obligations effectively. It provides guidance on the

compliance process, from appointing a specified individual to maintaining improved energy performance, including submission requirements, timelines, and documentation formats for each stage.

6.2.2 All submissions must be made through the electronic services provided on the BCA website, unless otherwise specified. Additional documents may be required and must be submitted in the form and manner specified by the Commissioner of Building Control ("CBC").


### Appointment of a Specified Individual

6.2.3 Upon receiving the audit notice, the building owner is required to appoint a specified individual to carry out the energy audit and develop the EEIP. The appointment notification must be submitted within 90 days from the date the MEI audit notice issued or within the period specified in the notice,

6.2.4 The specified individual appointed can be a Professional Engineer (Mechanical) or an energy auditor registered with BCA. Please refer to the listings available on the PE Board website and BCA website.

6.2.5 In the event that the building owner intends to appoint another specific individual before the expiry of the maintenance period, it is necessary to do so within 90 days after the cessation and notify the CBC of this change within 7 days after the date of appointment.

### Audit Report and Energy Efficiency Improvement Plan (EEIP)

6.2.6 The specified individual must prepare and sign an audit report of the result of the energy audit in the form and manner specified on the BCA website and Annex B of this Code.

6.2.7 The audit report, including the EEIP, must be submitted within 1 year from the date of the MEI audit notice issued or within the period specified in the notice.

6.2.8 If there are any changes to the measures carried out for the EEIP, the building owner must ensure that the specified individual amends the EEIP, showing clearly the departure and deviations and confirm that the measures in the amended EEIP will meet the specified or approved reduction in EUI. The amended EEIP must be submitted within 60 days after the owner becomes aware of the changes and in the form and manner specified by the CBC.

### Implementation of Energy Efficiency Measures and Certificate of Completion

6.2.9 The building owner must implement the measures set out in the EEIP and submit a certificate of completion within 3 years from the EEIP submission date. During this implementation period, progress reports on the status of energy efficiency measures may be required through a written direction.

6.2.10 Upon completion of all measures, the certificate of completion must be prepared and signed by the specified individual, certifying that all measures have been completed and the specified EUI reduction has been achieved.

**Maintenance of Improved Energy Performance and Report**

6.2.11 For a period of 1 year after the certificate of completion is submitted to the CBC, the building owner must maintain, at minimum, the specified EUI reduction and submit a maintenance report within 3 months after this period ends. The report is to be prepared by the specified individual and must state the building's EUI and, if the specified reduction is not maintained, include additional measures to supplement the EEIP.

# 7 REGISTRATION OF ENERGY AUDITOR

## 7.1 Eligibility Criteria

7.1.1 An individual will be eligible to be registered as an Energy Auditor with BCA under Section 22FC of the Act if he holds the following qualifications:

i. Possess at least an engineering or a building-related undergraduate degree in architecture, building science, facility management, or sustainable building design, or any equivalent professional qualification acceptable by the CBC;

ii. Have at least three (3) years of relevant practical experience in central air-conditioning design and installation, or operation;

iii. Completed two (2) ASHRAE Level III Energy Audits or three (3) Periodic Energy Audits on Building Cooling Systems under the supervision of a PE(Mechanical) or BCA registered Energy Auditor respectively; and

iv. Passed the interview and/or exam by the Energy Auditor Registration Committee.

7.1.2 For the purpose of ascertaining whether an individual can carry out the duties of an Energy Auditor, the CBC will consider the recommendations provided by the Energy Auditor Registration Committee appointed by him.

7.1.3 An application to be registered as an Energy Auditor can be made using the application form which is available on the BCA website. All applications must be accompanied with a fully completed form, supporting certificates and evidence of related work experiences as specified in the form.

7.1.4 The registration as an Energy Auditor shall be valid for 3 years, and each renewal of the registration shall also be valid for 3 years. Application for renewal of registration can be made using the application form which is available on the BCA website. All applications must be accompanied with a fully completed form, supporting certificates and evidence of related work experiences as specified in the form and renewal fee.

Annex A

# Energy Use Intensity Threshold (EUI)

Reference is made to the First Schedule of Building Control (Environmental Sustainability Measures for Existing Buildings) Regulation 2013

## Energy Use Intensity (EUI) Threshold

The threshold level of energy use intensity for a building that has one category of building use is as follows:

| Building Use | EUI Threshold (kWh/m$^2$.yr) |
|---|---|
| **A. Commercial buildings** | |
| 1. Hotel building | 310 |
| 2. Office building | 200 |
| 3. Retail building | 495 |
| **B. Healthcare facilities** | |
| 4. Hospital or specialist clinic | 360 |
| 5. Nursing home | 120 |
| 6. Polyclinic or private clinic | 190 |
| **C. Institutional buildings** | |
| 7. Autonomous university | 190 |
| 8. Civic building | 195 |
| 9. Community institution | 155 |
| 10. Cultural institution | 270 |
| 11. Other educational institution | 130 |
| **D. Sports and recreation centres** | |
| 12. Recreation club | 275 |
| 13. Sports centre | 180 |
| **E. Other energy uses** | |
| 14. Data centre operations | 6595 |
| 15. Laboratory operations | 560 |

**Mixed Categories of Building Uses**

The threshold level of energy use intensity for a building that has mixed categories of building use is the sum of the threshold level of EUI for each of the categories of building use as specified above) pro-rated in proportion to the percentage of gross floor areas (GFA) of the building that is used for that category of building use.

An example of EUI threshold determination for mixed categories of building uses is as follows :

A building with total gross floor area of 20,000 m$^2$, consisting of 70% office space and 30% retail space.

EUI Threshold = (70%*EUI Threshold for Office)+ (30% *EUI Threshold for Retail)
= (0.7 * 200) + (0.3 * 495)
= 288.5 kWh/m$^2$.yr

Note: For a building that is served by a third-party cooling system, the energy use intensity threshold shall be adjusted by a factor of 0.8 if the energy consumption information for cooling is not available.

Annex B

# Audit Report and Energy Efficiency Improvement Plan (EEIP)

Reporting Requirements and Templates

## Report Outline

### Part 1 - Audit Report

- Audit scope
- Building information
- Historical energy use data and utility cost
- Inventory of major energy-consuming systems and equipment
- Breakdown of energy consumption by end-use
- Energy efficiency of building cooling system
- Key findings and potential energy efficiency improvement measures

### Part 2 - Energy Efficiency Improvement Plan

- Feasibility assessment of EUI reduction
- Description of each recommended measures
- Expected energy savings and EUI reduction
- Implementation costs
- Simple payback period for each measure
- Implementation timeline

### Part 3 - Appendices

- Appendix A – Supporting documentation in relation to the audit of energy use of buildings and systems
- Appendix B – Supporting documentation in relation to the audit of energy efficiency level of building cooling systems
- Appendix C – Supporting documentation in relation to the EEIP

# Part 1 – Audit Report

- Audit Scope
- Building Information
- Historical energy use data and utility cost
- Inventory of major energy-consuming systems and equipment
- Breakdown of energy consumption by end-use
- Energy efficiency of building cooling system
- Key findings and potential energy efficiency improvement measures

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### Audit Scope

When preparing the audit scope, include the objectives, system covered and extent of coverage, audit methodology and assumption.

### Normative Information to be provided

The following are the tabulation and examples for reference and use :

| | | |
|---|---|---|
| **Building Name :** Example Building | | |
| **(A) Building Information** | | |
| Building Address | | |
| Postal Code | | |
| Primary Building Use Type and % Use | Office (50%) | |
| Other Building Use Type and % Use | Hotel (30%), Retail (10%) | |
| Building Age | | |
| Typical operation hours | 9 am to 6 pm (Office), 24 hrs (Hotel), 10 am to 9 pm (Retail) | |
| Gross Floor Area (GFA) in $m^2$ | | |
| Total Number of Blocks | 2 blocks | |
| Number of Floors | Block 1 - Office – 15<br>Block 2 – Retail (3 from Level 1 to 3) Hotel (15 from level 4-18) | |
| Air-Conditioned Areas in $m^2$ | | |
| Percentage owned (%) | | |
| Percentage leased (%) | | |
| Net Lettable Areas in $m^2$ | | |
| Carpark Areas in $m^2$ | | |
| Common Areas in $m^2$<br>*Note: To include all areas within the building such as lobbies, corridors, staircases, lifts, car parks, toilets, mechanical and electrical rooms, and other shared facilities that are not that are not leased to or owned by tenants.* | Air-Conditioned areas in $m^2$ | |
| | Non-Air Conditioned areas in $m^2$ | |

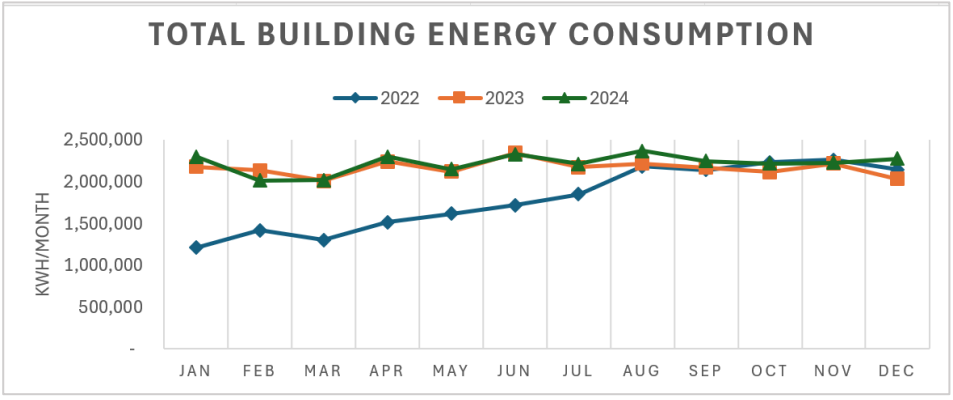
**Building Name :** Example Building

**(B) Historical Energy Use Data**

Monthly electricity consumption over the 3 years prior to the year of notice. If the year of MEI audit notice received is in 2025, the energy consumption data for year 2022, 2023 and 2024 is to be provided.

| **Year of MEI Audit Notice Received** | **2025** | | |
|---|---|---|---|
| **Building GFA ($m^2$)** | XXXX | | |
| **Month** | **Monthly Electricity Consumption** | | |
| | **2022** | **2023** | **2024** |
| Jan | | | |
| Feb | | | |
| Mar | | | |
| Apr | | | |
| May | | | |
| Jun | | | |
| Jul | | | |
| Aug | | | |
| Sep | | | |
| Oct | | | |
| Nov | | | |
| Dec | | | |
| **Total Building Electricity Consumption (TBEC) (kWh/year)** | | | |
| **Energy Use Intensity (EUI) kWh/$m^2$.year** | | | |
| **Average Total Building Electricity Consumption (kWh/year)** | $\frac{\sum(TBEC)_i}{3}$ | | |
| **Average Energy Use Intensity (EUI) (kWh/$m^2$.year)** | $\frac{\text{Average TBEC}}{\text{GFA}}$ | | |
| **Remarks** | *Please highlight any major changes in building operations, occupancy, or requirements that may have affected energy use, if applicable* | | |

*Note : The average EUI will be used as the baseline to accord the percentage reduction in EUI after implementation of EEIP.*



| **Building Name :** Example Building | | | |
|---|---|---|---|
| **(C) Utility Cost Arrangement** | | | |
| (1) Utility account under building owner/Landlord. Building owner will charge tenant based on tenancy lease where relevant. | | | Yes/No |
| (2) Tenants have direct account with utility provider and pay for their own electricity consumption. | | | Yes/No |
| (3) Landlord has the master utility accounts and sub-meter individual units and tenants pay for their metered usage and a share of common areas utilities. | | | Yes/No |
| Combination of above or others, pls specify : | | | |
| **(D) Utility Cost for Building Owner or Landlord** | | | |
| Type of Electricity Package | Pls state<br>Low tension supplies or High tension (small/large) supplies with contracted or uncontracted charges /reactive power charges | | |
| **Year of MEI Audit Notice Received** | **2025** | | |
| **Building GFA ($m^2$)** | XXXX | | |
| **Month** | **Monthly Electricity Cost** | | |
| | **2022** | **2023** | **2024** |
| Jan | | | |
| Feb | | | |
| Mar | | | |
| Apr | | | |
| May | | | |
| Jun | | | |
| Jul | | | |
| Aug | | | |
| Sep | | | |
| Oct | | | |
| Nov | | | |
| Dec | | | |
| **Total Electricity Cost ($/year)** | | | |
| **Average Monthly Electricity Cost ($/month)** | | | |

**Building Name :** Example Building

**(E) Inventory of Major Energy-Consuming Systems and Equipment**

**Building Cooling System (Required)**

| System/Equipment Type | |
|---|---|
| Chilled Water System | This information can be consolidated and provided under Section (G) – Energy Efficiency of Cooling System. |
| Chiller | |
| Chilled Water Pump | |
| Condenser Water Pump | |
| Cooling Tower | |
| VRF System | |
| Other Unitary Air Conditioning Systems | |

**Centralised Hot Water System (Required, where applicable)**

| System/Equipment Type | Quantity | Year Installed | Rated Capacity (kW) | Rated Power (kW) | Control System | Location/Remarks |
|---|---|---|---|---|---|---|
| Electric/Gas Boiler | | | | | | |
| Heat Pump | | | | | | |
| **Ancillary Equipment** | **Quantity** | **Pump Head (m)** | **Flow Rate (L/S)** | **Rated Pump/ Fan Efficiency (%)** | **Rated Motor Efficiency (%)** | **Location/Remarks** |
| Primary Circulation Pump | | | | | | |

**Mechanical Ventilation System (Required, if it is in the EEIP)**

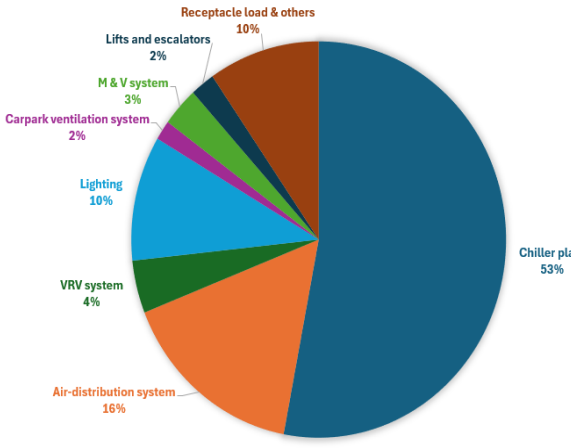
| System/Equipment Type | Quantity | Fan Type | Floor Areas served ($m^2$) | Air Changes per hour (ACH) | External Static (Pa) | Fan Motor Input Power (kW) | Fan Efficiency (W/CMH) | Location/ Remarks |
|---|---|---|---|---|---|---|---|---|
| Exhaust and Intake Fans for Carparks | | | | | | | | |

**Lighting System (Required, if it is in the EEIP)**

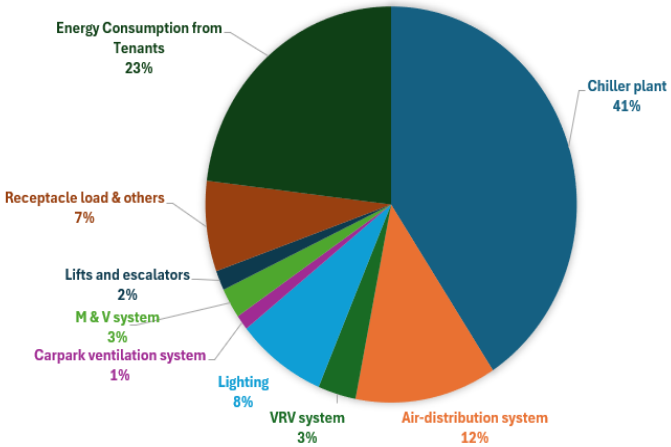
| S/No | Fitting Type | Location | Areas Covered ($m^2$) | Light Fitting Power (W) | No. of Fittings | Total Power Consumption include ballast loss (W) | Operating Hours (h) | Operating Lighting Power Budget ($W/m^2$) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| Building Name : Example Building | | |
|---|---|---|
| **(F) Breakdown of Energy Consumption by End-Use** | | |
| End-Use | Energy Consumption (kWh/year) | Data Source |
| **Building Cooling System** | | |
| Chilled Water System | | To indicate the data source for example data from BMS, sub-meter, spot measurement, spec and calculation. For others, pls specify |
| Unitary Air-Conditioning System | | |
| Air-Handling and Distribution System | | |
| **Centralised Hot Water System** | | |
| Electric/Gas Boiler | | Ditto |
| Heat Pump | | Ditto |
| **Other Equipment and System** | | |
| Lighting System | | Ditto |
| Carpark Ventilation System | | Ditto |
| Mechanical and Ventilation System | | Ditto |
| Lifts and Escalators | | Ditto |
| Receptacle load | | Ditto |
| Others (pls specify) | | Ditto |
| Total Energy Consumption from Building Systems | ∑ Energy Consumption from the above systems | |
| **Other Energy Use (if relevant)** | | |
| Energy Consumption from Tenants | | Electricity bills, sub-meter etc., |
| Others (pls specify) | | Ditto |
| Total Building Energy Consumption (TBEC) | ∑ Energy Consumption from the above systems and Tenants | |
| On-site Renewable Energy Generation (if any) | | Ditto |

Breakdown of Energy Consumption by End-Use (System Level)




Breakdown of Energy Consumption by End-Use (Building Level)




*Note : The distribution of energy consumption at system level will include the operation energy demand from the Landlord. If the building is solely occupied by an owner with no other tenancy, the distribution will be the same as that for building level.*

| | |
|---|---|
| **Building Name :** Example Building | |
| **(G) Energy Efficiency of Building Cooling System** | |
| **Audit Information** | |
| Type of Building Cooling System | Pls state the cooling system used :<br>For e.g.<br>(a) Water-Cooled Building Cooling System comprises the following systems and components, where relevant.<br>• Water-Cooled Chiller<br>• Water-Cooled Direct-Expansion (DX) System<br>• Chilled Water Pump<br>• Condenser Water Pump<br>• Cooling Tower<br>• Air Handling and Distribution System<br><br>(b) Air-Cooled Building Cooling System comprises the following systems and components, where relevant<br>• Unitary Air-Conditioners (Single or combination of systems)<br>o Variable Refrigerant Flow (VRF) system<br>o Single-Split Units<br>o Multi-Split Units<br>o Air Handling and Distribution System<br><br>• Air-Cooled Chilled-Water System<br>o Air-Cooled Chiller<br>o Chilled Water Pump<br>o Air Handling and Distribution System<br><br>(c) District Cooling System comprises the following systems and components, where relevant<br>• District level - Central chilled water system with distribution networks<br>• Building level – Air-handling and distribution System |
| Location of Cooling System | Office Block Basement 2 |
| Energy Audit Period | DD MMM YYYY - DD MMM YYYY |
| Building Cooling System Normal Operating Hours | For e.g. office<br>Monday to Friday : 0800 – 2000 Hrs<br>Saturday/Sunday : No operation |

**Building Name :** Example Building

**(G) Energy Efficiency of Building Cooling System -Cont'd**

**Chilled Water Plant / System**

**Measurement of Chilled Water System Energy Efficiency**

| | |
|---|---|
| Data Logging Interval | 1 minute sampling time interval and recorded at 3rd decimal place for minimum of 1 week |
| Trend Logged Parameters<br><br>*Note : The parameters may vary depending on the piping and electrical circuit design* | Chilled Water Supply main header temperature<br>Chilled Water Return main header temperature<br>Chilled Water flowrate at Chilled Water Return main header<br>Condenser Water Supply main header temperature<br>Condenser Water Return main header temperature<br>Condenser water flow rate at condenser water return main header<br>Power input to Chiller(s)<br>Power input to Chilled water pump(s)<br>Power input to Condenser water pump(s)<br>Power input to Cooling tower(s)<br>Power input to Pre-AHU(s)/AHU(s)/FCU(s) |

**Confirmation on the Accuracy of the Measurement Instrument used for Audit Process**

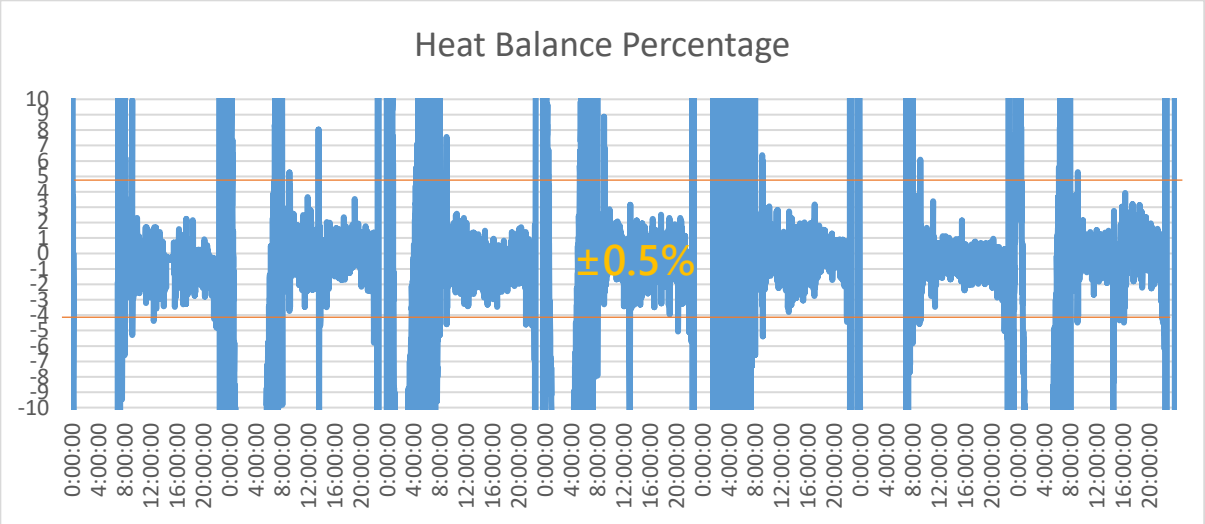
Instrumentations schedule and points of measurements

The measuring instruments complying with the standards in accordance with SS591-Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency are to be used for this purpose. The instrumentation schedule and points of measurement should be provided using the format shown in the example below:

| ID / Serial No. | Sensor Type | Installation Location | Measurement Uncertainty (%) | Last Calibration Date | Calibration Laboratory |
|---|---|---|---|---|---|
| EP80367 | 10K Thermistor | CHWS Header | ±0.03 °C | 09/05/2023 | XX laboratory |
| EP80364 | 10K Thermistor | CHWR Header | ±0.03 °C | 09/05/2023 | XX laboratory |
| EP80361 | 10K Thermistor | CWS Header | ±0.03 °C | 09/05/2023 | XX laboratory |
| EP80363 | 10K Thermistor | CWR Header | ±0.03 °C | 09/05/2023 | XX laboratory |
| 3k67201343004 | Magnetic Full Bore | CHWR Header | 0.50% | 29/10/2023 | factory calibration |
| 3k67201418063 | Magnetic Full Bore | CWR Header | 0.50% | 09/05/2024 | factory calibration |
| 38498 | True RMS, 3 phase | MSB Incoming 1 | 0.50% | 08/07/2024 | factory calibration |
| 1402404 | True RMS, 3 phase | MSB Incoming 2 | 0.50% | 08/07/2024 | factory calibration |
| 38491 | True RMS, 3 phase | CHW/6-1 | 0.50% | 08/07/2024 | factory calibration |
| 38487 | True RMS, 3 phase | CHW/6-1 | 0.50% | 08/07/2024 | factory calibration |
| 38490 | True RMS, 3 phase | CWP/6-1 | 0.50% | 08/07/2024 | factory calibration |
| .... | | | | | |
| .... | | | | | |

Summary of System Heat Balance and Checks required before measurement

Example of System Level Heat Balance Plot




| | Quantity | Unit | Formula |
|---|---|---|---|
| **Sum of total electrical energy used** | | kWh | (A) |
| **Sum of total cooling produced** | | RTh | (B) |
| **Sum of total heat rejected** | | RTh | (C) |
| **Chiller Plant Efficiency** | | kW/RT | (A) / (B) |
| **Total Heat Balance Data Count** | | - | (D) |
| **Data Count > + 5% error** | | - | (E) |
| **Data Count < - 5% error** | | - | (F) |
| **Data Count within ±5% error** | | - | (G) = (D) – (E) – (F) |
| **% Heat Balance within ±5% error** | | % | 100 x (G) / (D) |

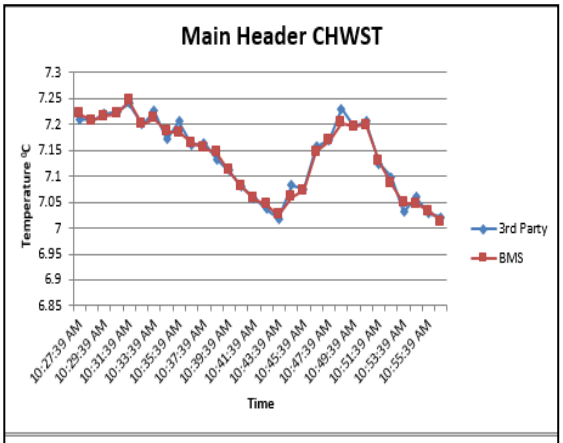
| | |
|---|---|
| BMS Check<br>(1) Temperature sensors' ABC coefficient constants input as reflected in the calibration certificate | ☐ |
| Power Meter (Consistency Check)<br>(2) Check power meter and BMS readings are the same<br>(3) Check power meter reading and chiller panel or pump VSD display reading is ≤ 3%<br>(4) Check current transformer ratio tally with power meter setting | ☐<br>☐<br>☐ |
| Flow Meter<br>(5) Check the sum of branch flowmeters matches with header flow meter header readings (if flow meters exist at header and individual chillers)<br>(6) Check flow meters and BMS readings are the same<br>(7) Check flow meters do not have any correction factor or offset factor input | ☐<br>☐<br>☐ |
| Verified Temperature Sensor Accuracy<br>(8) Use calibrated reference temperature sensor with end-to-end uncertainty of ≤ 0.05 °C<br>(9) Synchronise the reference temperature sensor device timing with BMS<br>(10) Collect at least 20 sets of readings from reference temperature sensor device (after insertion to the available test plug) and BMS<br>(11) Compare the difference between both set of readings, with average of absolute difference to be ≤ 0.07 °C<br>(12) Temperature verification data and plots are to be provided (see example below) | ☐<br>☐<br>☐<br>☐<br>☐ |

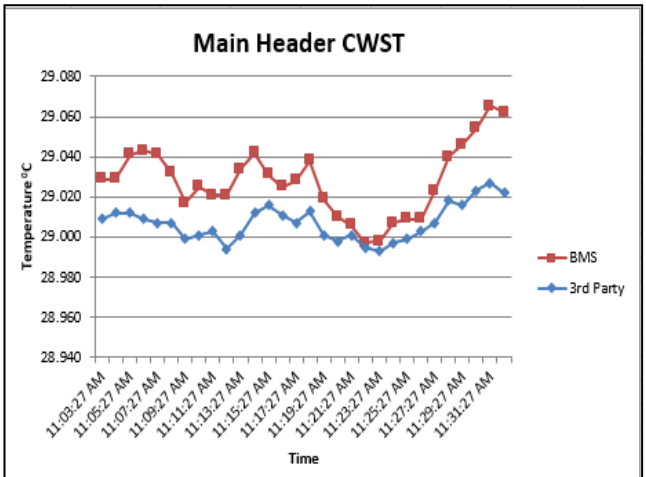
## Verified Temperature Sensor Accuracy (Cont'd)

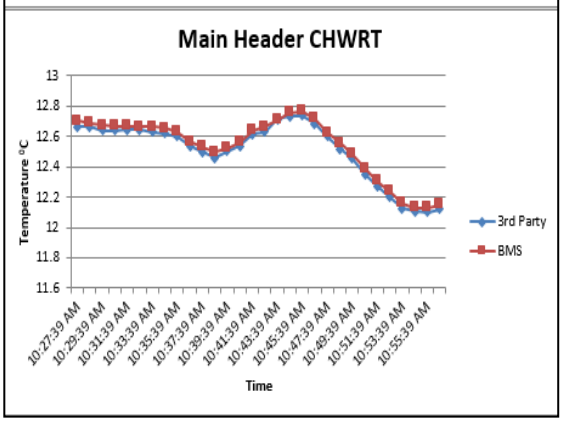
Example of temperature verification data and plots

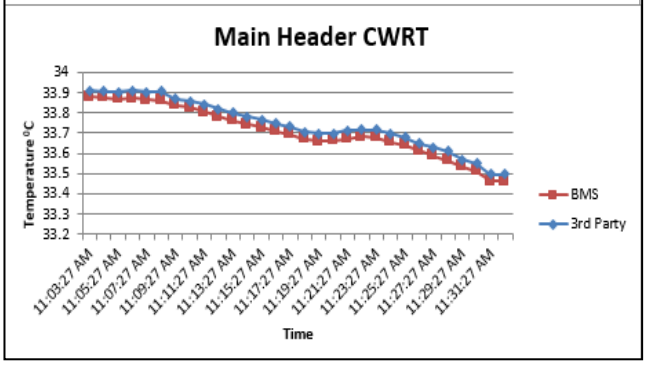
Building Name : XXX Building
Date of Verification : DDMMYY
Verification by : Name of specified individual

| Main Header Chilled Water Supply Temperature | | | | Main Header Chilled Water Return Temperature | | | | Main Header Condenser Water Supply Temperature | | | | Main Header Condenser Water Return Temperature | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 3rd Party (°C) | BMS(°C) | ABS | Time | 3rd Party (°C) | BMS(°C) | ABS | Time | 3rd Party (°C) | BMS(°C) | ABS | Time | 3rd Party (°C) | BMS(°C) | ABS |
| 10:27:39 am | 7.211 | 7.220 | -0.009 | 10:27:39 am | 12.663 | 12.703 | -0.040 | 11:03:27 am | 29.009 | 29.029 | -0.020 | 11:03:27 am | 33.912 | 33.879 | 0.033 |
| 10:28:39 am | 7.209 | 7.207 | 0.002 | 10:28:39 am | 12.665 | 12.690 | -0.025 | 11:04:27 am | 29.012 | 29.029 | -0.017 | 11:04:27 am | 33.907 | 33.876 | 0.031 |
| 10:29:39 am | 7.221 | 7.216 | 0.005 | 10:29:39 am | 12.640 | 12.674 | -0.034 | 11:05:27 am | 29.012 | 29.041 | -0.029 | 11:05:27 am | 33.904 | 33.867 | 0.037 |
| 10:30:39 am | 7.225 | 7.220 | 0.005 | 10:30:39 am | 12.640 | 12.671 | -0.031 | 11:06:27 am | 29.009 | 29.043 | -0.034 | 11:06:27 am | 33.910 | 33.874 | 0.036 |
| 10:31:39 am | 7.240 | 7.246 | -0.006 | 10:31:39 am | 12.642 | 12.668 | -0.026 | 11:07:27 am | 29.007 | 29.041 | -0.034 | 11:07:27 am | 33.902 | 33.864 | 0.038 |
| 10:32:39 am | 7.200 | 7.200 | 0.000 | 10:32:39 am | 12.642 | 12.663 | -0.021 | 11:08:27 am | 29.007 | 29.032 | -0.025 | 11:08:27 am | 33.906 | 33.862 | 0.044 |
| 10:33:39 am | 7.227 | 7.211 | 0.016 | 10:33:39 am | 12.628 | 12.662 | -0.034 | 11:09:27 am | 28.999 | 29.017 | -0.018 | 11:09:27 am | 33.867 | 33.840 | 0.027 |
| 10:34:39 am | 7.172 | 7.186 | -0.014 | 10:34:39 am | 12.622 | 12.653 | -0.031 | 11:10:27 am | 29.001 | 29.025 | -0.024 | 11:10:27 am | 33.858 | 33.826 | 0.032 |
| 10:35:39 am | 7.205 | 7.184 | 0.021 | 10:35:39 am | 12.601 | 12.631 | -0.030 | 11:11:27 am | 29.003 | 29.021 | -0.018 | 11:11:27 am | 33.841 | 33.806 | 0.035 |
| 10:36:39 am | 7.160 | 7.164 | -0.004 | 10:36:39 am | 12.537 | 12.567 | -0.030 | 11:12:27 am | 28.994 | 29.021 | -0.027 | 11:12:27 am | 33.818 | 33.781 | 0.037 |
| 10:37:39 am | 7.164 | 7.154 | 0.010 | 10:37:39 am | 12.499 | 12.532 | -0.033 | 11:13:27 am | 29.001 | 29.034 | -0.033 | 11:13:27 am | 33.801 | 33.764 | 0.037 |
| 10:38:39 am | 7.133 | 7.146 | -0.013 | 10:38:39 am | 12.460 | 12.497 | -0.037 | 11:14:27 am | 29.012 | 29.042 | -0.030 | 11:14:27 am | 33.780 | 33.744 | 0.036 |
| 10:39:39 am | 7.111 | 7.111 | 0.000 | 10:39:39 am | 12.501 | 12.523 | -0.022 | 11:15:27 am | 29.016 | 29.031 | -0.015 | 11:15:27 am | 33.767 | 33.729 | 0.038 |
| 10:40:39 am | 7.079 | 7.080 | -0.001 | 10:40:39 am | 12.535 | 12.560 | -0.025 | 11:16:27 am | 29.011 | 29.025 | -0.014 | 11:16:27 am | 33.746 | 33.709 | 0.037 |
| 10:41:39 am | 7.059 | 7.057 | 0.002 | 10:41:39 am | 12.614 | 12.640 | -0.026 | 11:17:27 am | 29.007 | 29.028 | -0.021 | 11:17:27 am | 33.734 | 33.696 | 0.038 |
| 10:42:39 am | 7.037 | 7.046 | -0.009 | 10:42:39 am | 12.631 | 12.664 | -0.033 | 11:18:27 am | 29.013 | 29.038 | -0.025 | 11:18:27 am | 33.706 | 33.672 | 0.034 |
| 10:43:39 am | 7.019 | 7.026 | -0.007 | 10:43:39 am | 12.712 | 12.710 | 0.002 | 11:19:27 am | 29.001 | 29.019 | -0.018 | 11:19:27 am | 33.697 | 33.660 | 0.037 |
| 10:44:39 am | 7.082 | 7.060 | 0.022 | 10:44:39 am | 12.732 | 12.758 | -0.026 | 11:20:27 am | 29.998 | 29.010 | 0.988 | 11:20:27 am | 33.698 | 33.662 | 0.036 |
| 10:45:39 am | 7.076 | 7.073 | 0.003 | 10:45:39 am | 12.736 | 12.767 | -0.031 | 11:21:27 am | 29.001 | 29.006 | -0.005 | 11:21:27 am | 33.712 | 33.670 | 0.042 |
| 10:46:39 am | 7.157 | 7.147 | 0.010 | 10:46:39 am | 12.683 | 12.718 | -0.035 | 11:22:27 am | 28.995 | 28.997 | -0.002 | 11:22:27 am | 33.718 | 33.681 | 0.037 |
| 10:47:39 am | 7.170 | 7.169 | 0.001 | 10:47:39 am | 12.600 | 12.626 | -0.026 | 11:23:27 am | 28.993 | 28.998 | -0.005 | 11:23:27 am | 33.718 | 33.679 | 0.039 |
| 10:48:39 am | 7.231 | 7.203 | 0.028 | 10:48:39 am | 12.518 | 12.557 | -0.039 | 11:24:27 am | 28.997 | 29.007 | -0.010 | 11:24:27 am | 33.699 | 33.658 | 0.041 |
| 10:49:39 am | 7.198 | 7.196 | 0.002 | 10:49:39 am | 12.453 | 12.484 | -0.031 | 11:25:27 am | 28.999 | 29.009 | -0.010 | 11:25:27 am | 33.679 | 33.642 | 0.037 |
| 10:50:39 am | 7.206 | 7.199 | 0.007 | 10:50:39 am | 12.351 | 12.392 | -0.041 | 11:26:27 am | 29.003 | 29.009 | -0.006 | 11:26:27 am | 33.648 | 33.615 | 0.033 |
| 10:51:39 am | 7.125 | 7.128 | -0.003 | 10:51:39 am | 12.273 | 12.305 | -0.032 | 11:27:27 am | 29.007 | 29.023 | -0.016 | 11:27:27 am | 33.628 | 33.586 | 0.042 |
| 10:52:39 am | 7.098 | 7.085 | 0.013 | 10:52:39 am | 12.201 | 12.239 | -0.038 | 11:28:27 am | 29.018 | 29.040 | -0.022 | 11:28:27 am | 33.611 | 33.564 | 0.047 |
| 10:53:39 am | 7.031 | 7.048 | -0.017 | 10:53:39 am | 12.124 | 12.161 | -0.037 | 11:29:27 am | 29.016 | 29.046 | -0.030 | 11:29:27 am | 33.568 | 33.535 | 0.033 |
| 10:54:39 am | 7.060 | 7.047 | 0.013 | 10:54:39 am | 12.106 | 12.131 | -0.025 | 11:30:27 am | 29.023 | 29.054 | -0.031 | 11:30:27 am | 33.549 | 33.511 | 0.038 |
| 10:55:39 am | 7.028 | 7.032 | -0.004 | 10:55:39 am | 12.100 | 12.129 | -0.029 | 11:31:27 am | 29.027 | 29.065 | -0.038 | 11:31:27 am | 33.498 | 33.463 | 0.035 |
| 10:56:39 am | 7.021 | 7.013 | 0.008 | 10:56:39 am | 12.122 | 12.148 | -0.026 | 11:32:27 am | 29.022 | 29.062 | -0.040 | 11:32:27 am | 33.496 | 33.462 | 0.034 |
| Average | 7.138 | 7.136 | 0.002 | Average | 12.508 | 12.537 | -0.029 | Average | 29.007 | 29.028 | -0.021 | Average | 33.743 | 33.706 | 0.037 |
| | | | Passed | | | | Passed | | | | Passed | | | | Passed |



## Chilled Water Plant Information based on Design Specifications and Nameplate

Table 1 : Chiller information (Example)

| ID | Description | Brand | Type | Name plate motor (kW) | Total Cooling Capacity (RT) | Chilled water LWT/EWT (°C) | Rated Efficiency (kW/RT) | Year Installed | Location |
|---|---|---|---|---|---|---|---|---|---|
| CH01 | Chiller 1 | Brand X | Centrifugal water-cooled | 162.8 | 300 | 7.5/13 | 0.543 | 2017 | B2 plant room |
| CH02 | Chiller 2 | Brand X | Centrifugal water-cooled | 162.8 | 300 | 7.5/13 | 0.543 | 2017 | B2 plant room |
| CH02 | Chiller3 | Brand X | Centrifugal water-cooled | 162.8 | 300 | 7.5/13 | 0.543 | 2017 | B2 plant room |

Table 2 : Ancillary equipment information (Example)

| ID | Brand | Type | Name plate motor (kW) | Pump Head (m) | Flow rate (L/S) | Rated Pump/ Fan Efficiency (%) | Rated Motor Efficiency (%) |
|---|---|---|---|---|---|---|---|
| CHWP 1 | Brand X | end suction | 1 1 | 23 | 33.65 | 80.00% | 92.40% |
| CHWP 2 | Brand X | end suction | 11 | 23 | 33.65 | 80.00% | 92.40% |
| CHWP 3 | Brand X | end suction | 11 | 23 | 33.65 | 80.00% | 92.40% |
| CWP 1 | Brand Y | end suction | 15 | 16 | 56.82 | 79.00% | 92.40% |
| CWP 2 | Brand Y | end suction | 15 | 16 | 56.82 | 79.00% | 92.40% |
| CWP 3 | Brand Y | end suction | 15 | 16 | 56.82 | 79.00% | 92.40% |
| CT 1 | Brand Z | cross flow | 5.5 x 1 Cell | - | 66.2 | 75% | 86% |
| CT 2 | Brand Z | cross flow | 5.5 x 1 Cell | - | 66.2 | 75% | 86% |
| CT 3 | Brand Z | cross flow | 5.5 x 1 Cell | - | 66.2 | 75% | 86% |

## Description of Chilled Water System Control Strategy

Please provide a summary of the system control strategy adopted, where relevant. The summary may include, but is not limited to, the following:

**Chiller sequencing**

*Describe how the chiller(s) operate to handle the varying building cooling load*

*e.g. chiller cut-in/out sequence varying with building load and addressing peak and off-peak load based on (supply water temperature, and/or building load, and/or compressor current running load amps) and time delay.*

**Chilled water pump**

*Describe the parameters used to control chilled water pumps*

*e.g. pump speed modulate based on ((differential) pressure sensor located at chiller header, or remote AHU cooling coil, or several zones of AHU cooling coil, or optimising pump pressure by critical valve control), set-point(s) and bypass valve controls to ensure chillers operate at minimum flow rate*

**Condenser water pump**

*Describe the parameters used to control condenser water pumps*

*e.g. modulate to maintain condenser water differential temperature set point or gpm/ton and the set-point(s).*

**Cooling tower**

*Describe the parameters used to control cooling towers*

*e.g. Modulate based on cooling tower approach temperature (difference between CT leaving water temperature and ambient wet-bulb temperature) set point (adjustable), or scheduled cooling tower leaving temperature set point, or dynamic optimized cooling tower leaving water temperature set point and the set-point(s)*

**Other optimisation**

*Describe any other optimisation used*

*e.g. Chilled water supply temperature reset. At off-peak period, reset based on outdoor air temperature/humidity, or VPF bypass control, or predefined schedule.*

*(Note: Resetting CHW temperature may incur higher pump power and may compromise on space temperature and relative humidity)*

## Chiller System Performance Analysis (1 week data)

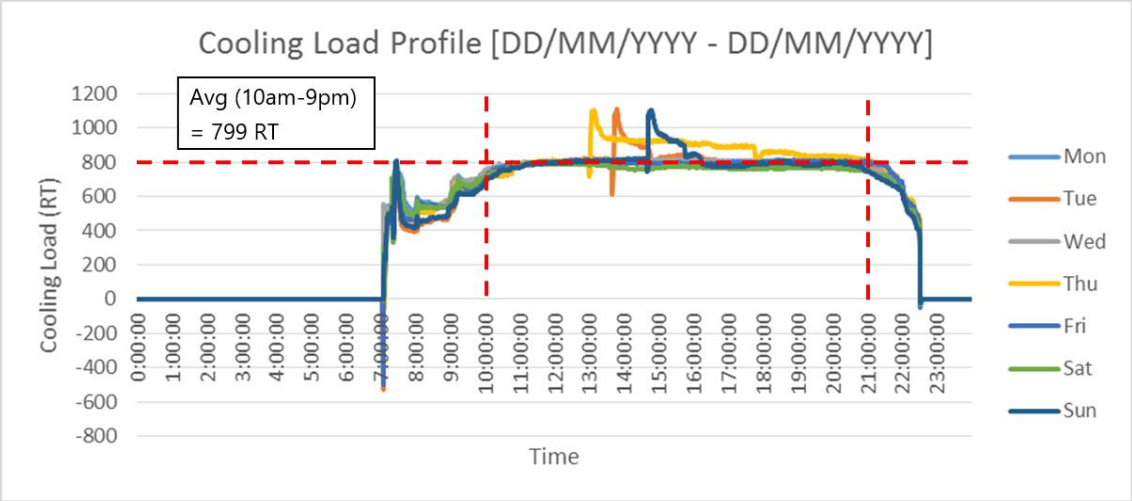



**Figure 1: Super-imposed plot of 24 hr Cooling Load Profile RT (Example)**

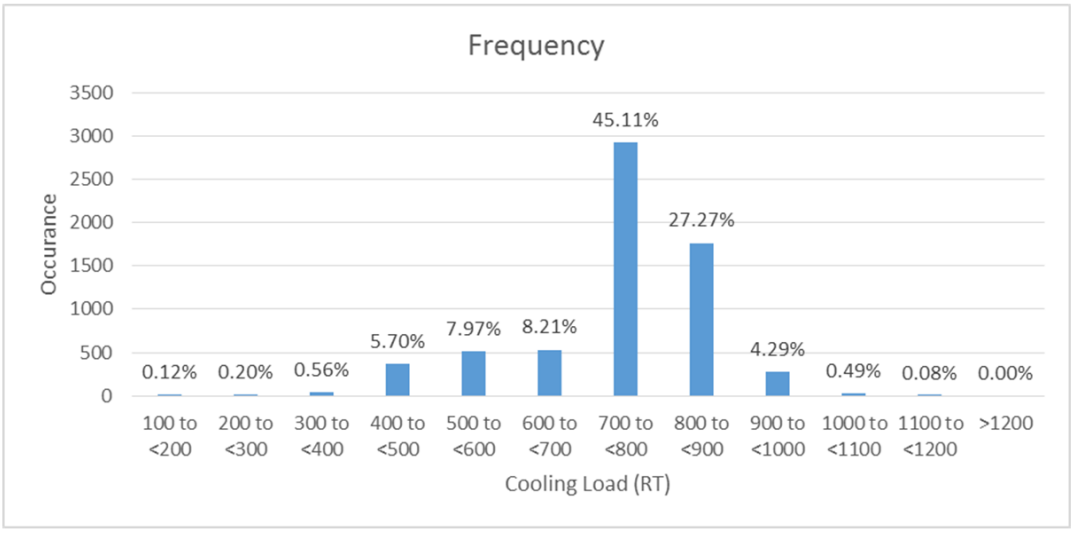



**Figure 2: Histogram of Cooling Load Occurrences (Example)**

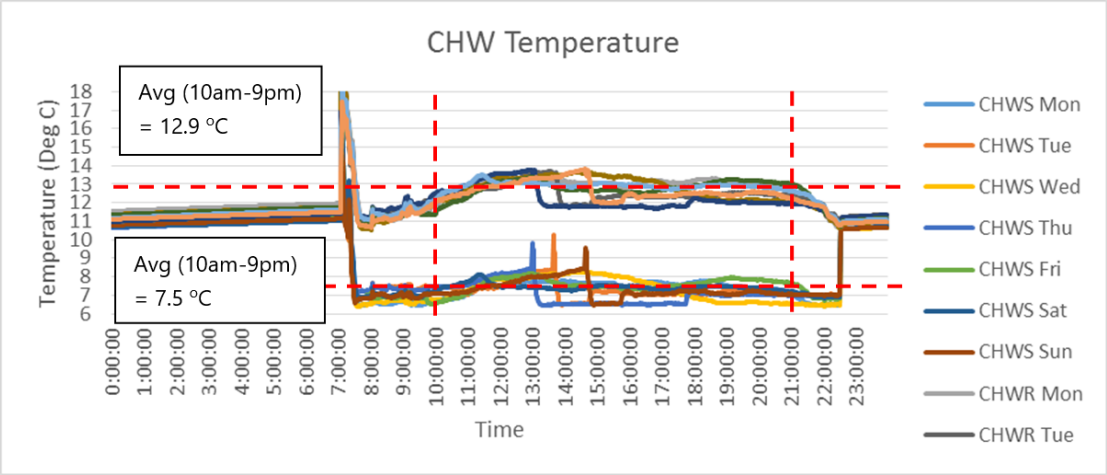



**Figure 3: Super-imposed plot of daily chilled water supply/return temperature °C (Example)**

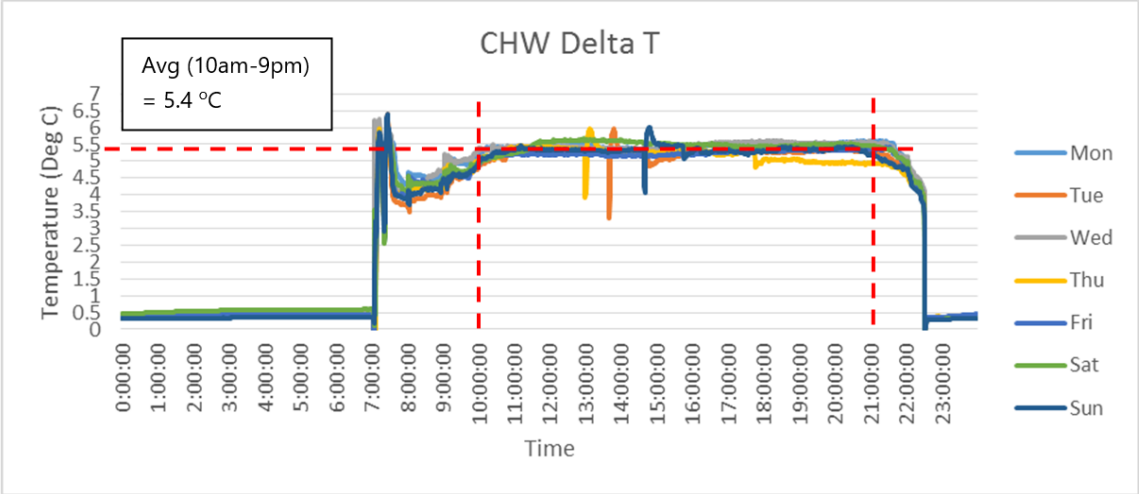



**Figure 4: Super-imposed plot of daily chilled water temperature difference °C (Example)**

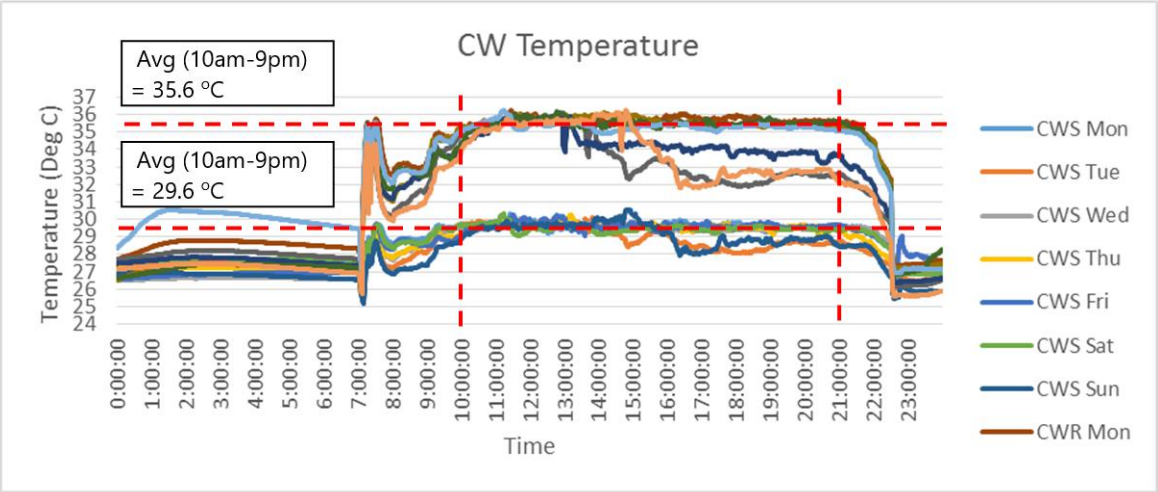



Figure 5: Super-imposed plot of daily condenser water supply/return temperature °C (Example)

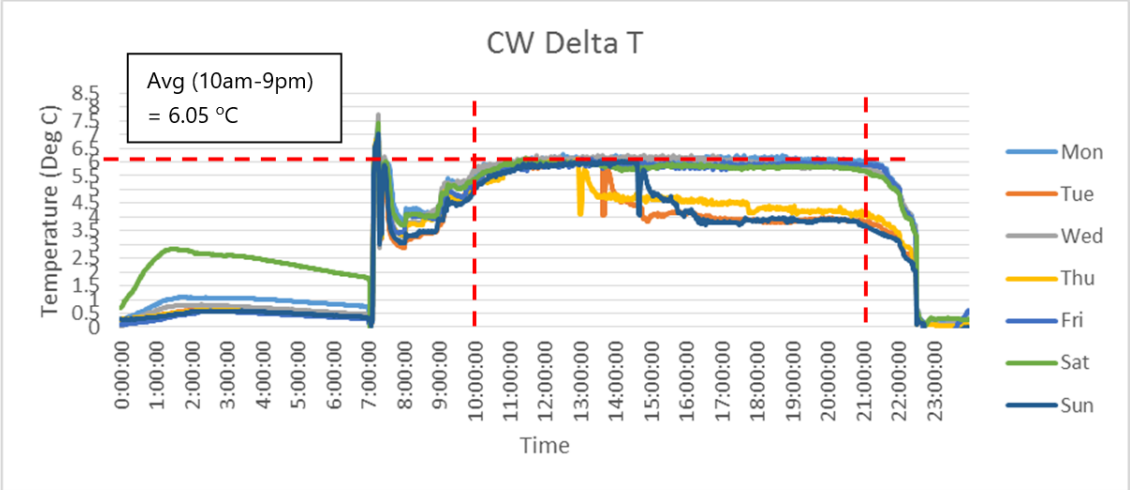



Figure 6: Super-imposed plot of daily condenser water temperature difference °C (Example)

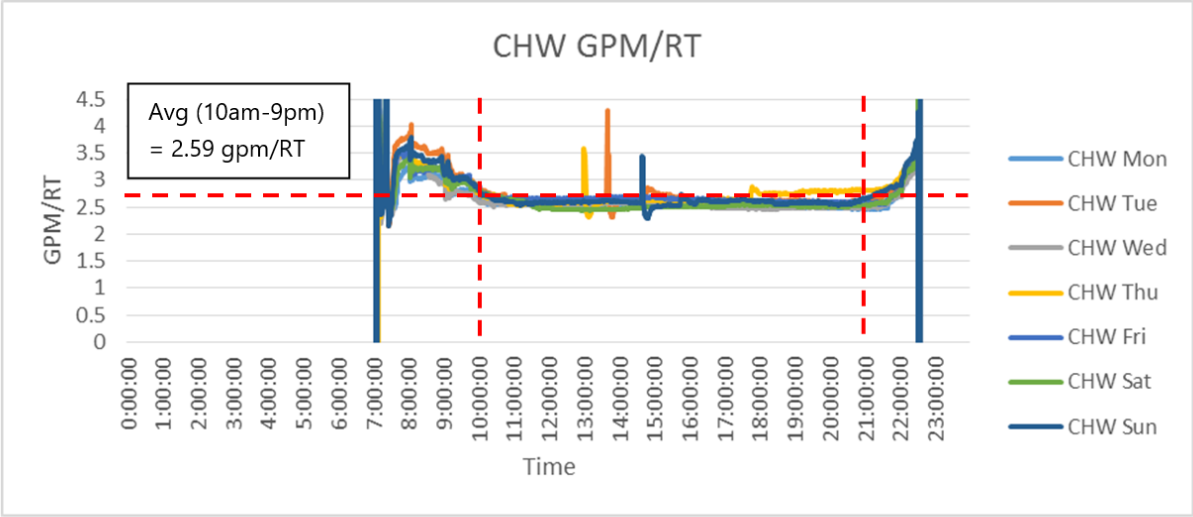



**Figure 7: Super-imposed plot of daily chilled water GPM/RT (Example)**

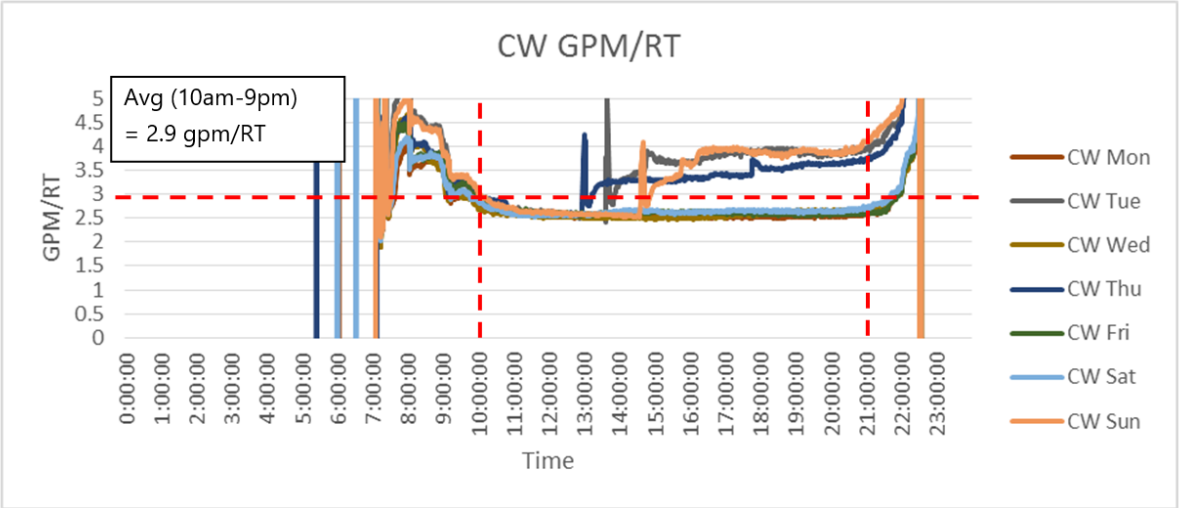



**Figure 8: Super-imposed plot of daily condenser water GPM/RT (Example)**

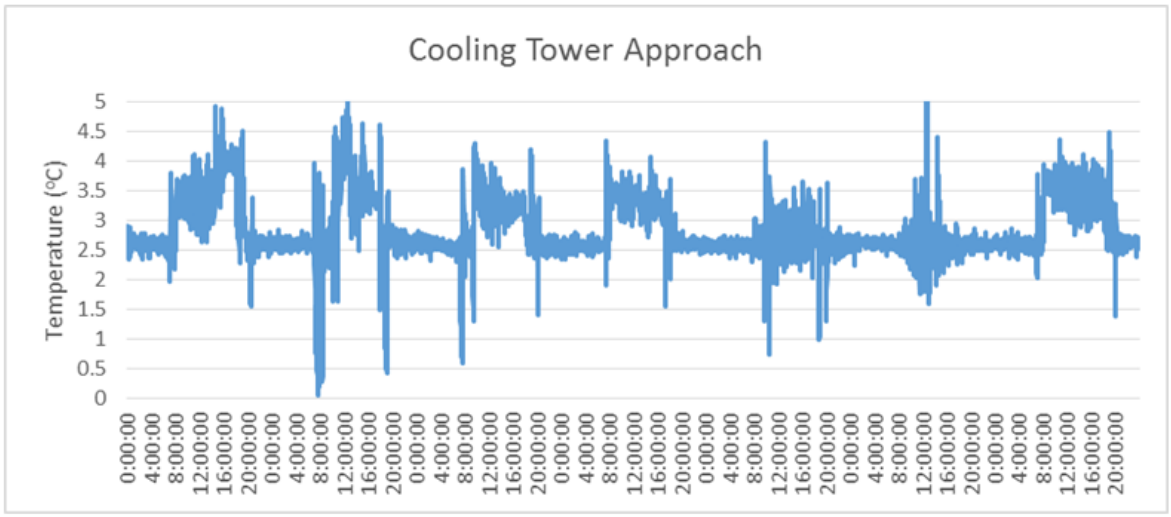



***Figure 9: Cooling Tower Approach Temperature (Example)**

*This is required if using wet bulb temperature as set point

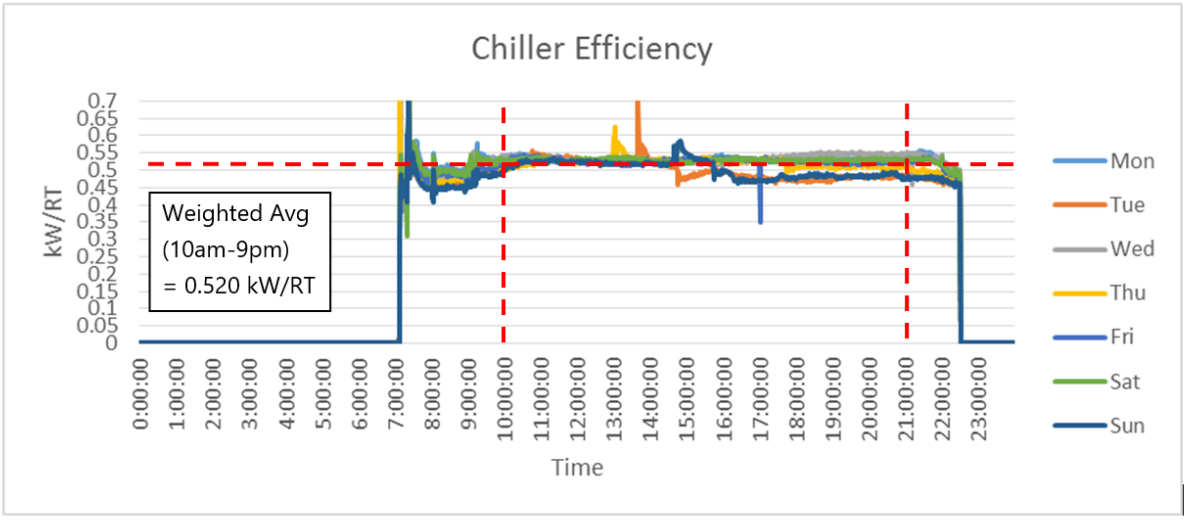



**Figure 10: Super-imposed plot of daily chiller efficiency kW/RT (Example)**

**Note : Weighted average = ∑ kW-hr / ∑ RT-hr**

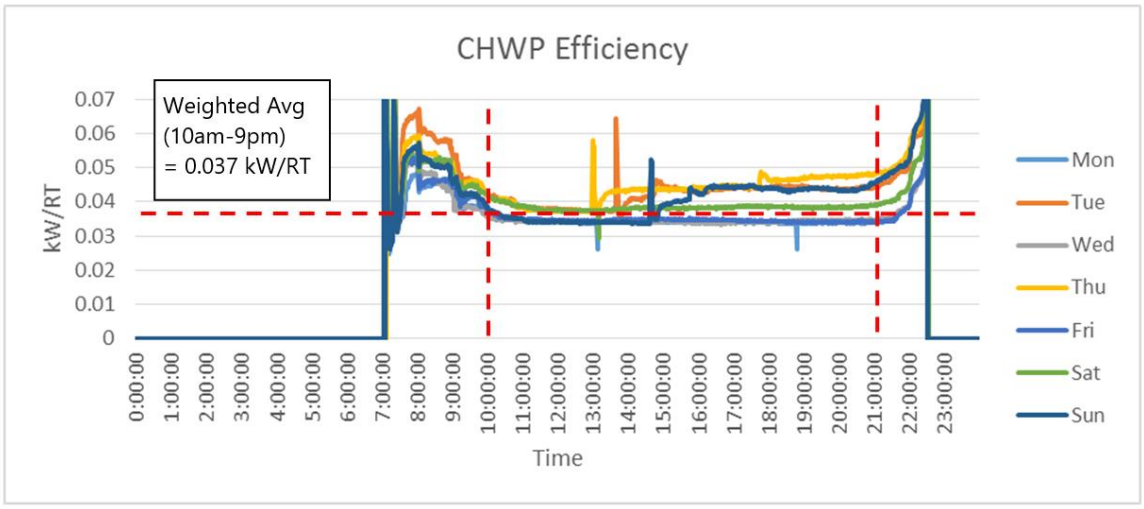



Figure 11: Super-imposed plot of daily chilled water pump efficiency kW/RT (Example)

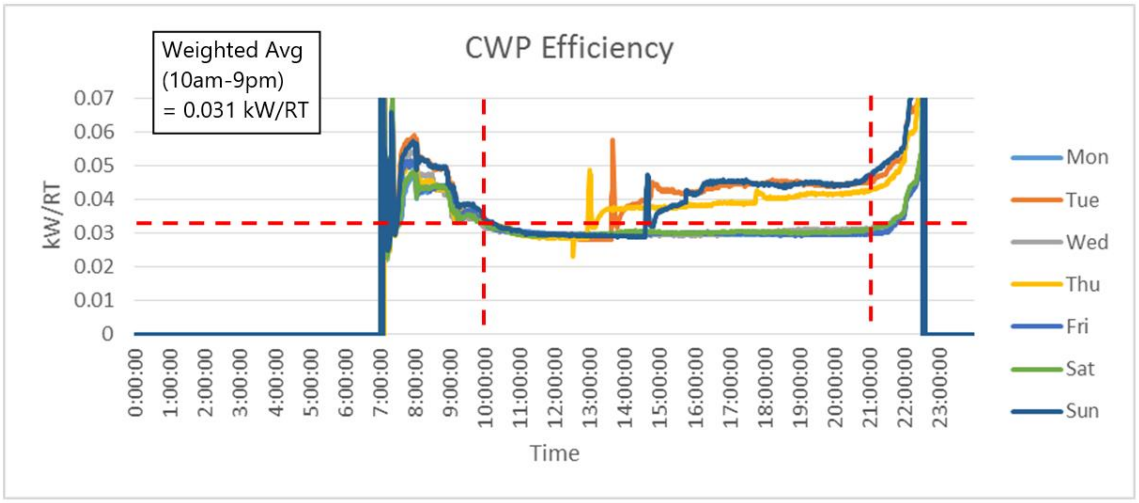



Figure 12: Super-imposed plot of daily condenser water pump efficiency kW/RT (Example)

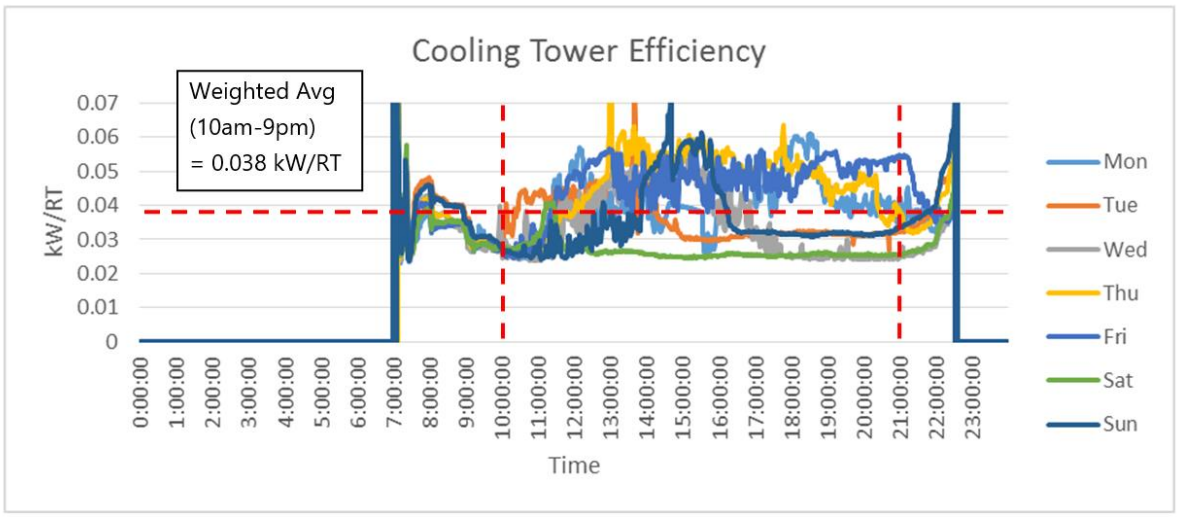



Figure 13: Super-imposed plot of daily cooling tower efficiency kW/RT (Example)

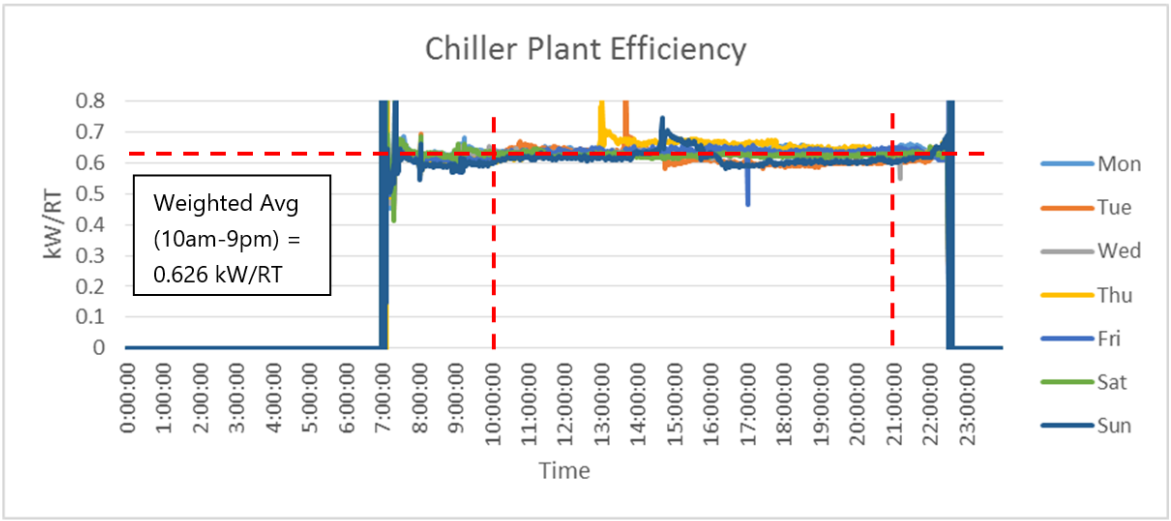



Figure 14: Super-imposed plot of daily chiller plant system efficiency kW/RT (Example)

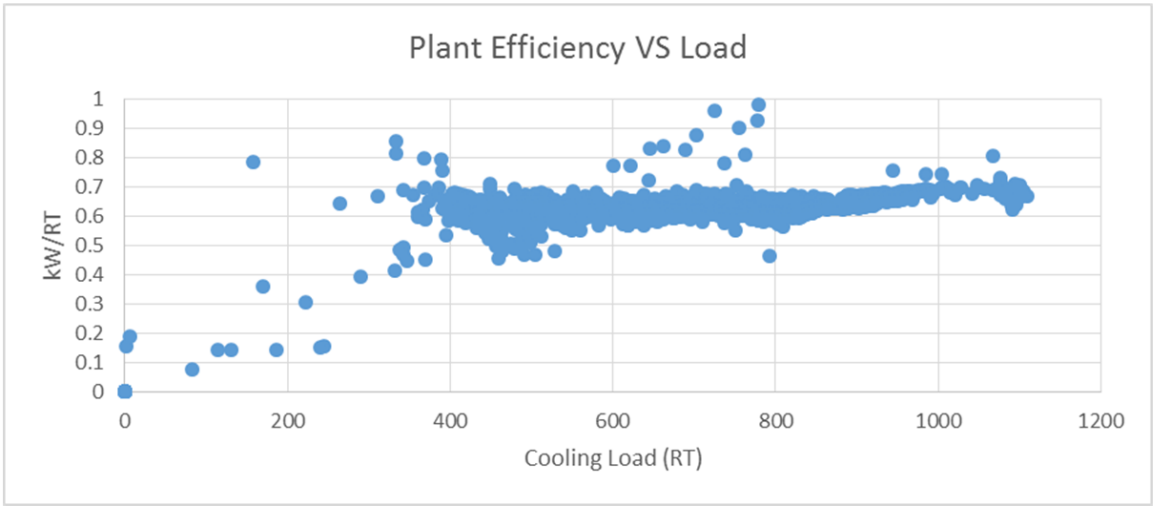



Figure 15: Scatter plot of chiller plant efficiency over cooling load (Example)

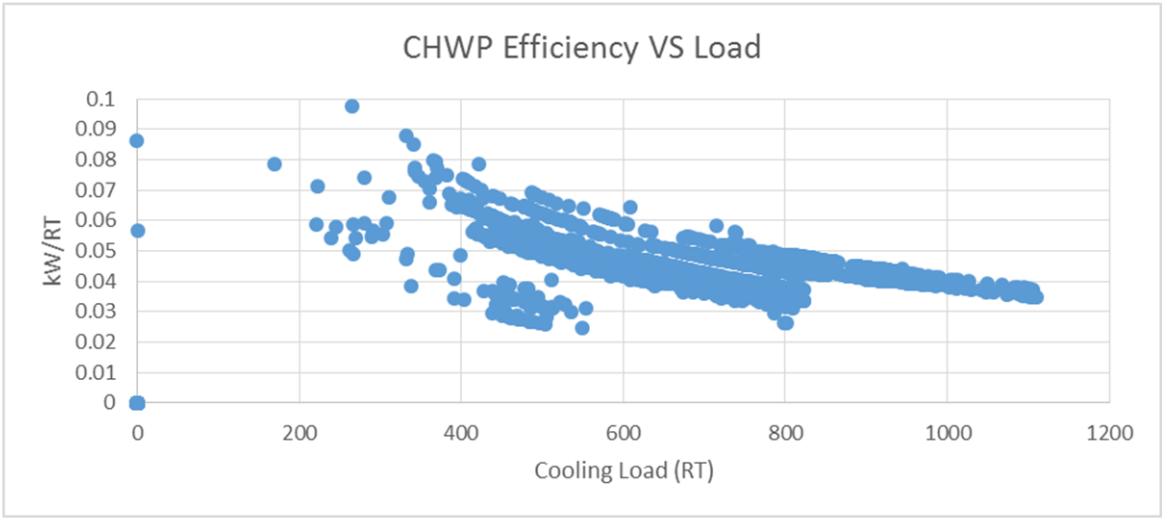



Figure 16: Scatter plot of chilled water pump efficiency over cooling load (Example)

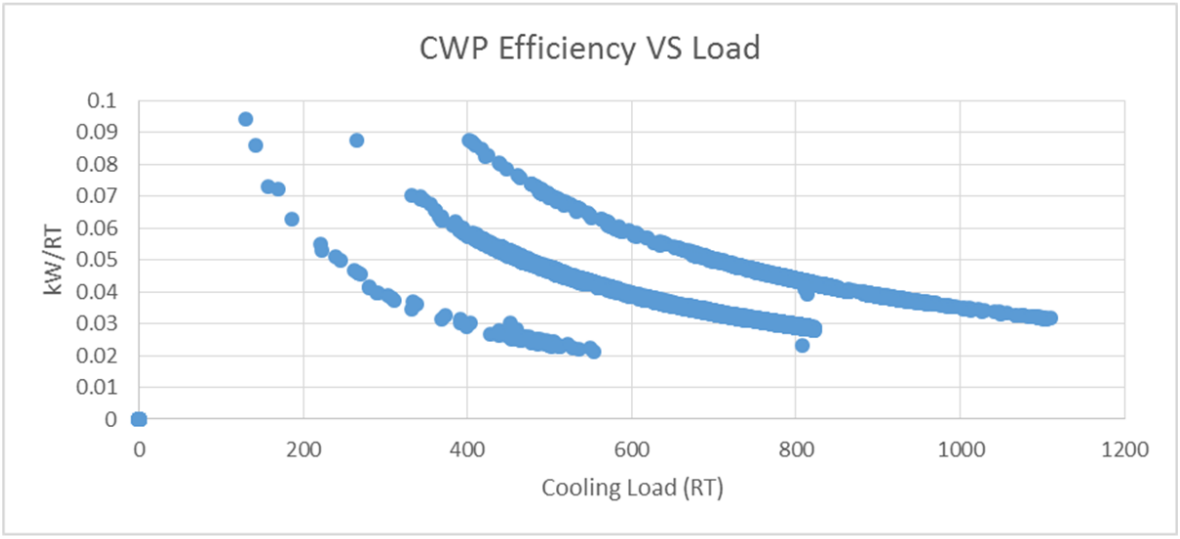



Figure 17: Scatter plot of condenser water pump efficiency over cooling load (Example)

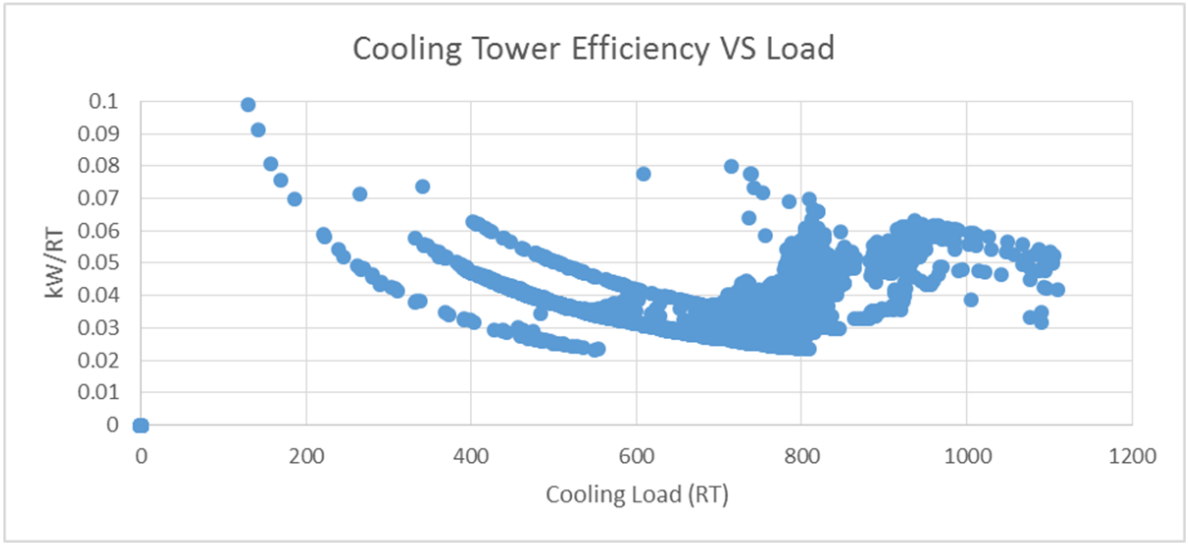



Figure 18: Scatter plot of cooling tower efficiency over cooling load (Example)

## Chilled Water System Operating Performance

The following data and performance indicators are to be provided:

| Daily Average Reading | Period | | Unit |
|---|---|---|---|
| | Day-time | Night-time | |
| Cooling Load | | | RTh |
| Cooling Load Density (Air-con area) | | | $m^2$/RT |
| Power Consumption | | | kWh |
| Chilled water supply temperature | | | $^oC$ |
| Chilled water return temperature | | | $^oC$ |
| Chilled water delta T | | | $^oC$ |
| Chilled water flow rate | | | l/s |
| Chilled water flow rate vs cooling load | | | USgpm/RT |
| *Condenser heat rejection | | | HRT |
| *Condenser water supply temperature | | | $^oC$ |
| *Condenser water return temperature | | | $^oC$ |
| *Condenser water delta T | | | $^oC$ |
| *Condenser water flow rate | | | l/s |
| *Condenser water flow rate vs cooling load | | | USgpm/RT |
| Chiller(s) efficiency | | | kW/RT |
| Chilled water pump(s) efficiency | | | kW/RT |
| *Condenser water pump(s) efficiency | | | kW/RT |
| *Cooling tower(s) efficiency | | | kW/RT |
| Overall chilled water system efficiency | | | kW/RT |

Note :

(1) The data in relation condenser pumps and cooling towers will not be applicable for air-cooled chilled water system.

(2) For comparison with the prevailing energy efficiency standard set, the energy performance can be determined based on the following operating hours for the different building typologies.

| Building Type | Operating Hours |
|---|---|
| Office Building | Monday to Friday: 9a.m. to 6p.m. |
| Retail Malls | Monday to Sunday: 10a.m. to 9p.m. |
| Hotels/Hospital | Monday to Sunday: 24 hours |
| Other buildings | Building specific operating hours |

The energy performance for the off-peak period or night-time should be considered if the cooling load demands are significant and presents opportunities to reduce energy consumption.

**Building Name :** Example Building

**(G) Energy Efficiency of Building Cooling System – Cont'd**

**Air Distribution System**

**Measurement of Air Distribution System Energy Efficiency**

**Air Handling Units (AHUs)**

| | |
|---|---|
| **Sample size** | Minimum of 5 no. of AHUs or 10% of the total number of AHUs, whichever is higher (Cap at 10 no.) |
| **Measurement Duration** | For BMS/EMS integrated systems: 1 week logging period at 5 min interval<br>For systems that are not linked to BMS/EMS systems: Spot measurement or via VSD with 1 day logging period at 5-min interval |

**Individual Air Handling Unit (AHU) Operating Performance**

The following data and performance indicators are to be provided:

| Parameters | Units | Measurement Approach | Compliance level |
|---|---|---|---|
| Rated Power | kW | Nameplate | Required |
| Rated Capacity | kW (RT) | Nameplate | Required |
| Operating Cooling Load | RT | Trend data from BMS/ EMS or Computation | Required |
| Input Power | kW | Trend data from BMS/ EMS /VSD or Spot measurement | Required |
| Off Coil Air Temp, RH | °C, % | Spot measurement | Required |
| On Coil Air Temp, RH | °C, % | Spot measurement | Required |
| Space Air Temp, RH, $CO_2$ | °C , % , ppm | Spot measurement | Required |
| CHWS Temp | °C | Trend data from BMS/EMS or onsite measurement | Recommended |
| CHWR Temp | °C | Trend data from BMS/EMS or onsite measurement | Recommended |
| CHW Flow | l/s or GPM | Trend data from BMS/EMS or onsite measurement | Recommended |
| Filter Area | $m^2$ | Site measurement or technical specification | Required if no trend data for Air flow rate |
| Air Velocity | m/s | Spot measurement | |
| Air Flow Rate | CMH | Trend data from BMS/EMS or Computation | Required |
| Outside Air Velocity | m/s | Spot measurement | Recommended |
| Outside Air Flow Rate | CMH | Computation | Recommended |
| Outside Air Ventilation Rate | $CMH/m^2$ | Computation | Recommended |
| Fan Efficiency | W/CMH | Computation | Required |
| Air Handling Unit (AHU) Efficiency | kW/RT | Trend data from BMS/ EMS or Computation | Required |

Cont'd

| Parameters | Units | Measurement Approach | Compliance level |
|---|---|---|---|
| Differential pressure across filter | Pa | Spot measurement | Recommended |
| Differential pressure across cooling coil | Pa | Spot measurement | Recommended |
| External Static Pressure | Pa | Spot measurement | Recommended |

**Fan Coil Units (FCUs)**

| | |
|---|---|
| **Sample size** | Minimum of 10% of the total number of FCUs |
| **Duration** | For BMS/EMS integrated systems: Logged data for 1 week at 5 min interval<br>For systems that are not linked to BMS/EMS systems : Spot measurement or equipment nameplate |

**Individual Fan Coil Unit (FCU) Operating Performance**

| Parameters | Units | Measurement Approach | Compliance level |
|---|---|---|---|
| Rated Power | kW | Nameplate | Required |
| Rated Capacity | kW (RT) | Nameplate | Required |
| Input Power | kW | Trend data from BMS/EMS or Computation | Required |
| Space Air Temp, RH, $CO_2$ | °C , % , ppm | Spot measurement | Required |
| Fan Efficiency | W/CMH | Computation | Required |
| Fan Coil Unit (FCU) Efficiency | kW/RT | Trend data from BMS/ EMS or Computation | Required |

**Overall Air Distribution System Operating Performance at Building Level**

Summary of Air Distribution System Operating Performance

| Air Distribution System | No. | ∑ Power consumption | Unit |
|---|---|---|---|
| Pre-AHUs | | | kWh |
| AHUs | | | kWh |
| FCUs (nameplate or input power x operation hrs) | | | kWh |
| (A) Total power consumption from all AHUs and FCUs | - | | kWh |
| (B) Chilled water system cooling load | - | | RTh |
| Overall air distribution system efficiency, $\eta_{a\ (Overall)}$ (A/B) | - | | kW/RT |

**Building Name :** Example Building

## (G) Energy Efficiency of Building Cooling System – Cont'd

### Total System Efficiency (TSE) of Building Cooling System

Total System Efficiency (TSE) of building cooling system is the combined system efficiency of the chiller water system (comprising chillers, pumps, cooling towers) and the air distribution system (comprising air handling system such as AHUs, FCUs etc). The following two tables illustrate the information required to be submitted showing the derivation of the TSE of the building cooling system during building operation and audit duration. The tables are to be read in conjunction with each other.

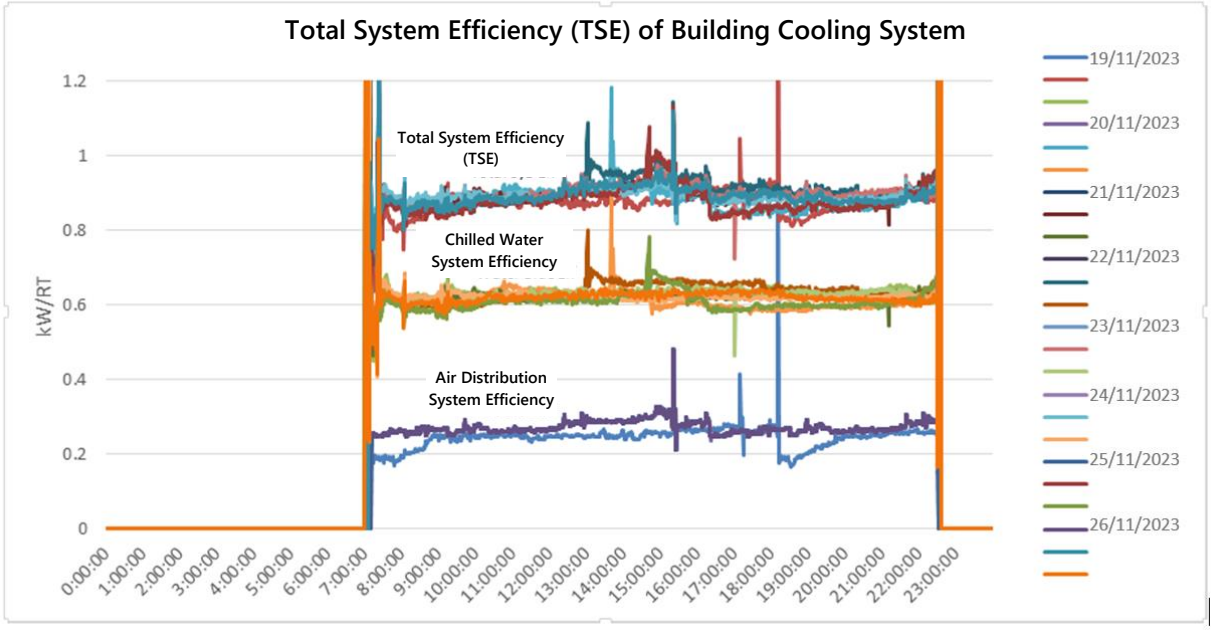
| Chilled Water System | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Cooling Load (RT) | No. of Chiller(s) in operation | Chiller(s) power input (kW) | No. of Chilled Water Pump(s) in operation | CHWP Power Input (kW) | No. of Condenser Water Pump(s) in operation | Condenser water pump(s) power input (kW) | No. of Cooling Tower(s) in operation | Cooling Tower(s) power input (kW) | Total Chilled Water System Power Input (kW) | Chilled Water System Efficiency (kW/RT) |
| | (A) | | (B) | | (C) | | (D) | | (E) | (F)=(B)+(C) + (D) + (E) | (G) = (F)/(A) |
| 9:00 | | | | | | | | | | | |
| 10:00 | | | | | | | | | | | |
| 11:00 | | | | | | | | | | | |
| 12:00 | | | | | | | | | | | |
| 13:00 | | | | | | | | | | | |
| 14:00 | | | | | | | | | | | |
| 15:00 | | | | | | | | | | | |
| 16:00 | | | | | | | | | | | |
| 17:00 | | | | | | | | | | | |
| 18:00 | | | | | | | | | | | |
| ... | | | | | | | | | | | |

| Air Distribution System | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | Please state the Configuration of Air Distribution System (FCU, PAU, AHU (CAV,VAV) etc. | Total CAV AHU Motor Input Power (kW) | Total VAV AHU Motor Input Power (kW) | Total FCU Motor Nameplate Input Power (kW) | Total Air Handling /Distribution System Motor Input Power (kW) | Air Handling/ Distribution System Efficiency (kW/RT) | Total Power Input (kW) | Total System Efficiency of Building Cooling System (kW/RT) |
| | | (H) | (I) | (J) | (K)=(H)+(I)+(J) | (L)=(K)/(A) | (M)=(F)+(L) | (M)/(A) |
| 9:00 | | | | | | | | |
| 10:00 | | | | | | | | |
| 11:00 | | | | | | | | |
| 12:00 | | | | | | | | |
| 13:00 | | | | | | | | |
| 14:00 | | | | | | | | |
| 15:00 | | | | | | | | |
| 16:00 | | | | | | | | |
| 17:00 | | | | | | | | |
| 18:00 | | | | | | | | |
| ... | | | | | | | | |
| | | | | | | | | |

## Total System Efficiency (TSE) of Building Cooling System – Cont'd

Summary of Building Cooling System Operating Performance

Example of super-imposed plot of daily Total System Efficiency (kW/RT)




| Daily Average Reading | Period | | Unit |
|---|---|---|---|
| | Day-time | Night-time | |
| **Air Distribution System Efficiency** | | | kW/RT |
| **Chilled Water Plant/System Efficiency** | | | kW/RT |
| **Total System Efficiency (TSE) of Building Cooling System** | | | kW/RT |

Note : For the comparison with the prevailing energy efficiency standard set, the energy performance can be determined based on the following operating hours for the different building typologies.

| Building Type | Operating Hours |
|---|---|
| Office Building | Monday to Friday: 9a.m. to 6p.m. |
| Retail Malls | Monday to Sunday: 10a.m. to 9p.m. |
| Hotels/Hospital | Monday to Sunday: 24 hours |
| Other buildings | Building specific operating hours |

The energy performance for the off-peak period or night-time should be considered if the cooling load demands are significant and presents opportunities to reduce energy consumption.

**Building Name :** Example Building

**(G) Energy Efficiency of Building Cooling System – Cont'd**

**Unitary Air-conditioning Systems**

**Determination of the Energy Efficiency of Unitary Air-Conditioning System**

Unitary Air-Conditioners (Single or combination of systems)

- Variable Refrigerant Flow (VRF) system
- Single-Split Units
- Multi-Split Units
- Air-Distribution System

For VRF system with built-in monitoring capabilities for energy efficiency

Energy efficiency data can be collected from the VRF system's built-in monitoring tools over a 1-week period for all operating hours of the system.

For other VRF system, single-split and multi-split unitary air conditioners

Based on the system's specifications, age, and typical operational patterns to estimate the current energy efficiency of the VRF system to obtain a general gauge of energy performance with due consideration of factors such as maintenance records, actual usage patterns, and site constraints that may influence the actual efficiency.

For consistency, the system energy efficiency can be derived based on the concept of Integrated Energy Efficiency Ratio (IEER), which would consider the different load capacities with due consideration for part-load conditions. However, this could be adjusted based on audit findings of the actual operating conditions to better reflect the energy performance of the system.

| **VRF System** | **Single-split and Multi-split Unitary Air Conditioners** |
|---|---|
| IEER = (0.020 x A) + (0.617 x B) + (0.238 x C) + (0.125 x D)<br><br>where<br>A = EER or COP at full load<br>B = EER or COP at 75% load<br>C = EER or COP at 50% load<br>D = EER or COP at 25% load | $COP_{weighted} = 0.4 \times COP_{100\%} + 0.6 \times COP_{50\%}$<br><br>where<br>*$COP_{100\%}$ is defined as the ratio of the cooling capacity to effective power input at full load cooling capacity*<br>*$COP_{50\%}$ is defined as the ratio of the cooling capacity to effective power input at 50% cooling capacity* |

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:

| | |
|---|---|
| **Energy efficiency of unitary air-conditioning system** | $EE_{Weighted}$ (in kW/RT) = $\dfrac{3.517/\ \sum(\text{Cooling Capacity} \times \text{IEER or } COP_{weighted})_i}{\text{Total Cooling Capacity}_{overall}}$ |

## Determination of the Energy Efficiency of Unitary Air-Conditioning System – Cont'd

Example of determining the Total System Efficiency of VRF system

*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 | | | | | | $IEER_i$ (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<br>Lift lobby Corridor<br>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, $\eta_{c\ (Overall)}$ (kW/RT) will be as follows :

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

$$= 3.517 / \left( \frac{(14.18 \times 6.16) + (28.36 \times 5.96) \times 3}{99.26} \right) = 0.608 \text{ kW/RT}$$

If site deration factor is about 10%, corrected $\eta_{c\ (Overall)}$ = 0.608 x 1.1 = 0.668 kW/RT

*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 $\eta_a$ 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 | – |

## Determination of the Energy Efficiency of Unitary Air-Conditioning System – Cont'd

*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 :

$$\eta_{a\ (Overall)}\ (\text{in kW/RT}) = \left( \frac{\sum (\text{Cooling capacity} \times \eta_a)_i}{\text{Total Cooling Capacity}_{(Overall)}} \right)$$

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

$$= 0.324 \text{ kW/RT}$$

*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

For simplicity, the system efficiency of the VAV-AHUs derived was assumed to be at full load condition similar to that for FCUs. To have a better estimate for the energy consumption for 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.

**Building Name** : Example Building

### (H) Schedule of Space Operating Condition

Other than the energy efficiency of building cooling system, there should have checks on the space operating conditions and thermal comfort by having a minimum of 10 spot measurements of indoor air conditions – dry bulb temperature, relative humidity and carbon dioxide concentration. Any observation on over-cooling/ under-cooling or inadequate ventilation should be highlighted to building owner for further assessment. An example of space condition schedule to be provided is as follows:

| Room name (i.e. Air conditioned occupied/ common Spaces) | | Normal operating room conditions | | Measured | | |
|---|---|---|---|---|---|---|
| | | Dry Bulb Temperature (°C) | Relative Humidity (%) | *Dry Bulb Temperature (°C) | *Relative Humidity (%) | *$CO_2$ Concentration (ppm) |
| 1 | i.e. Office 1 | | | | | |
| 2 | i.e. Office 2 | | | | | |
| 3 | i.e. Meeting Room 1 | | | | | |
| 4 | i.e. Meeting Room 2 | | | | | |
| 5 | …… | | | | | |
| 6 | ……. | | | | | |
| 7 | ……. | | | | | |

**Building Name :** Example Building

**(I) Key Findings and Potential Energy Efficiency Improvement Measures**

The key findings are to be provided and should be presented in a clear and concise manner providing the observation and context. Some examples below for reference.

| **Audit Finding (1)** | |
|---|---|
| **Focus Area** | Chilled water system efficiency |
| **Key Observations** | (a) Two 500-ton centrifugal chillers of about 10 years old<br>(b) Serving a 25,000 $m^2$ office complex<br>(c) Current chilled water system efficiency : 0.85 kW/RT<br>(d) Industry benchmark: 0.60 kW/ton for similar systems<br>(e) System is operating in bottom 30% of efficiency range<br>(f) Current chilled water system efficiency averages 0.85 kW/ton, about 30% below industry benchmark. Trend logs show frequent cycling at low loads and suboptimal sequencing. The main chillers are operating significantly below the designed efficiency levels, resulting in an estimate increase in energy consumption and operating costs by 30%. It was observed to have some potential issues with maintenance, control settings, and component degradation. |
| **Potential Measures** | (1) Conduct a comprehensive maintenance, including tube cleaning, refrigerant charge optimisation.<br>(2) Chiller system optimisation, including upgrading control system for improved sequencing and load management.<br>(3) Complement with installation of smaller capacity chiller to cater to low load conditions |
| **Audit Finding (2)** | |
| **Focus Area** | **Air Distribution System Operation** |
| **Key Observations** | (a) Existing AC fan motors in the AHUs are standard efficiency type, operating at constant speed regardless of load variations though they are equipped with VSDs. There are some signs of aging with reduced efficiency. Current fan system efficiency is below optimal levels, with higher energy consumption and maintenance requirements.<br>(b) The supply air temperature setpoint remains constant at 13°C regardless of building load conditions.<br>(c) Dirty cooling coils and blocked filters causing reduced heat transfer and increased fan power. |
| **Potential Measures** | (1) Optimise existing system:<br>• Implement proper VSD control strategies based on demand<br>• Service/repair existing motors and drives<br>• Review and calibrate pressure sensors<br>• Commission proper control sequences<br>(2) Consideration to replace existing AC motors with electronically commutated (EC) fans which come with higher motor efficiency (about 30% energy savings compared to AC motors) and better part-load performance<br>(3) Establish regular cleaning schedule and preventive maintenance programme for cooling coils along with filter differential pressure monitoring. |

| **Audit Finding (3)** | |
|---|---|
| **Focus Area** | **Lighting system efficiency and use** |
| Key Observations | (a) Current lighting using T8 fluorescent tubes (32 W) with magnetic ballasts for all office spaces of 20,000 $m^2$<br>(b) No occupancy sensors or daylight harvesting systems<br>(c) Lighting accounts for 15% of the total building energy consumption<br>(d) Current lighting system operates at an average efficacy of 60 lumens/watt, significantly below modern standards. Light level measurements show over-illumination in 50% of the office space, with an average of 650 lux at desk level. Energy monitoring reveals that 30% of lighting energy is consumed outside of standard operating hours. Estimated annual lighting energy consumption: 1,200,000 kWh Calculated lighting power density: 12 $W/m^2$, compared to best practice of 5-7 $W/m^2$ |
| Potential Measures | (1) Replace existing fixtures with LED panels (efficacy >120 lumens/watt)<br>(2) Install occupancy sensors in less frequently accessed areas<br>(3) Use time scheduling for open office areas, with manual override capability<br>(4) Integrate lighting control with the building management system upgrade |
| **Audit Finding (4)** | |
| **Focus Area** | **Carpark ventilation system** |
| Key Observations | (a) Conventional carpark ventilation system for all zones.<br>(b) It was observed that the carpark ventilation system is operating at full speed with fixed air changes per hour. It is expected to have higher energy consumption due to constant operation. |
| Potential Measures | (1) Upgrade to facilitate demand-controlled ventilation with CO sensors to monitor the air quality and modulate the fan speeds of the supply and exhaust fans based on CO level<br>(2) Reduction in energy consumption by way of operational scheduling. For e.g. to align ventilation with peak usage patterns, to reduce ventilation during low occupancy period and have such interface with carpark management system to facilitate such monitoring. |
| **Audit Finding (5)** | |
| **Focus** | **Excessive air leakage via door openings at entrance A & B** |
| Key Observations | (a) Door openings and lobby areas leading to building XYZ are not enclosed.<br>(b) Excessive infiltration of hot/humid outdoor air and loss of conditioned air was observed. This may have attributed to higher cooling load and energy consumption. |
| Potential Measures | (1) Adjustment of pressure control by optimising the AHU settings for proper pressurisation and balance the air distribution.<br>(2) Install automated self-closing doors to minimise excessive air leakage |

**Building Name :** Example Building

**(I) Key Findings and Potential Energy Efficiency Improvement Measures – Cont'd**

| **Audit Finding (6)** | |
|---|---|
| **Focus Area** | **Centralised hot water system operation (electric boilers)** |
| **Key Observations** | (a) The hot water system was operating on a high operating temperature (65°C) maintained throughout the day regardless of demand.<br>(b) Circulation pumps operating at constant speed 24/7<br>(c) Significant heat loss from poorly insulated distribution pipes |
| **Potential Measures** | (1) System Optimisation by implementing demand-based temperature control.<br>(2) Install VSD for circulation pumps and demand-based circulation control<br>(3) Improve on system insulation<br>(4) Replace with high efficiency boiler<br>(5) Tap on heat recovery from chiller condensers |
| **Audit Finding (7)** | |
| **Focus Area** | **Partnership with Tenants and Users** |
| **Key Observations** | (a) Lack of structured tenant/user engagement in reducing energy consumption.<br>(b) Energy saving efforts are fragmented, with no clear framework for tenant participation or incentives for energy-saving behaviors |
| **Potential Measures** | (1) Energy performance requirements in lease agreements<br>(2) Guidelines for fit out works<br>(3) Protocol for air-conditioning usage during off-peak hours<br>(4) Cost-sharing mechanism for energy efficiency improvements<br>(5) Tenant energy management programme<br>(6) Performance-linked rental rebates |

**Summary List of Potential Energy Efficiency Improvement Measures and Selection**

A summary list of all potential measures shall be tabulated in the format shown in the following table. For each measure, indicate:

- The system or initiative involved
- Energy saving potential (at system and building level)
- Potential cost range

For simplicity, the energy saving potential and likely implementation cost shall be classified as High, Medium, or Low, with ranges clearly defined by the specified individual in consultation with the building owner. Key assumptions and relevant factors shall be included where necessary for clarity.

| **Summary List of Potential Energy Efficiency Improvement Measures and Selection** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **S/No.** | **List of Potential Measures** | **Building System/ Initiative** | **Energy Saving Potential (High/Medium/Low)** | | **Potential Cost (High/Medium/Low)** | **Selection (Y/N)** | **Remarks** |
| | | | **System Level** | **Building Level** | | | |
| | | | | | | | |
| | | | | | | | |

Note that the energy saving potential at system level refer to the % savings specific to the system being modified and the energy saving potential at building level refer to the % savings relative to the total building energy consumption.

**Building Name :** Example Building

**(I) Key Findings and Potential Energy Efficiency Improvement Measures – Cont'd**

Example of a summary list of potential measures and selection :

**Summary List of Potential Measures and Selection (example)**

| S/No. | List of Potential Measures | Building System/ Initiative | Energy Saving Potential (High/Medium/Low) | | Potential Cost (High/ Medium/ Low) | Selection (Y/N) | Remarks/ Reasons (if not implementing) |
|---|---|---|---|---|---|---|---|
| | | | System Level | Building Level | | | |
| 1 | Conduct comprehensive maintenance including tube cleaning and refrigerant charge optimisation | Chiller system | Low | Low | Low | Yes | |
| 2 | Chiller optimisation including upgrading of control system | Chiller system | High | High | Medium | Yes | |
| 3 | Installation of smaller capacity chiller | Chiller system | High | High | High | Yes | |
| 4 | AHUs system optimisation | AHUs | Medium | Medium | Medium | Yes | |
| 5 | Replacement with EC fans | AHUs | High | Medium | Medium | No | To be considered at later stage as existing systems are within service life. |
| 6 | Regular cleaning schedule and preventive maintenance programme for cooling coils along with filter differential pressure monitoring | AHUs | Low | Low | Low | Yes | |
| 7 | Replacement of existing fixtures with LED panels | Lighting system | Low | Low | Low | Yes | |
| 8 | Install occupancy sensors in less frequently accessed areas | Lighting system | Low | Low | Low | Yes | |
| 9 | Use time scheduling for open office areas, with manual override capability | Lighting system | Low | Low | Low | Yes | |
| 10 | Integrate lighting control with the building management system upgrade | Lighting system | Medium | Low | Medium | No | Incompatible existing lighting circuits/systems |

**Building Name :** Example Building

**(I) Key Findings and Potential Energy Efficiency Improvement Measures – Cont'd**

Example of a summary list of potential measures and selection – Cont'd

**Summary List of Potential Measures and Selection (example)**

| S/No. | List of Potential Measures | Building System/ Initiative | Energy Saving Potential (High/Medium/Low) | | Potential Cost (High/ Medium/ Low) | Selection (Y/N) | Remarks |
|---|---|---|---|---|---|---|---|
| | | | System Level | Building Level | | | |
| 11 | Upgrade with demand-controlled ventilation with CO sensors to monitor the air quality and modulate the fan speeds of the supply and exhaust fans based on CO level | Carpark ventilation System | Medium | Low | Medium | No | Limited BMS integration capability for carpark systems |
| 12 | Change operational scheduling by aligning ventilation with peak usage patterns, to reduce ventilation during low occupancy period | Carpark ventilation System | Medium | Low | Low | Yes | |
| 13 | Adjustment of pressure control by optimising the AHU settings for proper pressurisation and balance the air distribution. | AHUs in relation to air leakage | Medium | Low | Low | Yes | |
| 14 | Install automated self-closing doors to minimise excessive air leakage | Door provision | Medium | Low | Low | Yes | |
| 15 | System Optimisation by implementing demand-based temperature control. | Centralised hot water system | High | Medium | Medium | No | Plan for boiler replacement |
| 16 | Install VSD for circulation pumps and demand-based circulation control | Centralised hot water system | High | Medium | Medium | No | Plan for boiler replacement |
| 17 | Improve on existing hot water system insulation | Centralised hot water system | Low | Low | Low | No | Plan for boiler replacement |
| 18 | Replace with high efficiency heat pump | Centralised hot water system | High | High | High | Yes | |
| 19 | Tap on heat recovery from chiller condensers | Centralised hot water system | Medium | Medium | Medium | Yes | Complement boiler replacement |

**Building Name :** Example Building

**(I) Key Findings and Potential Energy Efficiency Improvement Measures – Cont'd**

Example of a summary list of potential measures and selection – Cont'd

| **Summary List of Potential Measures and Selection (example)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **S/No.** | **List of Potential Measures** | **Building System/ Initiative** | **Energy Saving Potential (High/Medium/Low)** | | **Potential Cost (High/ Medium/ Low)** | **Selection (Y/N)** | **Remarks** |
| | | | **System Level** | **Building Level** | | | |
| 20 | Energy performance requirements in lease agreements | Tenant partnership programme | NA | Medium | Low | Yes | Limit to new tenants or at lease renewal stage |
| 20 | Guidelines for fit out works to required energy efficient equipment | Tenant partnership programme | NA | Medium | Low | Yes | Limit to new tenants or at lease renewal stage |
| 21 | Protocol for air-conditioning usage during off-peak hours | Tenant partnership programme | NA | Low | Low | Yes | |
| 22 | Cost-sharing mechanism for energy efficiency improvements | Tenant partnership programme | NA | High | Medium | Yes | Subject to tenants' agreement to terms like energy data sharing |
| 23 | Tenant energy management programme | Tenant partnership programme | NA | Medium | Low | Yes | |
| 24 | Performance-linked rental rebates | Tenant partnership programme | High | High | Medium | No | Subject to tenants' agreement to terms like energy data sharing |

Please provide the basis on how the energy saving potential and implementation cost are classified as High, Medium, or Low. For e.g.

| **Energy Saving Potential (example)** | | **Potential Implementation Cost (example)** |
|---|---|---|
| **System Level** | **Building Level** | |
| High: > 20%<br>Medium: 5% to 20%<br>Low: <5 % | High: > 1%<br>Medium: 0.5% to 1%<br>Low: <0.5 % | High: > $1 million<br>Medium: $300,000 to $1 million<br>Low: < $ 300,000 |

Note : Please state the assumptions, factors considered and other relevant information where relevant.

## Part 2 Energy Efficiency Improvement Plan (EEIP)

- Feasibility assessment of EUI reduction
- Description of each recommended measures
- Expected energy savings and EUI reduction
- Implementation costs
- Simple payback period for each measure
- Implementation timeline

---

### Energy Efficiency Improvement Plan (EEIP)

Based on the potential measures evaluated in Part 1, the specified individual, in consultation with the building owner, shall develop an EEIP to address the feasibility of EUI reduction and provide detailed descriptions of recommended measures to be implemented over the stipulated period of 3 years. The plan shall include expected energy and cost savings, implementation costs, simple payback period, and a timeline for implementation.

### Feasibility Assessment of EUI Reduction

The specified individual is required to provide a written evaluation of whether the specified Energy Use Intensity (EUI) reduction can be achieved without major energy use change, specifically assessing if the target can be met without the installation, substantial alteration or replacement of the building cooling system.

If the specified EUI reduction of 10% cannot be achieved without major energy use change, please provide a detailed explanation including:

- The current constraints limiting the target 10% reduction in EUI from being met
- Recommendations on the necessary improvements to the cooling system to meet the target
- An estimate of the potential EUI reduction that could be achieved with these improvements.

### List of recommended measures for implementation

The recommendations provided can be broadly grouped in two categories :

(a) **Energy Reduction recommendation** which comprises measures that are not related to the installation, substantial alteration or replacement of the building cooling system such as

- Maintenance-related works, including:
  - replacement of faulty sensors
  - replacement of air filter
  - hot water system insulation
  - install occupancy sensors for areas with intermittent occupancy
  - tuning of equipment to ensure optimal performance and energy efficiency
- Chiller system optimisation
- Air distribution system performance improvement and optimisation
- Change of air-conditioned zones to naturally ventilated spaces
- Incentive, collaboration programmes between tenants and owner or green leasing initiatives which impose requirements for tenants to adopt energy efficient practices or equipment
- Conversion of spaces from full air-conditioning to hybrid cooling or natural ventilation
- Others

(b) **Capital Investment recommendation** which involves major energy use change and energy efficiency retrofits. For e.g.

- **System Replacements (Full/Partial)**
  - Chiller systems/components
  - AHUs and FCUs
  - Pumps
  - Lighting systems
  - Mechanical ventilation
  - Centralised hot water systems
- **New System Installations**
  - Additional chiller plant
  - Complementary systems to existing setup
  - Self-closing doors/Air curtain systems
- **Major System Upgrades**
  - Building management system overhaul
  - Control system upgrade

### Normative Information to be provided

Detailed description of each recommended measures must be provided along with the following details

- Proposed energy improvement measures to be implemented
- Building systems and initiatives to be addressed
- Electricity consumption before implementing the proposed measures.
- Expected electricity consumption after implementing the proposed measures
- Expected energy savings (in percentage and in kWh) and related cost savings.
- Estimated implementation cost and simple payback period
- Implementation timeline including expected time of implementation and completion

This information is to be provided in the tabulated form as shown below :

| S/No. | Proposed Energy Improvement Measures | Building Systems/ Initiatives | Annual Electricity Consumption and Cost Savings | | | | | Cost and Simple Payback Period | | Implementation Plan | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Electricity Consumption (before EEIP) (kWh) | Expected Electricity Consumption (after EEIP) (kWh) | Percentage Savings (%) | Electricity Savings (kWh) | Cost Savings ($) | Estimated Implementation Cost ($) | Simple Payback Period (Year) | Start Date | Estimated End Date |
| Energy Reduction Recommendations | | | | | | | | | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| Capital Investment Recommendations | | | | | | | | | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| | | | | | | | $ - | $ - | | | |
| Remarks : | | | ∑ kWh | ∑kWh | % | ∑kWh | $ - | $ - | | | |

Please provide parameters and documentation to support the energy and cost savings calculation including:

- Baseline data
- Calculation method
- Technical justification where relevant
- Implementation approach
- Verification approach to track results
- Electricity Tariff (cents/kWh)

An example of the tabulation is as shown below. Note that these two tables should be read in conjunction.

| S/No. | Proposed Energy Improvement Measures | Building Systems/ Initiatives | Annual Electricity Consumption and Cost Savings | | | | |
|---|---|---|---|---|---|---|---|
| | | | Electricity Consumption (before EEIP) | Expected Electricity Consumption (after EEIP) | Percentage Savings | Electricity Savings (kWh) | Cost Savings ($) |
| **Energy Reduction Recommendation** | | | | | | | |
| 1 | Conduct comprehensive maintenance including tube cleaning and refrigerant charge optimisation | Chiller system | | | | | $ - |
| 2 | Chiller optimisation including upgrading of control system | Chiller system | | | | | $ - |
| 3 | AHUs system optimisation | AHUs | | | | | $ - |
| 4 | Regular cleaning schedule and preventive maintenance programme for cooling coils along with filter differential pressure monitoring | AHUs | | | | | $ - |
| 5 | Install occupancy sensors in less frequently accessed areas | Lighting system | | | | | $ - |
| 6 | Use time scheduling for open office areas, with manual override capability | Lighting system | | | | | $ - |
| 7 | Change operational scheduling by aligning ventilation with peak usage patterns, to reduce ventilation during low occupancy period | Carpark ventilation system | | | | | $ - |
| 8 | Adjustment of pressure control by optimising the AHU settings for proper pressurisation and balance the air distribution. | AHUs in relation to air leakage | | | | | $ - |
| 9 | Install automated self-closing doors to minimise excess air leakage | Door provision in relation to air leakage | | | | | |
| 10 | Energy performance requirements in lease agreements | Tenant Partnership Programme | | | | | |
| 11 | Guidelines for fit out works to required energy efficient equipment | Tenant Partnership Programme | | | | | |
| 12 | Protocol for air-conditioning usage during off-peak hours | Tenant Partnership Programme | | | | | |
| 13 | Cost-sharing mechanism for energy efficiency improvements | Tenant Partnership Programme | | | | | |
| 14 | Tenant energy management programme | Tenant Partnership Programme | | | | | |
| **Capital Investment Recommendation** | | | | | | | |
| 15 | Installation of smaller capacity chiller | Chiller system | | | | | $ - |
| 16 | Replacement of all existing fixtures with LED panels | Lighting system | | | | | $ - |
| 17 | Replace with high efficiency heat pump | Centralised hot water system | | | | | $ - |
| **Remarks :** | | | **∑ kWh** | **∑kWh** | | **∑kWh** | **$ -** |

| S/No. | Proposed Energy Improvement Measures | Building Systems/ Initiatives | Cost and Simple Payback Period | | Implementation Plan | |
|---|---|---|---|---|---|---|
| | | | Estimated Implementation Cost ($) | Simple Payback Period (Year) | Start Date | Estimated End Date (where applicable) |
| **Energy Reduction Recommendation** | | | | | | |
| 1 | Conduct comprehensive maintenance including tube cleaning and refrigerant charge optimisation | Chiller system | | | 15 Oct 2026 | 15 Dec 2026 |
| 2 | Chiller optimisation including upgrading of control system | Chiller system | | | 1 Mar 2027 | 30 Jul 2027 |
| 3 | AHUs system optimisation | AHUs | | | 1 Mar 2027 | 30 Jul 2027 |
| 4 | Regular cleaning schedule and preventive maintenance programme for cooling coils along with filter differential pressure monitoring | AHUs | | | 1 Jan 2027 | Ongoing |
| 5 | Install occupancy sensors in less frequently assessed areas | Lighting system | | | 1 Jan 2027 | Ongoing |
| 6 | Use time scheduling for open office areas, with manual override capability | Lighting system | | | 1 Jan 2027 | Ongoing |
| 7 | Change operational scheduling by aligning ventilation with peak usage patterns, to reduce ventilation during low occupancy period | Carpark ventilation system | | | 15 Feb 2027 | Ongoing |
| 8 | Adjustment of pressure control by optimising the AHU settings for proper pressurisation and balance the air distribution. | AHUs in relation to air leakage | | | 15 Mar 2027 | Ongoing |
| 9 | Install automated self-closing doors to minimise excess air leakage | Door provision in relation to air leakage | | | 1 Apr 2027 | 31 Aug 2027 |
| 10 | Energy performance requirements in lease agreements | Tenant Partnership Programme | | | 1 Jun 2027 | Ongoing<br>Remarks : For new lease |
| 11 | Guidelines for fit out works to required energy efficient equipment | Tenant Partnership Programme | | | 1 Jun 2027 | Ongoing<br>Remarks : Apply to new leases and lease renewals |
| 12 | Protocol for air-conditioning usage during off-peak hours | Tenant Partnership Programme | | | 1 Mar 2027 | Ongoing |
| 13 | Cost-sharing mechanism for energy efficiency improvements | Tenant Partnership Programme | | | 1 Mar 2027 | Ongoing |
| 14 | Tenant energy management programme | Tenant Partnership Programme | | | 1 Mar 2027 | Ongoing |
| | | | | | | |
| 15 | Installation of smaller capacity chiller | Chiller system | | | 1 Sep 2027 | 30 Mar 2027 |
| 16 | Replacement of all existing fixtures with LED panels | Lighting system | | | 30 Oct 2027 | 31 Dec 2027 |
| 17 | Replace with high efficiency heat pump | Centralised hot water system | | | 30 Mar 2027 | 30 Oct 2027 |
| **Remarks :** | | | **∑ kWh** | **∑kWh** | **∑kWh** | |

Note : Under the column 'Implementation Plan', the start date refers to the commencement of physical implementation works on site or initiatives/programmes. For measures with defined completion points, an estimated end date is provided based on typical implementation timelines. Ongoing operational measures, such as tenancy agreements, regular maintenance schedule and preventive programmes, they can be recorded as 'Ongoing' as these measures will continue as part of regular operations after implementation. For clarity, please state if implementation is restricted to specific situations.

### Determination of Expected EUI Reduction (Percentage)

For consistency, the building's energy use intensity before implementing the efficiency measures is to be determined by taking the average of the building's yearly energy use intensity for the 3-year period prior to the year of notice. The example below shows the required tabulation and computation.

(1) Determine the $EUI_{baseline}$

| **Energy Use Intensity (EUI) (kWh/m²/year)** | | | **Baseline: Average EUI over three years** |
|---|---|---|---|
| 2022 | 2023 | 2024 | $EUI_{baseline} = \sum EUI_i/3$ = 400 kWh/m²/year |
| 402 | 403 | 395 | |

(2) Determine the percentage reduction in energy use intensity after implementation of proposed measures under the Energy Efficiency Improvement Plan

| | |
|---|---|
| **Total Expected Energy Savings after implementing EEIP (kWh/year)** | Assume : 1,000,000 kWh/year |
| **Energy Use Intensity (EUI) reduction (kWh/m²/year)** | Assume : Building's Gross Floor Areas (GFA) of 25,000 m²<br>Expected EUI reduction = $\frac{\text{Total expected energy savings}}{\text{GFA}}$ = $\frac{1{,}125{,}000}{25{,}000}$ = 45 kWh/m²/yr |
| | % EUI reduction = $\frac{\text{Expected EUI reduction}}{EUI_{baseline}}$ = 45/400 = 11.25% > 10% ok |

(3) Estimate the EUI reduction over 3-year period as the energy improvement measures are progressively completed based on EEIP and implementation plan.

| **Expected Reduction in Energy Use Intensity (EUI) by Phases (example)** | | | | | |
|---|---|---|---|---|---|
| **Details** | | **Year 0** | **Year 1** | **Year 2** | **Year 3** |
| **Expected Building's EUI** | | 400 | 385 | 365 | 355 |
| **Expected EUI reduction** | **By phase over 3-year period** | 0 | 15 | 20 | 10 |
| | **Cumulative** | 0 | 15 | 35 | 45 |
| **% EUI reduction (Cumulative)** | | 0 | 3.75% | 8.75% | 11.25% >10% |

# Part 3 Appendices

Appendix A – Supporting documentation in relation to the audit of energy use of buildings and systems

Appendix B – Supporting documentation in relation to the audit of energy efficiency level of building cooling system

Appendix C – Supporting documentation in relation to Operating System Efficiency (OSE) report of the building cooling system

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## Appendix A

**Supporting documentation in relation to the audit of energy use of buildings and system**

| S/No. | Supporting documents to be provided | Related Sections under Annex B – Part 1 |
|---|---|---|
| 1.1 | Past energy use data:<br>• Monthly utility bills over the 3 years prior to year of notice<br>• On-site renewable energy generation over the same period (where relevant) | (B) Historical energy use data<br>(D) Utility cost for building owner or landlord |
| 1.2 | As-built schematic drawings indicating the location of the major energy-consuming systems:<br>• Building cooling system<br>• Unitary air conditioners<br>• Centralised hot water system (Required, where applicable)<br>• Mechanical ventilation system for carparks (Required, if in EEIP)<br>• Lighting system (Required, if in EEIP) | (E) Inventory of major energy-consuming systems and equipment |
| 1.3 | Photographic evidence :<br>• Major energy-consuming systems and equipment<br>• Areas identified with energy wastage and inefficiencies | |
| 1.4 | Energy use records:<br>• Submetering data or energy consumption measurements for:<br>o Building cooling system<br>o Unitary air-conditioners<br>o Centralised hot water system (where relevant) | (F) Breakdown of Energy Consumption by End-use |
| 1.5 | Energy consumption calculations and estimates (where relevant), including the following:<br>• Equipment specifications and performance data<br>• Building Management System (BMS) data<br>• System operating schedules<br>• Derivation of energy consumption from tenants<br>• Any other relevant supporting basis | |

## Appendix B

**Supporting documentation in relation to the audit of energy efficiency level of building cooling system**

| S/No. | Supporting documents to be provided | Related Sections under Annex B – Part 1 |
|---|---|---|
| 2.1 | Chilled Water System:<br>• As-built schematic drawings of the chiller plant configuration.<br>• As-built drawings of chiller plant room plan layout and locations of the measurement and verification instrumentation.<br>• Data points in file format that are supported in Excel and to be presented with 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 1 week raw data of the pump(s), condenser water pump(s) and cooling tower(s) (kW). The excel file should include all the chart plots specified in Annex B.<br>• Instruments' calibration certificates from the accredited laboratories and their factory calibration certificates from manufacturers.<br>• Calculation of the overall uncertainty of measurement of the resultant chiller plant in kW/RT to be within ±5% of the true value based on instrumentation specifications and calibration certificates for (a) central chilled water system; and (b) for individual chillers (if the permanent measuring instruments or devices are installed at individual chillers and header/risers).<br>• Chiller(s) part load performance (at 10% interval from 100% to minimum value) from equipment supplier at operating conditions. | (G) Energy Efficiency of Building Cooling System |
| 2.2 | Air Handling and Distribution System:<br>• As-built schematic drawings of the air distribution system (AHUs / FCUs).<br>• 1-week raw data of the following data points if trended from BMS/EMS in file format that are supported in Excel and to be presented with date and time stamp: electrical power of air distribution system (kW) (AHUs / FCUs). Refer to ANNEX C for more details of the data points, type of instrumentation, measurement uncertainty, and sampling size and interval. | (G) Energy Efficiency of Building Cooling System |
| 2.3 | Unitary Air-conditioning System:<br>• As-built plan showing the location of the unitary air-conditioners and VRF system<br>• Records of the energy efficiency data collected from the VRF system's built-in monitoring tools for a period of 1 week<br>• Energy Efficiency calculations and estimates (where relevant) including the technical specification or basis. | (G) Energy Efficiency of Building Cooling System |

## Appendix C

**Supporting documentation in relation to the Energy Efficiency Improvement Plan (EEIP)**

| S/No. | Supporting documents to be provided | Related Sections under Annex B – Part 2 |
|---|---|---|
| 3.1 | Technical information:<br>• Equipment specifications/catalogues<br>• Energy savings calculations with assumptions<br>• Calculations showing expected EUI reduction<br><br>Cost and benefits analysis:<br>• Indicative cost estimates<br>• Energy cost savings<br>• Simple payback period calculations<br><br>Implementation feasibility:<br>• Project schedule outline and alignment with the stipulated 3 year timeframe<br><br>Tenant partnership or sustainability programme:<br>• Proposed programme framework<br>• Planned engagement approach<br>• Methodology for estimating tenants' energy savings | Energy Efficiency Improvement Plan (EEIP) |

[End of Document]