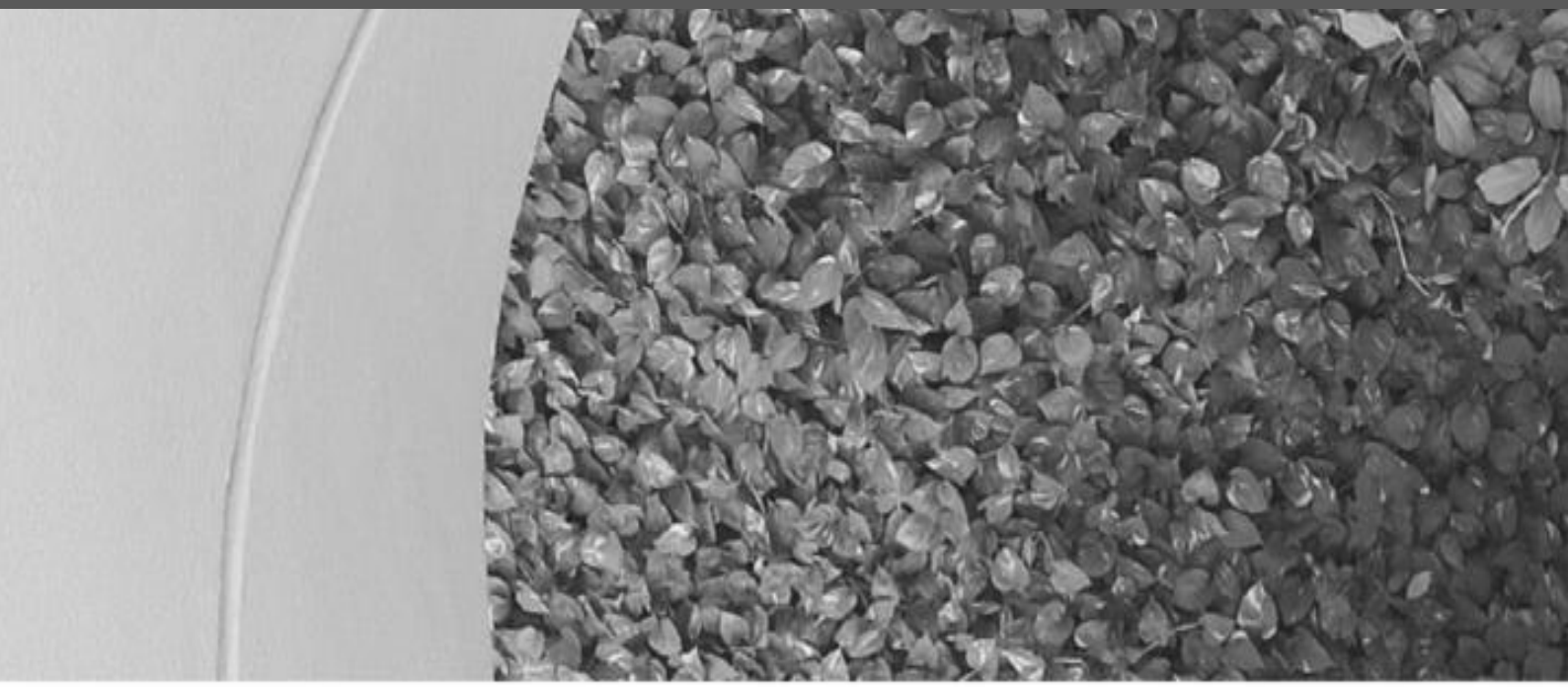
CODE ON

PERIODIC ENERGY AUDIT OF BUILDING COOLING SYSTEMS

Edition 4.0



Building and Construction Authority

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CODE ON
PERIODIC ENERGY AUDIT OF BUILDING COOLING SYSTEM

Edition 4.0

March 2023

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INTRODUCTION

In 2012, the Building and Construction Authority ("**BCA**") introduced the requirements governing the Periodic Energy Audit of Building Cooling Systems under Part 3B of the Building Control Act ("**Act**") and the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 ("**ESM Regulations 2013**").

Under this legislative framework, a notice will be issued to require a building owner to appoint a qualified professional to carry out a periodic energy audit on the building cooling system. This is to ensure that the building cooling system, which takes up a significant share of the energy demand of the building, continues to operate efficiently as designed.

The intent of this Code on Periodic Energy Audit of Building Cooling Systems (referred to as "**Code**" or "**Energy Audit Code**") is to set out the minimum requirements on the energy efficiency standard applicable to a cooling system of a building referred to in section 22FF(1) of the Act. This Code describes the compliance methodology in determining the energy efficiency standard of the building cooling system. Additionally, it stipulates the relevant qualifications and experience required for an individual to be registered as an energy auditor under Section 22FG of the Act.

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

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

(a) sets out the energy efficiency standard applicable to a cooling system of a building;

(b) stipulates the manner that an energy audit is to be carried out in determining the level of energy performance of the building cooling system during operation; and

(c) spells out the qualification and experience required for the registration or renewal of the registration as an energy auditor.

The provisions under the Energy Audit Code shall apply to:-

(i) Any building in respect of which an application for planning permission is submitted to the competent authority under the Planning Act 1998 on or after 1 December 2010; and

(ii) Any prescribed building which has undergone a major energy-use change *(that is the installation, substantial alteration or replacement of a prescribed cooling system of the building)*, except for the following Type A and Type B buildings:

Type A
- Data centres;
- Religious buildings;
- Residential buildings (other than serviced apartments); or
- Utility buildings.

Type B
- Industrial buildings;
- Railway premises;
- Port services and facilities; or
- Airport services and facilities.

For details, please refer to Regulation 3 of the ESM Regulations 2013.

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

2 DEFINITIONS

For the purpose of the Energy Audit Code, the following definitions shall apply:

Building Cooling System	A chiller cooling system that is complete with water-side and air-side components installed in a building to provide comfort cooling to the space.
Chilled Water Plant	A centralised air conditioning system that makes use of chilled water as the medium for removing the heat from the buildings. This includes the chillers and its ancillary equipment, including pumps and cooling towers where applicable.
Operating System Efficiency (OSE)	The measured system efficiency of the Chilled Water Plant or condenser unit and air-distribution system where required.

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).
Total System Efficiency (TSE)	The combined system efficiency of the water-side component and air-side component of the building cooling system. It is a measure of how efficiently the building cooling system would operate to meet the operating condition and requirements in providing an acceptable indoor thermal environment.
Unitary Air Conditioning System	One or more factory-made assemblies that normally include an evaporator or cooling coil and a compressor combination. Units that perform a heating function area are also included.

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

3 STATUTORY REQUIREMENTS

3.1 Act and Regulations

Other than the Act and the ESM Regulations 2013, this Code also refers to the Building Control (Environmental Sustainability) Regulations 2008 ("**ES Regulations 2008**").

3.2 Reference Codes and Standards

The following codes and standards have relevance:

(a) Code for Environmental Sustainability of Buildings

(b) Code on Environmental Sustainability Measures for Existing Buildings

(c) SS 530 : Code of Practice for Energy Efficiency Standard for Building Services and Equipment

(d) SS 531-1 : Code of Practice for Lighting of Work Places - Indoor

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

(f) SS 554 : Code of Practice for Indoor Air Quality for Air-Conditioning Buildings

(g) SS 591 : Code of Practice for Long Term Measurement of Central Chilled Water System Energy Efficiency

3.3 Responsibility

3.3.1 The building owner on whom a notice is served under section 22FF (1) of the Act shall appoint a Qualified Professional to carry out an audit as to whether the Building Cooling System meets the energy efficiency standard as described in the ESM Regulations 2013 and this Code. If the Building Cooling System does not meet the energy efficiency standard stipulated under Section 3.4 of this Code, maintenance work or other measures in relation to the Building Cooling System must be carried out to ensure compliance. The building owner is required to submit the report of the energy audit prepared by the Qualified Professional appointed within the time frame specified in the notice.

3.3.2 The appointed Qualified Professional shall carry out the energy audit in the prescribed manner stated in this Code, and may recommend to the building owner such measures as may be necessary to attain the energy efficiency standard. On completion of the energy audit, the Qualified Professional shall prepare and submit his report on the results of the energy audit (including any maintenance works and other measures taken to meet the prescribed energy efficiency standard) in the format as specified by the Commissioner of Building Control ("**CBC**"), as stipulated in Annex A of this Code.

3.4 Minimum Operating System Efficiency (OSE) Standard for Building Cooling Systems

3.4.1 The aim of the periodic energy audit is to ensure that the Building Cooling System installed continues to operate as efficiently as per its initial design throughout its life cycle. To meet this objective, the Building Cooling System shall have the level of Operating System Efficiency (OSE) that minimally meets the prescribed energy performance standard stipulated in these Codes referred to in the ES Regulations 2008 and ESM Regulations 2013, unless otherwise stated.

3.4.2 For buildings that have earlier undergone major energy-use change regulated under the ESM Regulations 2013, the Operating System Efficiency (OSE) of the Building Cooling System must meet the standard as stated in following Tables 1 and 2.

Table 1 –Chilled Water Plant Efficiency (kW/RT)

System Type	**Building Cooling Load**		**Applicable to buildings for which the design score submission under the ESM Regulations 2013 were made in the following time period**
	< 500RT	**≥500RT**	
Water-Cooled Chilled Water Plant	0.85	0.75	From 2 January 2014 to 31 March 2019
	0.80	0.75	From 1 April 2019 to 31 May 2022
Air-Cooled Chilled Water Plant	1.10	1.00	From 2 January 2014 to 31 May 2022

Table 2 – Total System Efficiency of Building Cooling System (TSE)(kW/RT)

Water-Cooled Building Cooling System	0.9	**Applicable to buildings for which the design score submission under the ESM Regulations 2013 were made on or after 1 June 2022**

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

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

Air-Cooled Building Cooling System	1.0	**Applicable to buildings for which the design score submission under the ESM Regulations 2013 were made on or after 1 June 2022**

where the minimum requirement on the water-side component efficiency for air-cooled chilled water plant is 0.85 kW/RT.

3.4.3 For buildings in respect of which an application for planning permission were submitted to the competent authority under the Planning Act 1998 on or after 1 December 2010 and regulated under the ES Regulations 2008, the Operating System Efficiency (OSE) of the Building Cooling System must meet the energy efficiency standard stipulated in the following subsections 3.4.3.1 and 3.4.3.2.

3.4.3.1 This subsection shall apply to the whole or part of buildings that are on land sold under the Government Land Sales ("**GLS**") Programme, and which were subject to the ES Regulations 2008. The Operating System Efficiency (OSE) of the Building Cooling System of such buildings must meet the energy efficiency standard stated in following Tables 3 and 4.

Table 3 – Chilled Water Plant Efficiency (kW/RT)

Applicable for buildings wholly or partly on land sold from 1 Dec 2010 to 29 Jun 2022 under the GLS programme and subject to the ES Regulations 2008

System Type	**Green Mark Certification Standard stipulated in ES Regulations 2008**	**Chilled Water Plant Efficiency (kW/RT)**	
		Building Cooling Load	
		< 500RT	**≥500RT**
Water-Cooled Chilled Water Plant	Gold^{Plus}	0.70	0.65
	Platinum	0.70	0.65
Air-Cooled Chilled Water Plant	Gold^{Plus}	0.85	Not applicable
	Platinum	0.78	

Table 4 – Total System Efficiency (TSE) of Building Cooling Systems (kW/RT)

Applicable for buildings wholly or partly on land sold on or after 30 Jun 2022 under the GLS programme and subject to the ES Regulations 2008

System Type	**Green Mark Certification Standard stipulated in ES Regulations 2008**	**Total System Efficiency (kW/RT)**	
		Building Type	
		Office/Retail/Hotel/Institute of Higher Learning	**Others**
Building Cooling System *(inclusive of Water-Cooled or Air-Cooled Chilled Water Plant and Air Distribution System)*	Platinum Super Low Energy (SLE)	0.68	0.70

3.4.3.2 This subsection shall apply to all other buildings that were subject to the ES Regulations 2008. The Operating System Efficiency (OSE) of the Building Cooling System of such buildings must meet the energy efficiency standard as stated in following Tables 5 and 6.

Table 5 –Chilled Water Plant Efficiency (kW/RT)			
System Type	**Building Cooling Load**		**Applicable for buildings for which the applications for planning permission were submitted to the competent authority under the Planning Act 1998 from 1 Dec 2010 to 30 Nov 2021**
	< 500RT	**≥500RT**	
Water-Cooled Chilled Water Plant	0.80	0.70	
Air-Cooled Chilled Water Plant	0.90	0.80	

Table 6 – Total System Efficiency of Building Cooling System (TSE)(kW/RT)			
Water-Cooled Building Cooling System	New Buildings *(based on classification under the Code for Environmental Sustainability of Building (Edition 4.0))*	Existing Buildings with Major Retrofits / Major Additions & Alteration	**Applicable for buildings for which the applications for planning permission were submitted to the competent authority under the Planning Act 1998 on or after 1 Dec 2021**
	0.85	0.9	

where TSE refers to combined system efficiency of the chilled water plant and air distribution system. The minimum water-side component efficiency for commercial building development shall not be more than 0.63 kW/RT. As for other building developments, the minimum water-side component efficiency will be based on the chilled water supply temperature and as follows :

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

Air-Cooled Building Cooling System	1.0	**Applicable for buildings for which the applications for planning permission were submitted to the competent authority under the Planning Act 1998 on or after 1 Dec 2021**

where the minimum requirement on the water-side component efficiency for air-cooled chilled water plant is 0.85 kW/RT.

3.4.3.3 Where there is a combination of water-cooled and air-cooled chiller cooling systems, the minimum OSE applicable to these cooling systems is to be complied with.

4 ENERGY AUDIT METHODOLOGY

4.1 General

4.1.1 The energy audit of the Building Cooling System shall be carried during the normal operating hours, as defined below.

Office Buildings: ▪ Monday to Friday: 9a.m. to 6p.m. **Retail Malls:** ▪ Monday to Sunday: 10a.m. to 9p.m.	**Hotels/Hospitals:** ▪ Monday to Sunday: 24 hours **Other building types:** ▪ To be determined based on the operating hours

4.1.2 The data required for the determination of the Operating System Efficiency (OSE) shall be obtained from the permanent instrumentations and power meters installed.

4.1.3 In the case for Chilled Water Plant, the accuracy of its permanent temperature sensors shall be first checked with a portable calibrated temperature sensor before extracting any data for the computation of performance data. The average deviation between the two sensors, after considering the effects of possible heat gain/loss in the pipe, shall not exceed 0.07°C as illustrated in Appendix B of Annex A – Energy Audit Report for Building Cooling System. In the event that there is a deviation exceed the tolerance level, there will be a need to replace and/or recalibrate the instrument.

4.1.4 The data required to establish the performance of the Chilled Water Plant shall be sampled and acquired simultaneously and continuously for a minimum of one (1) week at one (1) minute intervals, unless otherwise specified.

4.1.5 The determination of the system energy efficiency of the Chilled Water Plant and air-distribution system shall be conducted under normal operating conditions with the indoor space conditions, maintained within the recommended limits stated in SS553 and SS554, where applicable.

4.1.6 The energy audit shall include a 10-point spot measurements of indoor air conditions – dry bulb temperature, relative humidity and carbon dioxide concentration. These measurements are to be recorded and tabulated in accordance with the format shown in "Schedule of Space Operating Conditions" of Annex A – Energy Audit Report for Building Cooling System.

4.2 Heat Balance Substantiating Test for Water-Cooled Chilled Water Plant

4.2.1 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 OSE of the Building Cooling System. This is not applicable to air-cooled Chilled Water Plant.

4.2.2 The OSE of the water-cooled Chilled Water Plant shall be verified and carried out by computing the system heat balance of the plant in accordance with the SS591, to the extent as prescribed.

4.2.3 A perfect heat balance of the Chilled Water Plant can be represented by the following equation :

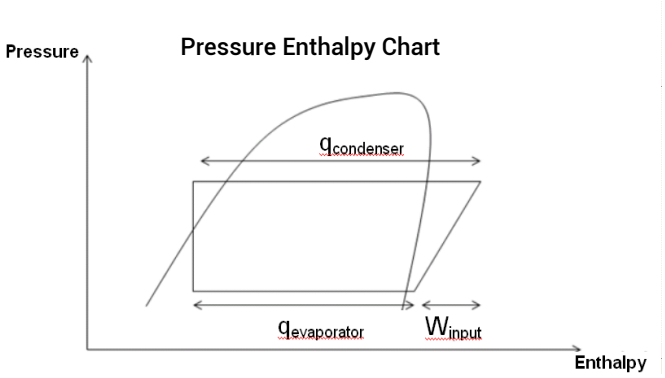
$$q_{condenser} = q_{evaporator} + W_{input.}$$

where $q_{condenser}$ = heat rejected by condenser, kW

$q_{evaporator}$ = heat gain in evaporator, kW

W_{input} = power input to compressor, kW

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



4.2.5 The system heat balance of the Chilled Water Plant shall be computed using the formula stated below over the normal operating hours,

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

4.2.6 For open drive chillers, the W_{input} shall take into account the motor efficiency provided by the manufacturer as illustrated in the following example:

Input power to motor (measured)	= 100 kW
Motor rated efficiency (η)	= 90%
Adjusted power input to compressor W_{input}	= 100 kW x 90%
	= 90 kW

4.2.7 Where hydraulic losses of pumps constitute a substantial heat gain, these losses shall be accounted for as illustrated in the following examples 4.2.7 (a) and (b). The values shall be determined from motor efficiency and pump efficiency values provided by the manufacturer.

(a) **For chilled water pump(s) adjustment,**

Motor input power (measured)	= 30 kW	(A)
Motor rated efficiency (η)	= 90%	(B)
Pump rated efficiency (η)	= 80%	(C)
Hydraulic losses[1]	= (A) x (B) x [(100% – (C)]	
	= 30kW x 90% x (100% - 80%)	
	= 5.4 kW	
Adjusted total input power W_{input}	= kW_i (chillers) + 5.4kW	

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

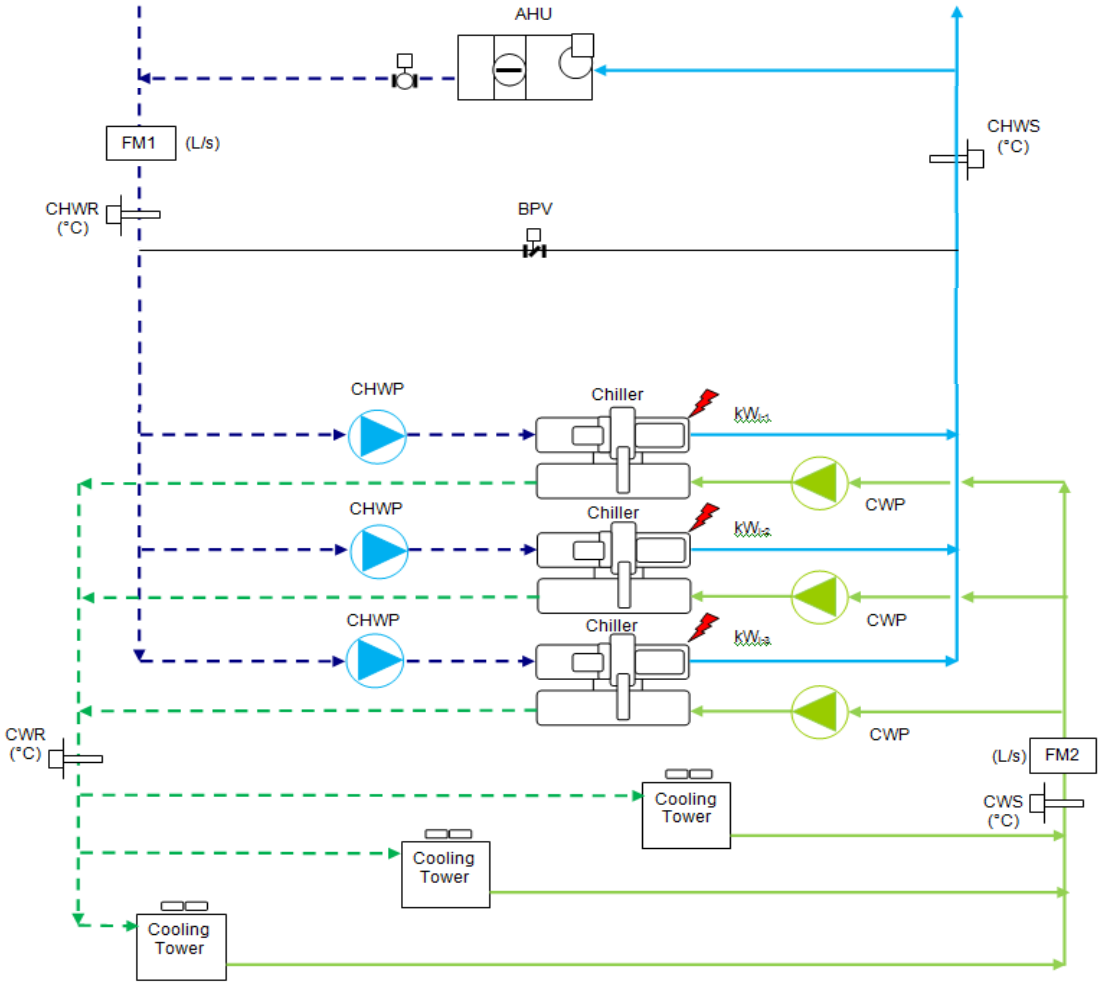
(b) **For condenser water pump(s) adjustment,**

Motor input power (measured)	= 20 kW	(A)
Motor rated efficiency (η)	= 90%	(B)
Pump rated efficiency (η)	= 80%	(C)
Hydraulic losses[1]	= (A) x (B) x [(100% – (C)]	
	= 20kW x 90% x (100% - 80%)	
	= 3.6 kW	
Adjusted $q_{condenser(adj)}$	= $q_{condenser}$ - 3.6Kw	

[1] For equipment with VSD, the equation shall include variable speed drive losses, harmonic filter losses (where applicable).

4.2.8 The Chilled Water Plant configuration is to be considered in determining the heat balance and as illustrated in the following examples :

Figure A - Example of a Constant Primary Water-Cooled Central Chilled Water System



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

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

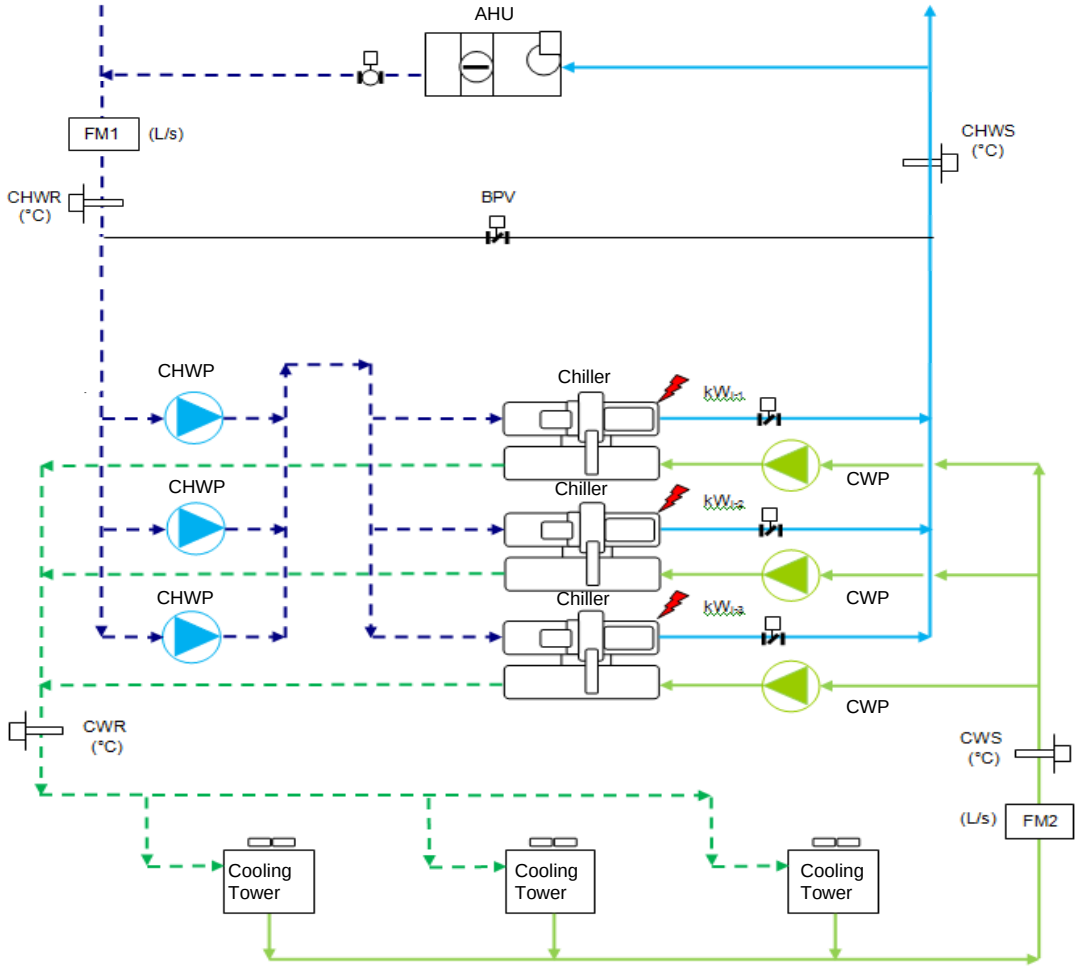
C: W_{input} = kW_{i-1} + kW_{i-2} + kW_{i-3}

where Cp = 4.19 kJ/kg °C & density of water is assumed to be 1kg/L

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

Note : Hydraulic losses of pumps constituting substantial heat gain, $W_{input}/q_{condenser}$ may be adjusted to account for these additional heat gains. The values shall be determined from variable speed drive losses, harmonic filter losses (where applicable), motor efficiency and pump efficiency values certified by the manufacturer.

Figure B - Example of a Variable Primary Water-Cooled Central Chilled Water System



i

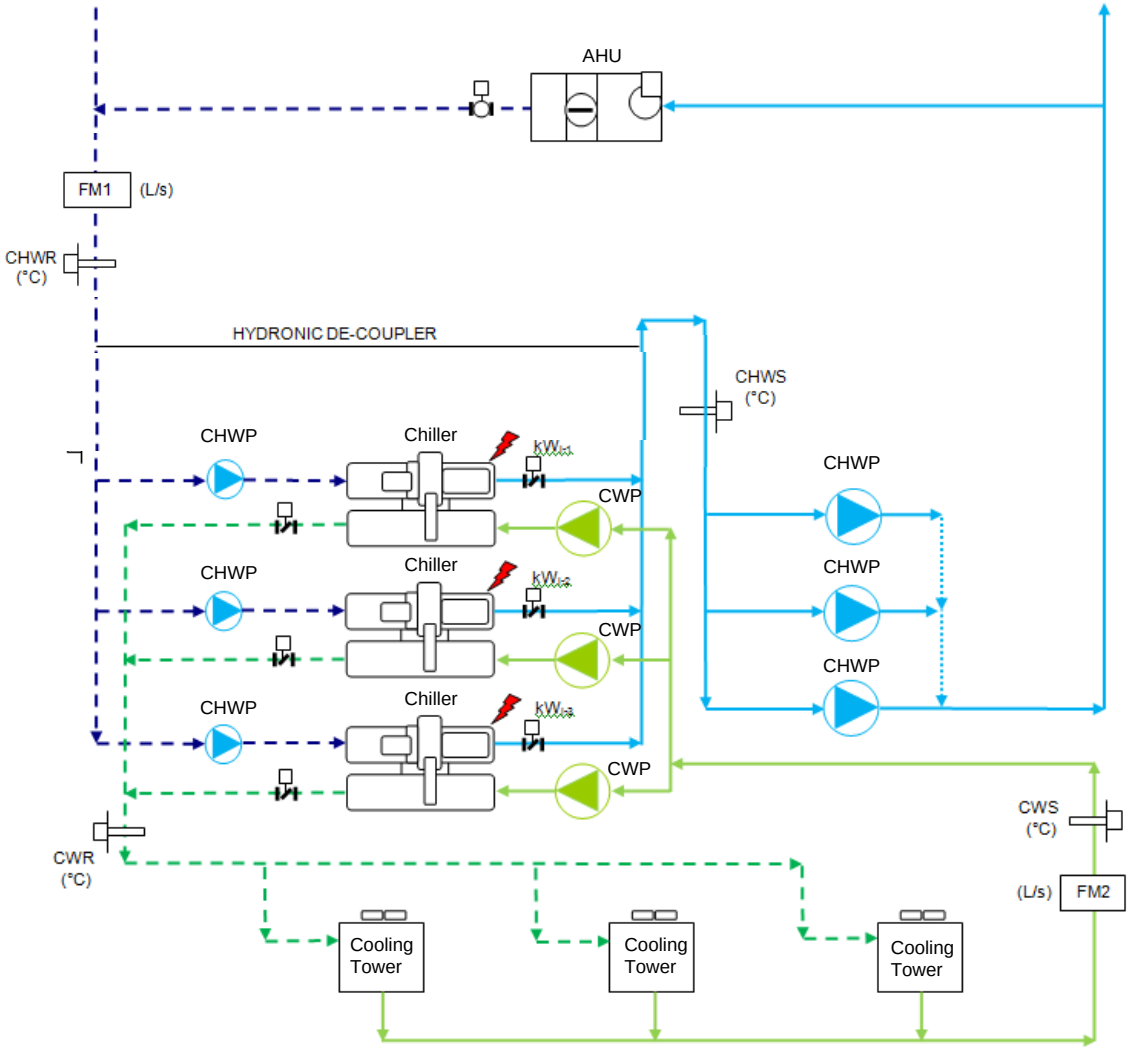
A: $q_{evaporator}$ = FM1 x Cp x (CHWR - CHWS)
B: $q_{condenser}$ = FM2 x Cp x (CWR - CWS)
C: W_{input} = kW_{i-1} + kW_{i-2} + kW_{i-3}

where Cp = 4.19 kJ/kg °C & density of water is assumed to be 1kg/L

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

Note: In the event where hydraulic losses of pumps constitute substantial heat gain, $W_{input}/q_{condenser}$ may be adjusted to account for these additional heat gains. The value shall be determined from variable speed drive losses, harmonic filter losses (where applicable), motor efficiency and pump efficiency values certified by the manufacturer.

Figure C – Example of a Constant Primary and Variable Secondary Water-Cooled Central Chilled Water System



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

where Cp = 4.19 kJ/kg °C & density of water is assumed to be 1kg/L

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

Note: In the event where hydraulic losses of pumps constitute a substantial heat gain, these losses have to be properly accounted for. The value shall be determined from variable speed drive losses, harmonic filter losses (where applicable) and pump efficiency values certified by the manufacturer.

4.2.9 The heat balance shall be computed and to meet the requirement of within 5% for at least 80% of the computed heat balance points during the normal operating hours as defined in subsection 4.1.1 over a one(1) week period. The following example illustrates a heat balance where more than 80% of the computed heat balance falls within ± 5% as required.

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

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

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

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

4.3 Measurement of the Air Distribution System Efficiency at Building Level

4.3.1 The determination of the air distribution system efficiency is required for :

(a) buildings for which the design score submission under the ESM Regulations 2013 were made on or after 1 June 2022;

(b) buildings where the applications for planning permission were submitted to the competent authority under the Planning Act 1998 on or after 1 December 2021 under the ES Regulations 2008; and

(c) buildings wholly or partly on land sold on or after 30 June 2022 under the GLS Programme and subject to the ES Regulations 2008.

4.3.2 The measurement method, duration and coverage in deriving the power consumption from air distribution system are as summarised below :

Measurement of Air-Distribution System Efficiency at Building Level				
Air-side Components	**Measurement Method**	**Duration**	**Coverage**	**Total Power Consumption per week**
(A) Air- Handling Units (VAV-AHUs and CAV-AHUs)	Trend data from BMS/EMS	One (1) week	All	kWhrs
	If there is no linkage with BMS/EMS		Sample 10% of total no. of AHUs Min five(5) measurements (Cap at 10)	kW_{ave} x Number of Operating hours per week x Number of AHUs = kWhrs
	• VAV-AHUs : Trend log input power using portable power meters with accuracy of IEC Class 1 or equivalent	Log for one (1) day		
	• CAV-AHUs : Spot Measurements using portable power meters with accuracy of IEC Class 1 or equivalent	Spot measurements during normal operating hours with a minimum duration of five (5) mins		
(B) Fan Coil Units (FCUs)	Trend data from BMS/EMS	One (1) week	Sample 10% of total no. of FCUs	kW_{ave} x Number of Operating hours per week x Number of FCUs = kWhrs *Alternatively, the power consumption can be computed based on the Nameplate motor power of FCUs instead of measurement.*
	Spot measurements using portable power meters with accuracy of IEC Class 1 or equivalent	Spot measurements during normal operating hours with a minimum duration of five (5) mins		

Air-side efficiency at building level, η_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.

5 SUBMISSION PROCEDURES

5.1 General

5.1.1 CBC may serve the first notice requiring periodic audit of energy efficiency of Building Cooling Systems to building owners, no less than 36 months from the date of the Notice of Approval of the As-Built Score for buildings that were earlier subject to the ESM Regulations 2013. Whilst for buildings that were earlier subject to the ES Regulations 2008, BCA may serve the first notice at any time after the issuance of the Temporary Occupation Permit ("**TOP**") or Certificate of Statutory Completion ("**CSC**"), if there was no TOP application.

5.1.2 The building owner may be served each subsequent Notice not less than 36 months from the date of the last Notice, for subsequent Energy Audit Submission.

5.1.3 The building owner on whom a notice is served under section 22FF (1) of the Act shall appoint a Qualified Professional to carry an audit on the energy efficiency of the Building Cooling System and to submit the energy audit report within the timeframe specified in the notice. A Notice of Approval will be

issued to the building owners if the Operating System Efficiency of the Building Cooling Systems meets the stipulated minimum standard stated under Section 3.4 and the submitted energy audit report is in order.

5.2 Submission Requirements

5.2.1 The building owner and appointed Qualified Professional shall submit an application for approval of Operating System Efficiency of Building Cooling Systems (i.e. Form BCA-EB OSE01) along with supporting documents after completing the energy audit.

5.2.2 The following prescribed form and supporting documents are to be e-signed and submitted to the CBC electronically via CORENET e-submission system for approval.

(A) Form BCA-EB-OSE01	Application for Approval of Periodic Audit Report of Energy Efficiency of Building Cooling System

(B) Supporting Documents to Form BCA-EB-OSE01 :

General

- Scanned copy of CBC's notice for the submission of the Energy Audit in pdf form.
- Energy Audit Report in the prescribed format and details as in Annex A.

Documents in relation to Energy Audit of Chilled Water System

- As-built schematic drawings of chiller plant configuration.
- As-built drawings of chiller plant room plan layout and locations of the measurement and verification instrumentation.
- 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) & cooling tower(s) (kW). The excel file should include all the chart plots specified in Annex A.
- Instruments' calibration certificates from the accredited laboratories and their factory calibration certificates from manufacturers.
- Drawings showing the details of permanent measuring instruments installed.
- All input parameters for the permanent measuring instruments and devices (e.g. flow meter settings for pipe material, diameter, circumference, thickness, roughness, type of lining etc.)
- 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).
- Chiller(s) part load performance (at 10% interval from 100% to minimum value) from equipment supplier at operating conditions.

Documents in relation to Energy Audit of Air Distribution System where applicable

- As-built schematic drawings of the air distribution system (AHUs / FCUs).
- 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 A for more details of the data points, type of instrumentation, measurement uncertainty, and sampling size and interval.
- Instruments' calibration certificates from the accredited laboratories and their factory calibration certificates from manufacturers.

5.2.3 Submission of other documents may be required and shall be made in such manner and be in such form as the CBC requires upon request.

6 REGISTRATION OF ENERGY AUDITOR

6.1 Eligibility Criteria

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

(a) 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;

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

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

(d) Passed the interview and/or exam by the Energy Auditor Registration Committee.

6.1.2 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.

6.1.3 An application to be registered as an Energy Auditor can be made using the Application Form BCA-EAS-APL which can be downloaded from http://www.bca.gov.sg. All applications must be accompanied with a fully completed form, supporting certificates and evidence of related work experiences as specified in the form.

6.1.4 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 BCA-EAS-RAPL which can be downloaded from http://www.bca.gov.sg. 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 Audit Report for Building Cooling System – Reporting Requirements and Template

ANNEX A – Energy Audit Report For Building Cooling System

Date: DD/MM/YYYY

ENERGY AUDIT REPORT
FOR BUILDING COOLING SYSTEM

for

ENTER BUILDING NAME

at

ENTER BUILDING ADDRESS

(BUILDING IMAGE)

Submitted By

Enter name of PE/Energy Auditor

Signature of PE/Energy Auditor

PE (Mech) Registration No*: Enter No.

Energy Auditor Registration No*: Enter No.

*Delete whichever is not applicable

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1.0 Executive Summary & Recommendation

(Example)

This report highlights the findings and recommendations obtained from the energy audit performed at Enter Building Name from [Enter Period of Audit] DD/MM/YYYY to DD/MM/YYYY for 24 hrs.

Corrective measures taken by PE (Mech)/ Energy Auditor to comply with PEA Notice.

1) *<Description of findings/ measures>*
2) *<Description of findings/ measures>*
3) *<Description of findings/ measures>*

Recommended energy improvement measures for Building Owners :

1) *<Description of recommendations>*
2) *<Description of recommendations>*
3) *<Description of recommendations>*

2.0 Building Information

Enter a brief description of the building here.

Project Reference Number	: **Enter project reference indicated in CORENET submission**
Building Name	:
Building Address	:
Postal Code	:
Building Type	:
Building Age	:
Date of last Energy Audit Submission	:
Gross floor area (GFA), m^2	:
Air conditioned area, m^2	:
Number of guest rooms (for hotels/service apartments)	:

3.0 Energy Audit Information For Building Cooling System

Enter PE(Mechanical) / Energy Auditor Name was appointed by **Enter Owner Name/ MCST**, owner of **Enter Building Name** to be the Energy Auditor for the submission of the operating system efficiency (OSE) of the building cooling system. The report will present the OSE of the building cooling system based on the measurements from the permanent instrumentations installed on site.

Location	:	**Enter location of Chilled Water Plant**
Energy Audit Period	:	**Enter Energy Audit period *Note: Min 1 week**
Date of notice served	:	**Enter date of notice served by BCA**
Date of submission in notice	:	**Enter submission deadline stipulated in BCA notice**
OSE standard to comply (kW/RT)	:	**Enter Min OSE standard for Chilled Water Plant**
OSE standard to comply (kW/RT)	:	**Enter Min OSE standard for Total System Efficiency**
Data Logging Interval	:	1 minute sampling
Trend Logged Parameters*	:	Chilled Water Supply main header temperature
		Chilled Water Return main header temperature
		Chilled Water flow rate at chilled water return main header
		Condenser Water Supply main header temperature
		Condenser Water Return main header temperature
		Condenser water flow rate at condenser water return main header
		Power input to Chiller(s)
		Power input to Chilled water pump(s)
		Power input to Condenser water pump(s)
		Power input to Cooling tower(s)
		Power input to Pre-AHU(s)/AHU(s)/FCU(s)

**** Trend logged parameters are not limited to the above and may vary depending on the piping and electrical circuit design.***

I hereby confirm the following check have been carried and verified by me as part of the energy audit process.

BMS Check	
1. Temperature sensors' ABC coefficient constants input as reflected in the calibration certs	☐
Power Meter (Consistency Check)	
2. Check power meter reading and BMS reading are same	☐
3. Check power meter reading and chiller panel or pump VSD display reading is ≤ 3%	☐
4. Check the Current Transformer ratio tallies with power meter setting	☐
Flow Meter	
5. Check sum of flow meter branches tallies with flow meter header reading (if there are flowmeters at header and individual chillers)	☐
6. Check flowmeter reading and BMS reading are same	☐
7. Check flowmeter do not have any correction factor or off-set factor input	☐
Verified Temperature Sensor Accuracy	
8. Use calibrated reference temperature sensor with end-to-end uncertainty of ≤0.05 ^{o}C	☐
9. Synchronise the reference temperature sensor device timing with BMS	☐
10. Collect at least 20 sets of reading from reference temperature sensor device (after insertion into spare test plug) and BMS	☐
11. Compare the difference between both set of readings, with average of absolute difference to be ≤ 0.07 ^{o}C	☐

3.1 Chilled Water Plant Design Information*

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

Table 1: Chiller 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	11	23	33.65	80.0%	92.4%
CHWP 2	Brand X	end suction	11	23	33.65	80.0%	92.4%
CHWP 3	Brand X	end suction	11	23	33.65	80.0%	92.4%
CWP 1	Brand Y	end suction	15.0	16.0	56.82	79.0%	92.4%
CWP 2	Brand Y	end suction	15.0	16.0	56.82	79.0%	92.4%
CWP 3	Brand Y	end suction	15.0	16.0	56.82	79.0%	92.4%
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%

Table 2: Ancillary water-side equipment Information (Example)

*Based on equipment design specifications and name plate ratings

3.2 Air-Side Design information*

ID	Model (Serial Number)	Type (Centrifugal/ EC Centrifugal / Axial)	Motor Power (kW)	Input Power (kW)	Rated Airflow (m^3/h)	Ext Static Pressure (Pa)	Total Static Pressure (Pa)	Cooling Capacity (Ton)	Filter Type/ Rating	Outdoor air provision
AHU 1	Mod Xx	Centrifugal	3.0	2.67	6523	205	768	10.2	Bag/F7	Direct opening to external/ via PAHU or FAF
AHU 2	Mod Xx	Centrifugal	3.0	2.67	6523	205	768	10.2	Bag/F7	
AHU 3	Mod Xx	Centrifugal	3.0	2.67	6523	205	768	10.2	Bag/F7	
AHU 4	Mod Xx	Centrifugal	3.0	2.67	6523	205	768	10.2	Bag/F7	
AHU 5	Mod Xx	Centrifugal	3.0	2.67	6523	205	768	10.2	Bag/F7	
AHU 6	Mod Xx	Centrifugal	3.0	2.67	6523	205	768	10.2	Bag/F7	
Pre-Cooled AHU 1	Mod Yx	Centrifugal	11.0	10.8	18500	705	1221	42	Bag/F7	
Pre-Cooled AHU 2	Mod Yx	Centrifugal	11.0	10.8	18500	705	1221	42	Bag/F7	
Summation			-	X	-	-	-	X	-	

Table 3: Ancillary air-side equipment Information (Example)

*Based on equipment design specifications and name plate ratings

3.3 Chilled Water Plant Normal Operating Hours

Monday to Friday : 1000 – 2100 Hrs

Saturday / Sunday : No operations

Note: The audit period shall be based on the operating hours defined in the subsection 4.1.1 of the Energy Audit Code.

3.4 Description of Plant Control Strategy

Summary of the present plant control strategy adopted for the applicant's building chiller plant systems' operation. You may include but not limited to the following:

1) 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.

2) Chilled water pump (if applicable)

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

3) Condenser water pump (if applicable)

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).

4) Cooling tower (if applicable)

Describe the parameters used to control cooling towers
e.g. Modulate base 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)

5) Other optimisation (if applicable)

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)

Example of the information to be provided on the control strategy adopted is as illustrated below :

System adopted : Variable Primary Chilled Water System

Chiller Configuration:<*x*> **unit(s) of** <*x*> **RT chiller &** <*x*> **unit(s) of** <*x*> **RT chiller**

Variable Condenser Pump

1) Chiller sequencing

Scenario for Cut-in: *Chilled water supply header temperature is above set point of <x> °C + <deadband> OR total system tonnage is above <x> RT for a period of <x> minutes.*

Scenario for Cut-out: *Chilled water supply header temperature is below set point of <x> °C + <deadband> AND total system tonnage is below <x> RT for a period of <x> minutes.*

Time delay: *Whenever any chiller cuts-in/out, there is <x> minutes delay to allow system to stabilize.*

2) Chilled water pump (CHWP)

Primary CHWP speed is modulated to maintain a differential pressure set point of <x> psi + <deadband>. Differential pressure sensors are installed at chilled water pipe headers. CHWP speed is limited to <x> Hz to ensure chillers running at minimum flow. When CHWP speed ramps down to minimum and differential pressure rises above set point, the bypass valve will open to maintain DP set point and minimum flow rate.

3) Condenser water pump (CWP) <fixed/variable>

Minimum running speed of CWP is <x> Hz. When condenser flow rate is reduced to set point of <x> l/s or <x> gpm/ton, CWP speed would be increased and vice versa.

4) Cooling Tower (CT)

CT fan speed is modulated to maintain leaving condenser water temperature set point of <x> °C which is equal to outdoor air wet-bulb temp plus <x> °C. When chiller(s) is in operation, all CTs would be turn on. When CT leaving water temperature falls below the set point, CT fan speed would be decreased until minimum speed of <x> Hz.

5) Other Optimisation

Chilled water temperature set point is reset to <x> °C during off-peak period from 2000hrs to 0800hrs.

4.0 Instrumentations

Accurate measuring instruments complying with the Code on Environmental Sustainability Measures for Existing Buildings or the Code for Environmental Sustainability of Buildings (2nd edition and onwards) that is prevailing at the time of installation were used during the audit to gather information on the power consumption, temperatures and flow rate.

The points of measurements are listed in the following table:

ID / Serial No.	Brand	Sensor Type	Installation Location	Measurement Uncertainty (%)	Last Calibration Date	Calibration Laboratory
EP80367	Brand X	10K Ω Thermistor	CHWS Header	±0.03 °C	09/05/2014	XX laboratory
EP80364	Brand X	10K Ω Thermistor	CHWR Header	±0.03 °C	09/05/2014	XX laboratory
EP80361	Brand X	10K Ω Thermistor	CWS Header	±0.03 °C	09/05/2014	XX laboratory
EP80363	Brand X	10K Ω Thermistor	CWR Header	±0.03 °C	09/05/2014	XX laboratory
3k67201343004	Brand X	Magnetic Full Bore	CHWR Header	0.5%	29/10/2013	factory calibration
3k67201418063	Brand X	Magnetic Full Bore	CWR Header	0.5%	09/05/2014	factory calibration
38498	Brand X	True RMS, 3 phase	MSB Incoming 1	0.5%	08/07/2014	factory calibration
1402404	Brand X	True RMS, 3 phase	MSB Incoming 2	0.5%	08/07/2014	factory calibration
38491	Brand X	True RMS, 3 phase	CH/6-1	0.5%	08/07/2014	factory calibration
38487	Brand X	True RMS, 3 phase	CHP/6-1	0.5%	08/07/2014	factory calibration
38490	Brand X	True RMS, 3 phase	CWP/6-1	0.5%	08/07/2014	factory calibration
38499	Brand X	True RMS, 3 phase	CT/6-1	0.5%	08/07/2014	factory calibration
38497	Brand X	True RMS, 3 phase	CH/6-2	0.5%	08/07/2014	factory calibration
38483	Brand X	True RMS, 3 phase	CHP/6-2	0.5%	08/07/2014	factory calibration
1402325	Brand X	True RMS, 3 phase	CWP/6-2	0.5%	08/07/2014	factory calibration
38572	Brand X	True RMS, 3 phase	CT/6-2	0.5%	08/07/2014	factory calibration
1402399	Brand X	True RMS, 3 phase	CH/6-3	0.5%	08/07/2014	factory calibration
38574	Brand X	True RMS, 3 phase	CHP/6-3	0.5%	08/07/2014	factory calibration
38485	Brand X	True RMS, 3 phase	CWP/6-3	0.5%	08/07/2014	factory calibration
38486	Brand X	True RMS, 3 phase	CT/6-3	0.5%	08/07/2014	factory calibration

Table 4: Instrumentation Table (Example)

5.0 Chiller Plant Performance Analysis (1 week data)

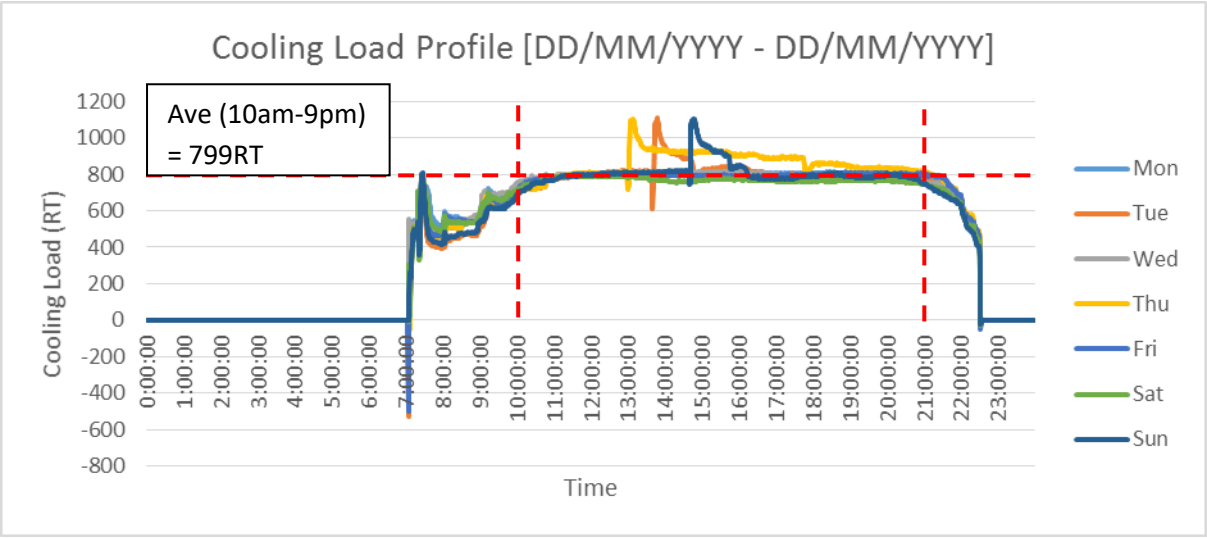

Figure 1: Super-imposed plot of 24 hr Cooling Load Profile RT (Example)

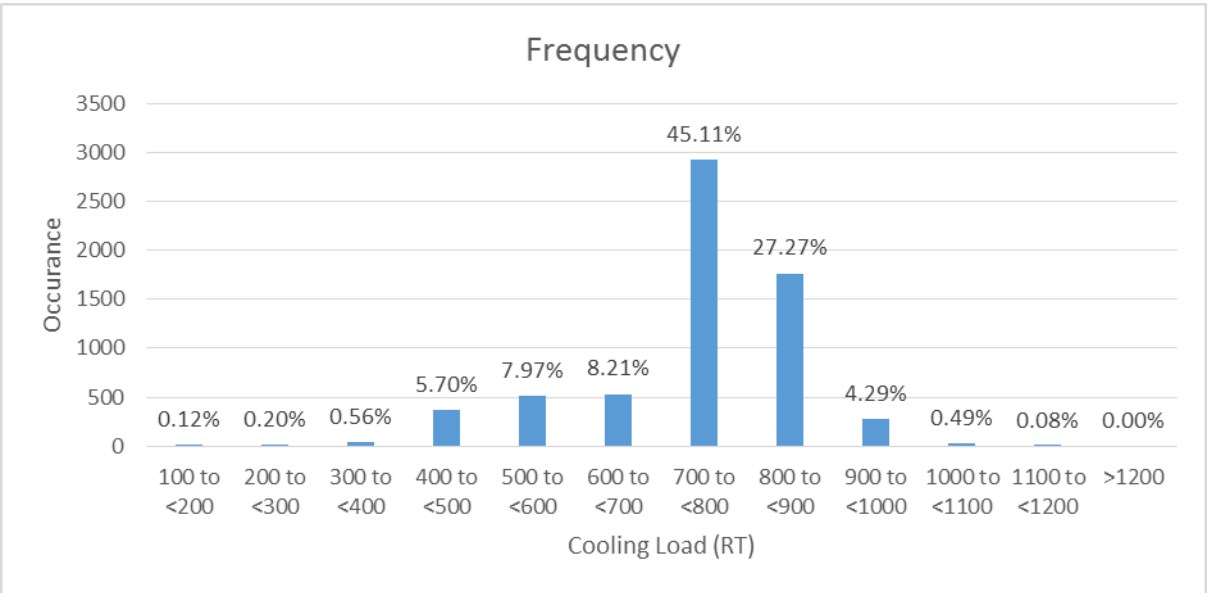

Figure 2: Histogram of Cooling Load Occurrences (Example)

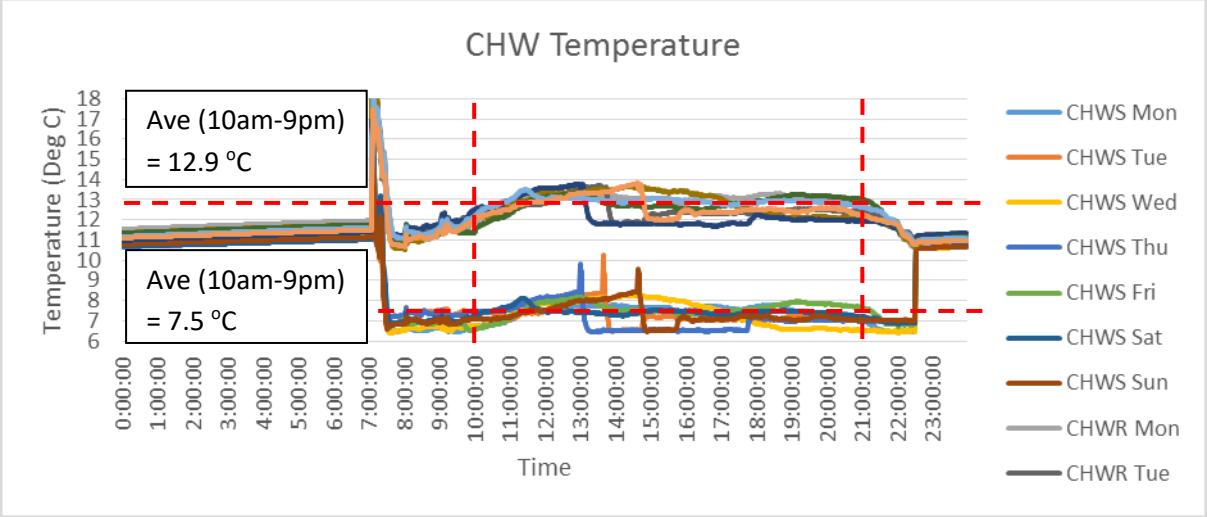

Figure 3: Super-imposed plot of daily chilled water supply/return temperature °C (Example)

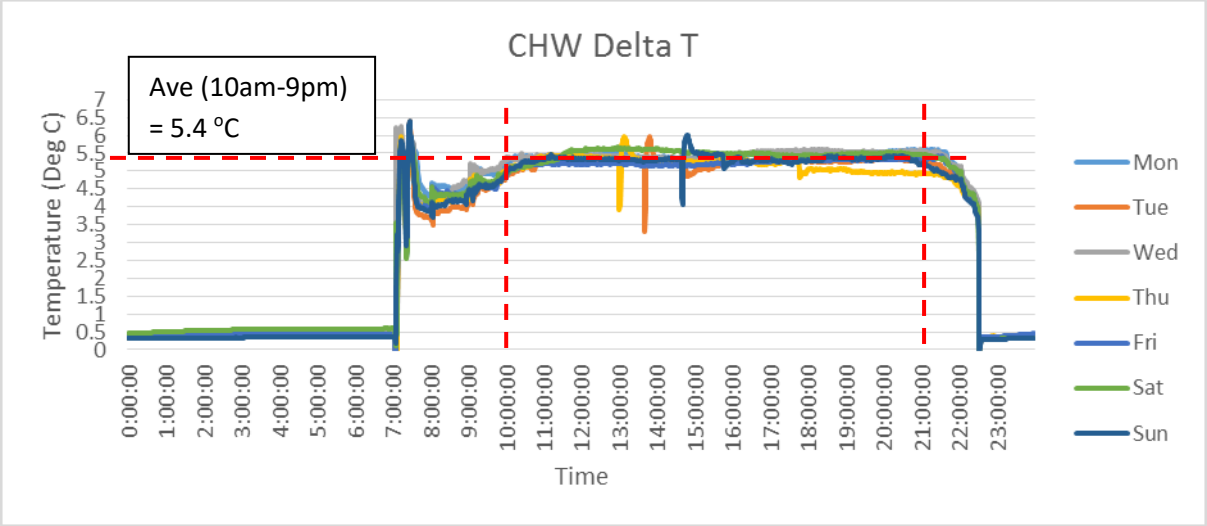

Figure 4: Super-imposed plot of daily chilled water temperature difference °C (Example)

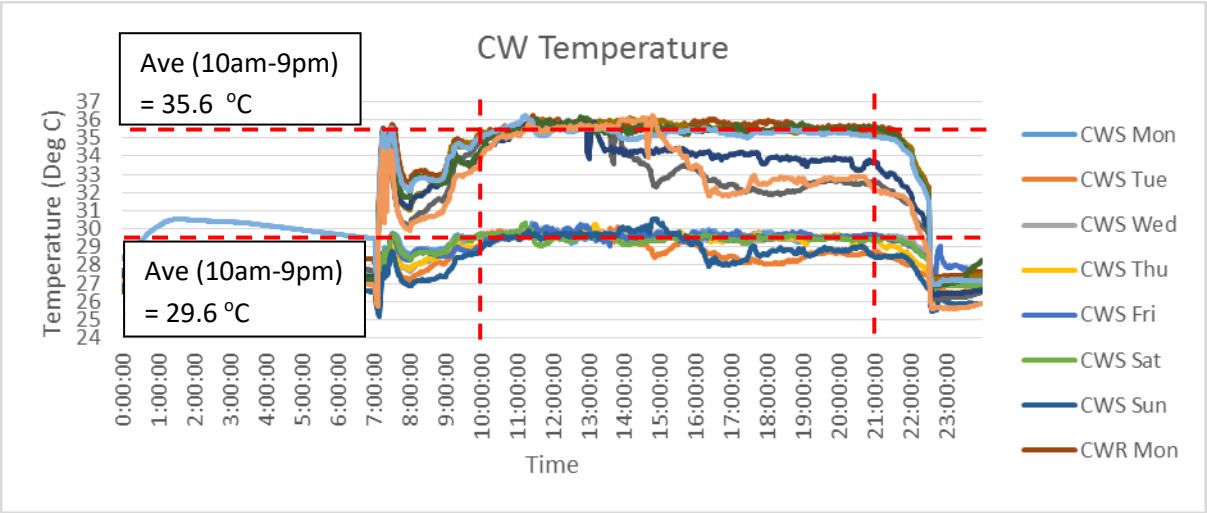

Figure 5: Super-imposed plot of daily condenser water supply/return temperature °C (Example)

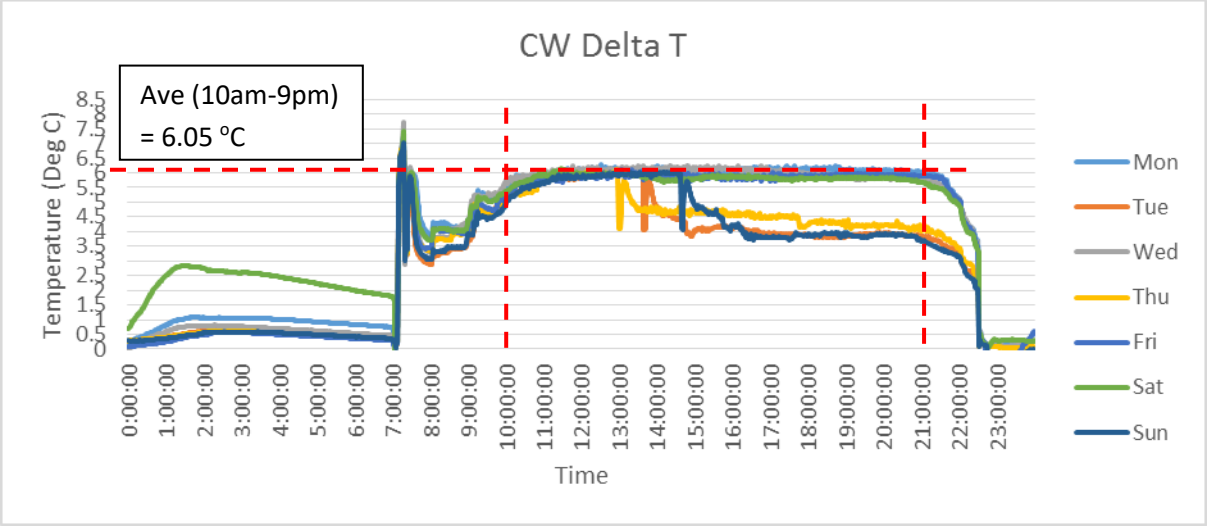

Figure 6: Super-imposed plot of daily condenser water temperature difference °C (Example)

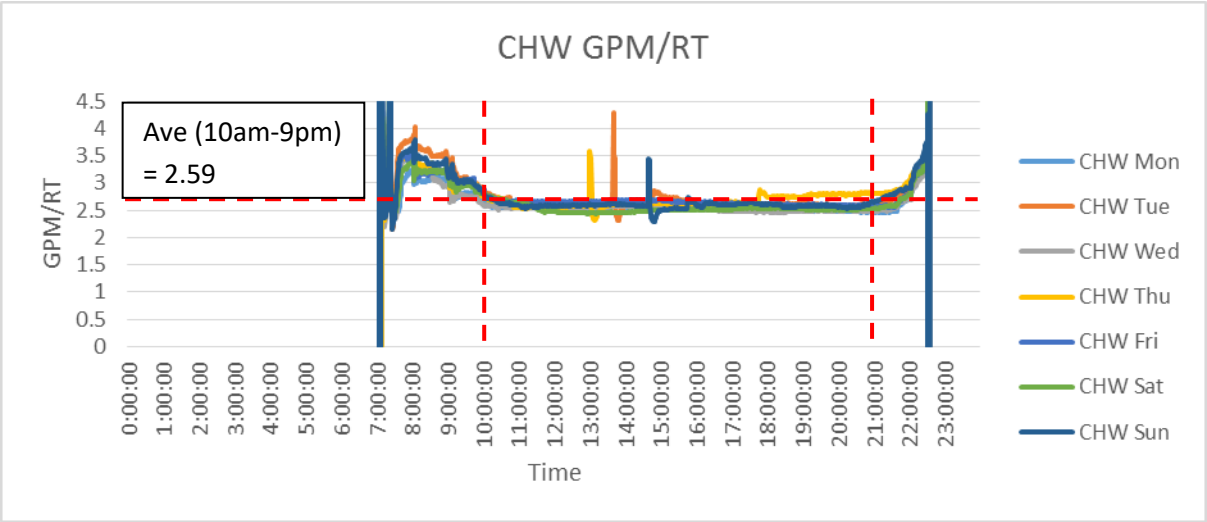

Figure 7: Super-imposed plot of daily chilled water GPM/RT (Example)

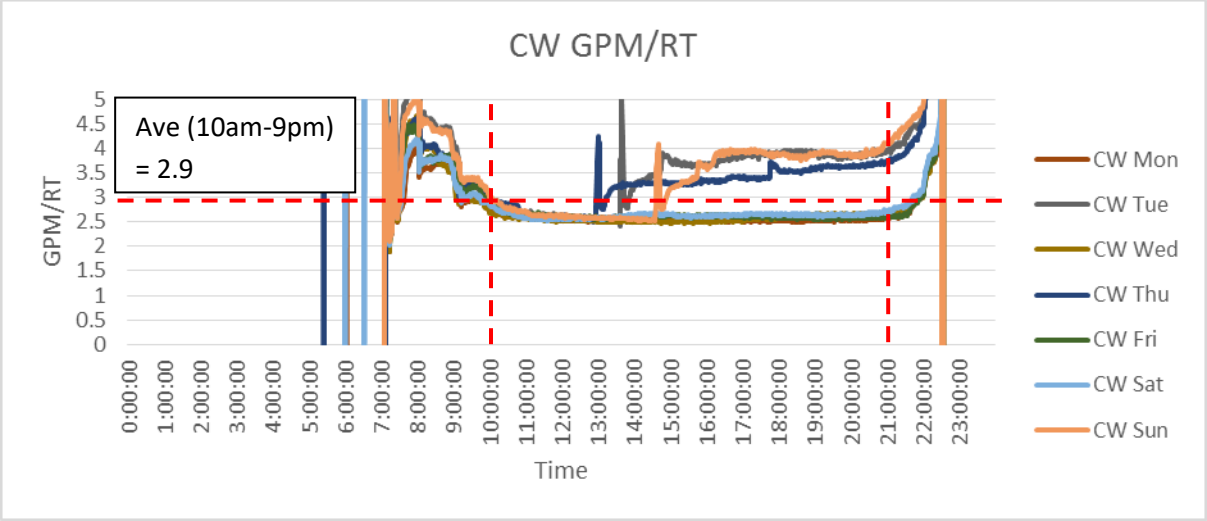

Figure 8: Super-imposed plot of daily condenser water GPM/RT (Example)

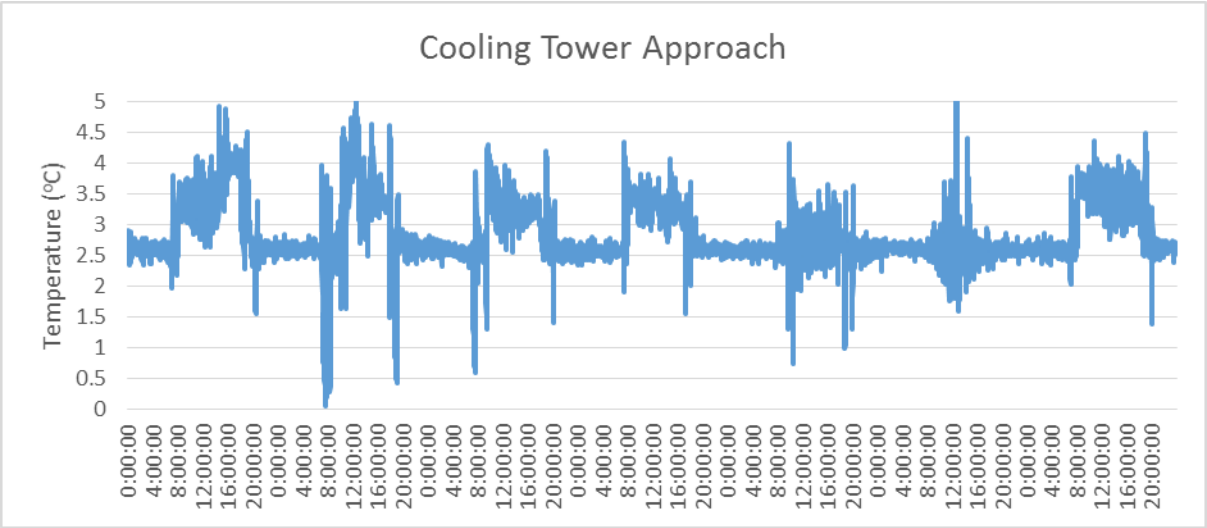

***Figure 9: Cooling Tower Approach Temperature (Example)**

*required if using wet bulb temperature as set point

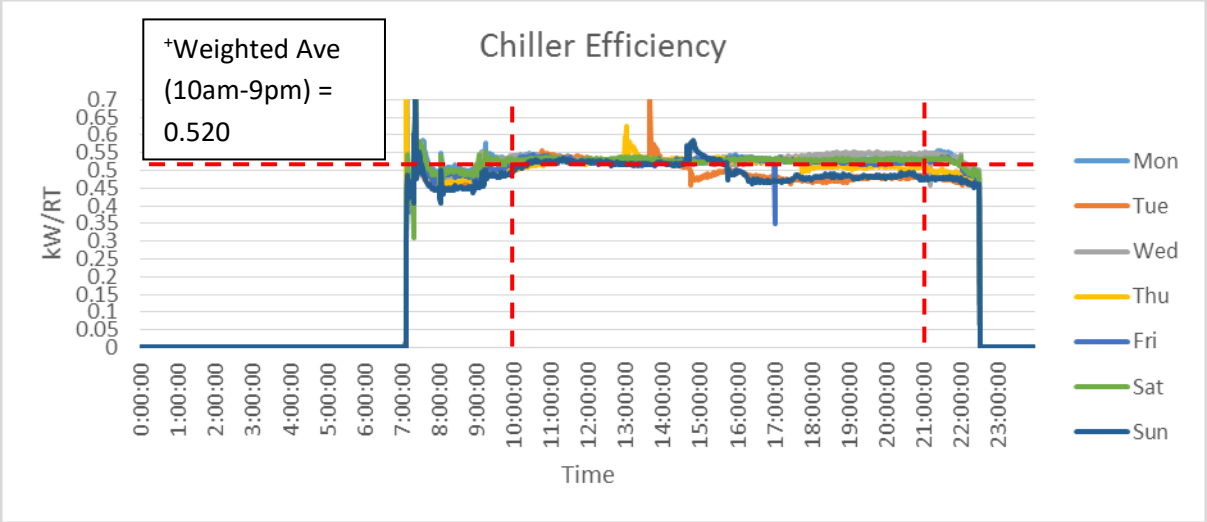

Figure 10: Super-imposed plot of daily chiller efficiency kW/RT (Example)

+Weighted average: ∑ kW-hr / ∑ RT-hr

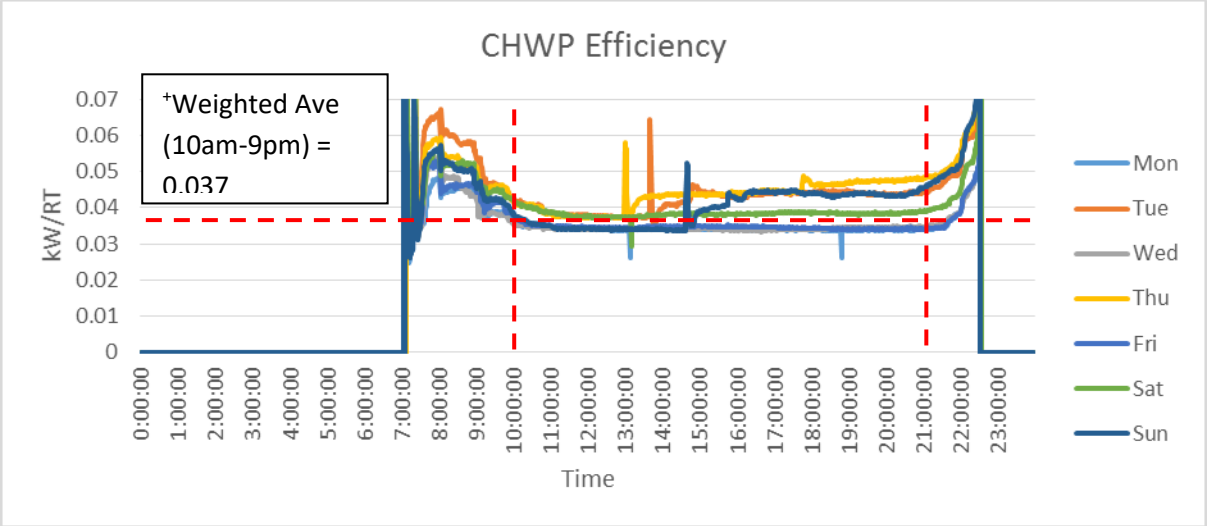

Figure 11: Super-imposed plot of daily chilled water pump efficiency kW/RT (Example)

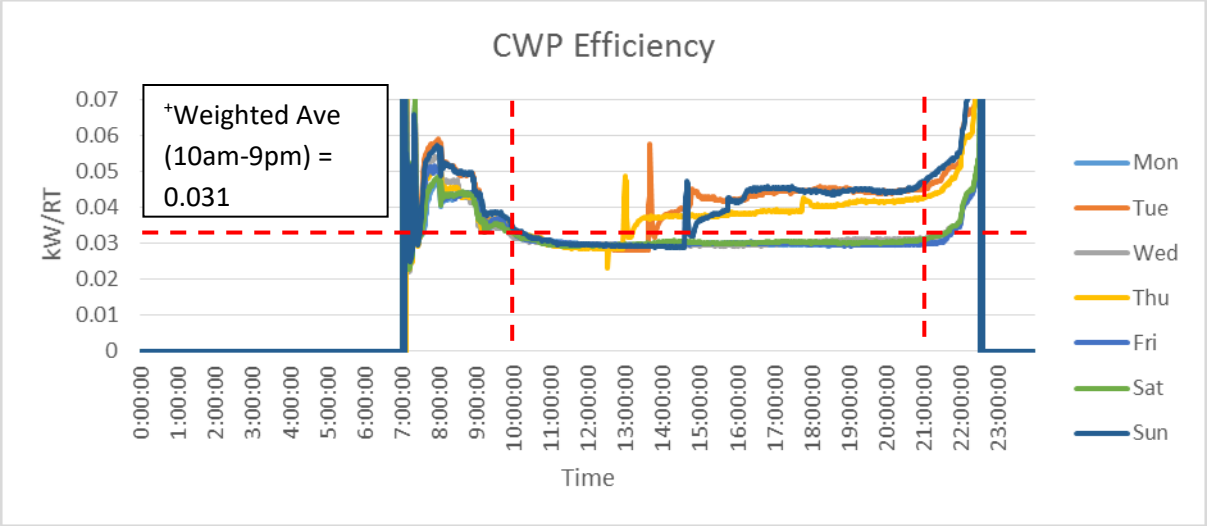

Figure 12: Super-imposed plot of daily condenser water pump efficiency kW/RT (Example)

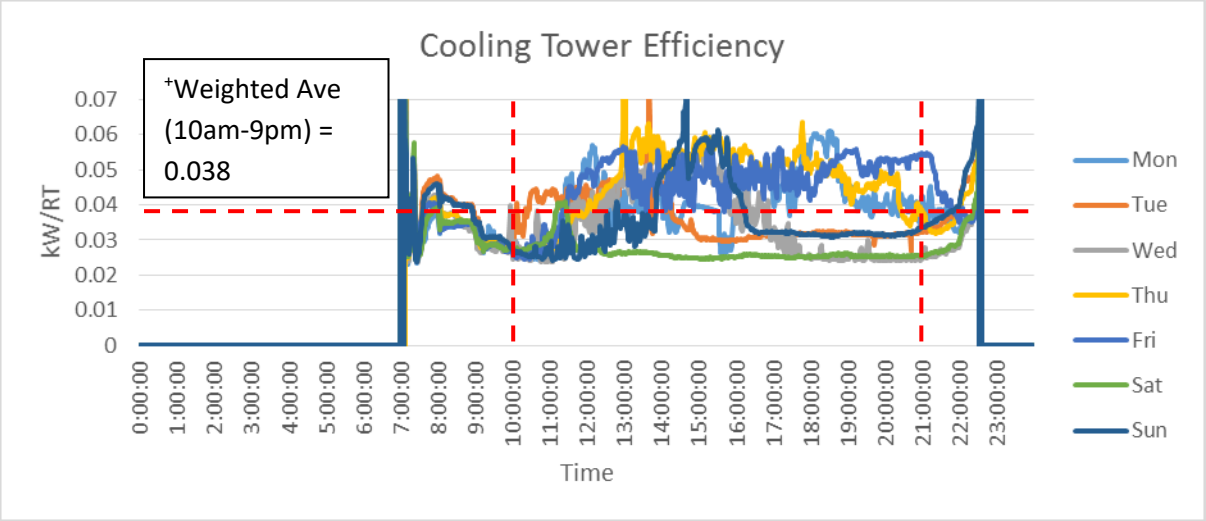

Figure 13: Super-imposed plot of daily cooling tower efficiency kW/RT (Example)

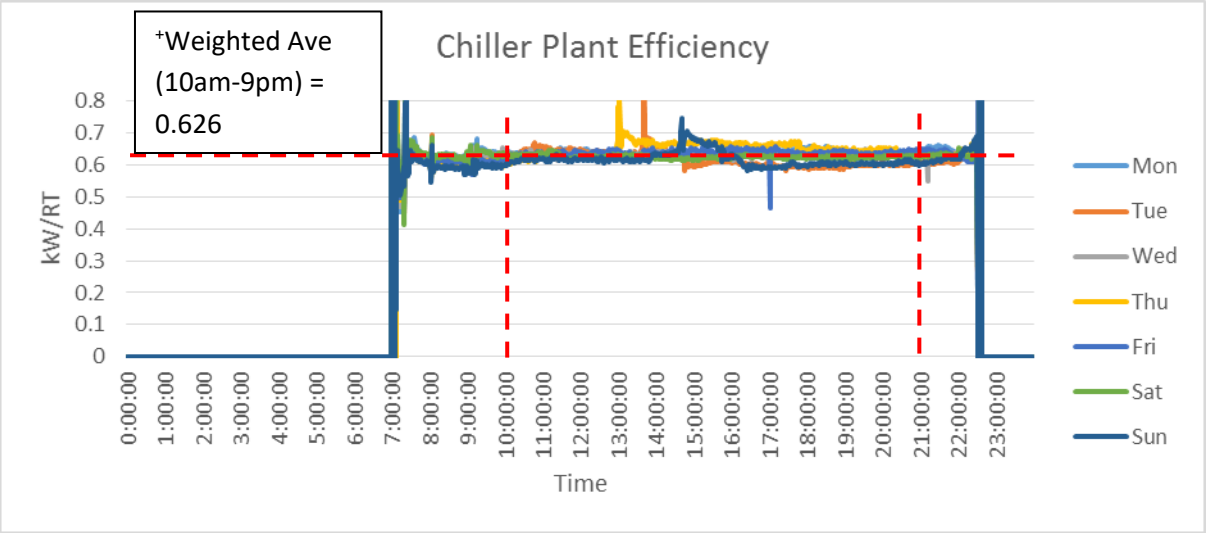

Figure 14:Super-imposed plot of daily chiller plant system efficiency kW/RT (Example)

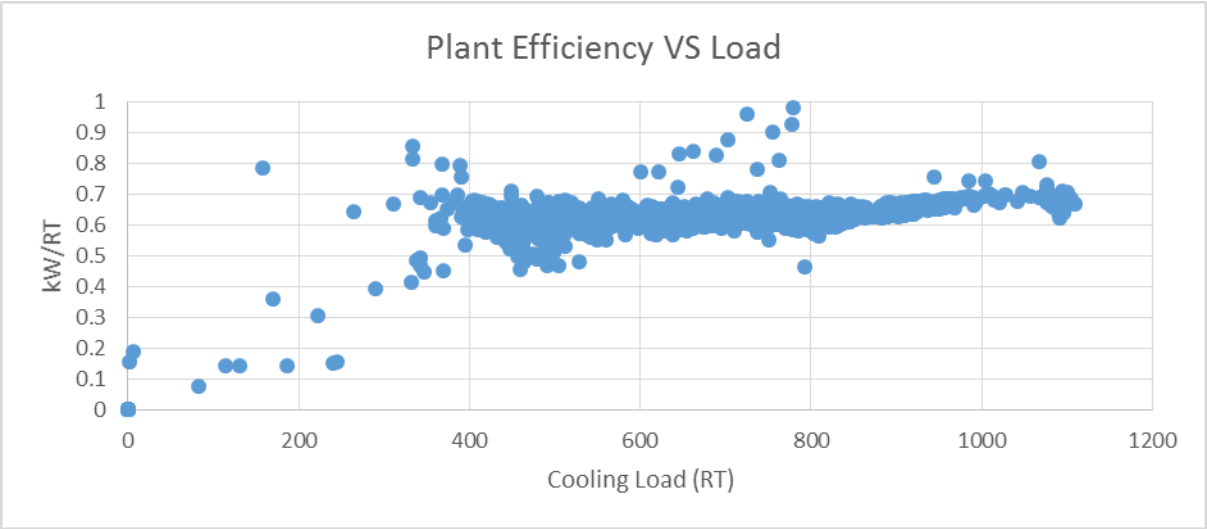

Figure 15: Scatter plot of chiller plant efficiency over cooling load (Example)

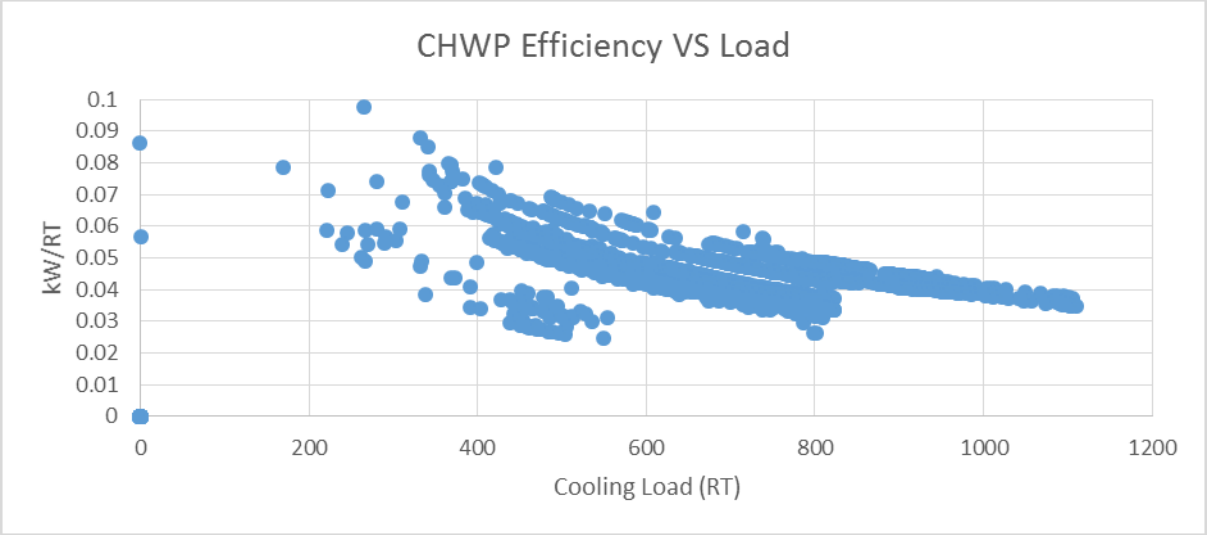

Figure 16: Scatter plot of chilled water pump efficiency over cooling load (Example)

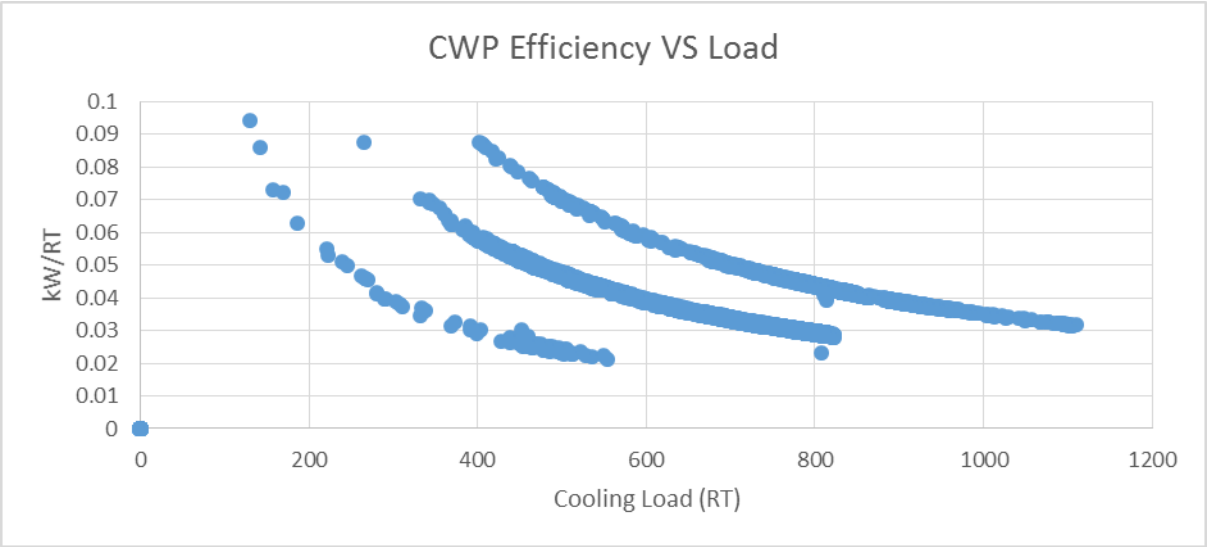

Figure 17: Scatter plot of condenser water pump efficiency over cooling load (Example)

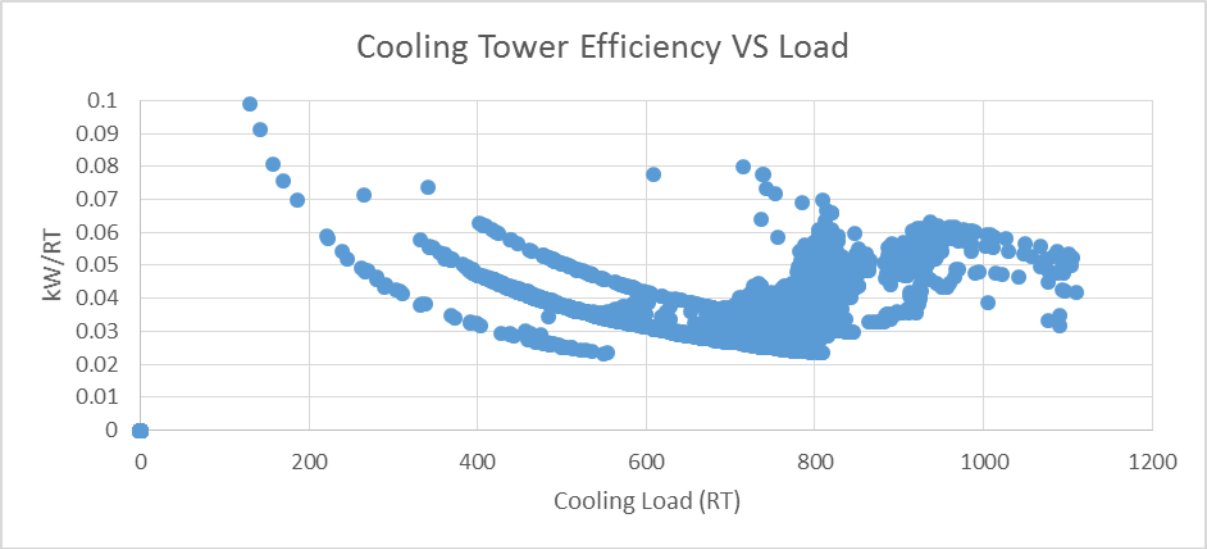

Figure 18: Scatter plot of cooling tower efficiency over cooling load (Example)

5.1 Summary of Chilled-Water Plant Operating Performance

Daily Average Reading	Period		Unit
	Daytime^	Night-time~	
Cooling Load			RTh
Cooling Load Density (Air-con area)			m2/RT
Power Consumption			kWh
Chilled water supply temperature			°C
Chilled water return temperature			°C
Chilled water delta T			°C
Chilled water flow rate			l/s
Chilled water flow rate vs cooling load			USgpm/RT
*Condenser heat rejection			HRT
*Condenser water supply temperature			°C
*Condenser water return temperature			°C
*Condenser water delta T			°C
*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 chiller plant efficiency			kW/RT

Table 5: Chilled Water Plant Performance Summary

*Not applicable to air-cooled Chilled Water Plant

~For hotels and other developments with 24-hour operations only; Night-time shall refer to the period from 11pm – 7am;

^ For hotels and other developments with 24-hour operations, day-time shall refer to the period from 7am – 11pm; for all other developments, daytime shall refer to the normal operating hours stipulated in subsection 4.1.1 of the Energy Audit Code.

5.2 Summary of Air-Side System Operating Performance

Daily Average Reading	Period		Unit
	Daytime^	Night-time~	
Air-side power consumption (a)			kWh
- Pre-AHU (measured)			kWh
- AHU (measured)			kWh
- FCU (nameplate or input power x op			kWh
Chiller plant cooling load (b)			RTh
Overall air-side efficiency (a / b)			kW/RT

Table 6: Air-Side System Performance Summary

5.3 Summary of Building Cooling System Operating Performance

Daily Average reading	Period		Unit
	Daytime^	Night-time~	
Overall air-side efficiency (where applicable)			**kW/RT**
Overall water-side efficiency			**kW/RT**
Total cooling system efficiency (TSE)			**kW/RT**

Table 7: Summary of Building Cooling System Operating Performance (including airside)

6.0 Summary of System Heat Balance (Chilled Water Plant)

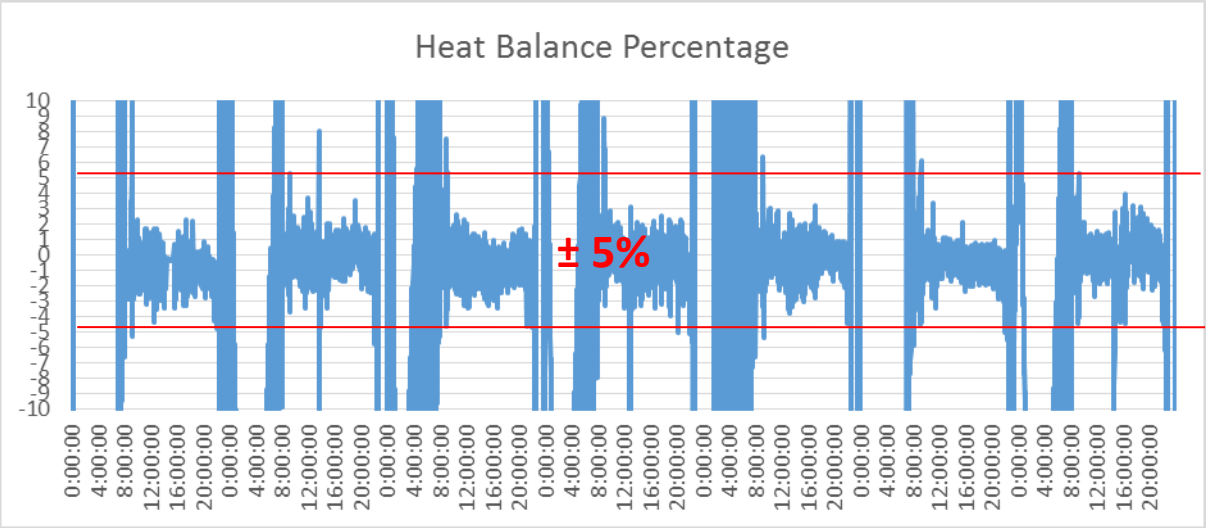

Figure 19: System Level Heat Balance Plot (Example)

	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)

Table 8: Heat Balance Summary

7.0 Schedule of Space Operating Conditions

(10 points Spot measurements)

		Normal operating room conditions		Measured		
	Room name (i.e. Air conditioned occupied/ common Spaces)	**Dry Bulb Temperature (°C)**	**Relative Humidity (%)**	***Dry Bulb Temperature (°C)**	***Relative Humidity (%)**	***CO2 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						
8						
9						
10						

Table 9: Space Condition Schedule (Example)

* Any observation on over-cooling/ under-cooling and ventilating of space conditions should first be investigated and corrected before the energy audit is carry out. Refer to recommended limits of SS553 and SS 554.

8.0 Schedule of AHU Operating Conditions (5 typical units)

(Spot Measurements)

AHU no.	Parameters	Pre-Cooled AHU #1	Pre-Cooled AHU #2	AHU #1	AHU #2	AHU #3
1	Return Air Temp Setpoint(°C)	-	-			
2	Return Air Temp (°C)	-	-			
3	Supply Air Temp Setpoint(°C)	-	-			
4	Supply Air Temp (°C)					
5	Fan Speed Setpoint (Hz/%)					
6	Fan Speed (Hz /%)					
7	Rated (kW)					
8	Running (kW)					
9	Nameplate Airflow (CMH)	-	-			
10	Nameplate W/CMH	-	-			
11	CO2 Setpoint (ppm)	-	-			
12	CO2 (ppm)					
13	Outdoor Air Damper Opening (%)					
14	Outdoor Air Provision (Direct opening to external/ via PAHU or FAF)					
15	Filter Type/ Rating (Bag/ F7)					

Table 10: Schedule of AHU Operating Condition (5 Typical Units)

APPENDIX A

Checklist of Plant Operating Condition (for best practices)

	Yes	No	Actual value
Is the airside efficiency ≤ 0.2 kW/RT?			
Is Chilled water delta T >5.5 °C?			
Is the cooling tower approach temperature ≤ 2.0 °C as compared with outdoor wet bulb temperature?			
Is the Chilled water pump efficiency ≤ 0.03 kW/RT?			
Is the Condenser water pump efficiency ≤ 0.035 kW/RT?			
Is the Cooling Tower efficiency ≤ 0.03 kW/RT?			
Does Refrigerant Condenser approach within the range of 0.5 °C to 1.5 °C?			
Does Refrigerant Evaporator approach within the range of 0.5 °C to 1.5 °C?			

Table 11: Checklist of Plant Operating Condition (for best practices)

APPENDIX B

Temperature Sensor Verification Plots (Example)

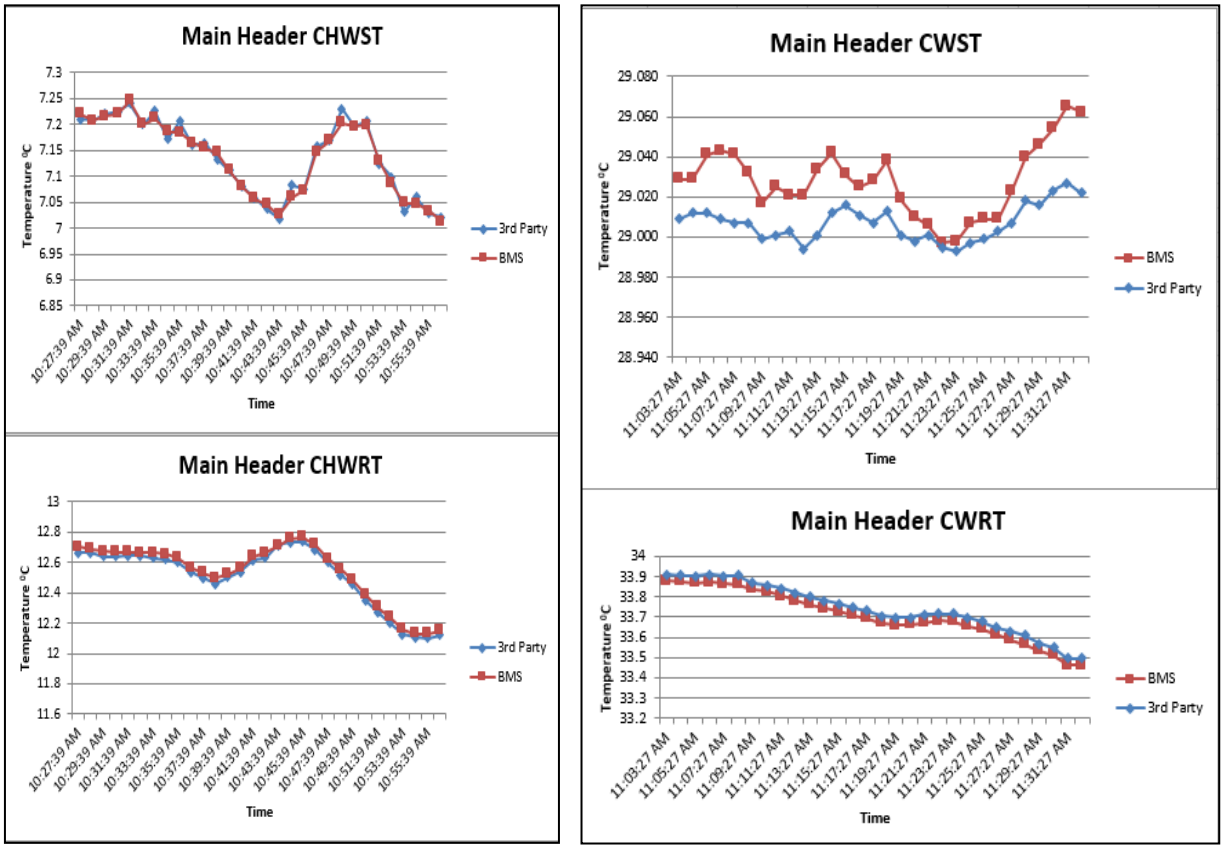

Figure 20: Temperature Verification Plots for Water-Cooled Chiller Plant System (Example)

Project Name: Enter name of project

Date of Verification: Enter date (dd/mm/yyyy)

Verification by: Enter name of PE (Mech)/Energy Auditor

Main Header Chilled Water Supply Temperature				Main Header Chilled Water Return Temperature			
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
10:28:39 AM	7.209	7.207	0.002	10:28:39 AM	12.665	12.690	-0.025
10:29:39 AM	7.221	7.216	0.005	10:29:39 AM	12.640	12.674	-0.034
10:30:39 AM	7.225	7.220	0.005	10:30:39 AM	12.640	12.671	-0.031
10:31:39 AM	7.240	7.246	-0.006	10:31:39 AM	12.642	12.668	-0.026
10:32:39 AM	7.200	7.200	0.000	10:32:39 AM	12.642	12.663	-0.021
10:33:39 AM	7.227	7.211	0.016	10:33:39 AM	12.628	12.662	-0.034
10:34:39 AM	7.172	7.186	-0.014	10:34:39 AM	12.622	12.653	-0.031
10:35:39 AM	7.205	7.184	0.021	10:35:39 AM	12.601	12.631	-0.030
10:36:39 AM	7.160	7.164	-0.004	10:36:39 AM	12.537	12.567	-0.030
10:37:39 AM	7.164	7.154	0.010	10:37:39 AM	12.499	12.532	-0.033
10:38:39 AM	7.133	7.146	-0.013	10:38:39 AM	12.460	12.497	-0.037
10:39:39 AM	7.111	7.111	0.000	10:39:39 AM	12.501	12.523	-0.022
10:40:39 AM	7.079	7.080	-0.001	10:40:39 AM	12.535	12.560	-0.025
10:41:39 AM	7.059	7.057	0.002	10:41:39 AM	12.614	12.640	-0.026
10:42:39 AM	7.037	7.046	-0.009	10:42:39 AM	12.631	12.664	-0.033
10:43:39 AM	7.019	7.026	-0.007	10:43:39 AM	12.712	12.710	0.002
10:44:39 AM	7.082	7.060	0.022	10:44:39 AM	12.732	12.758	-0.026
10:45:39 AM	7.076	7.073	0.003	10:45:39 AM	12.736	12.767	-0.031
10:46:39 AM	7.157	7.147	0.010	10:46:39 AM	12.683	12.718	-0.035
10:47:39 AM	7.170	7.169	0.001	10:47:39 AM	12.600	12.626	-0.026
10:48:39 AM	7.231	7.203	0.028	10:48:39 AM	12.518	12.557	-0.039
10:49:39 AM	7.198	7.196	0.002	10:49:39 AM	12.453	12.484	-0.031
10:50:39 AM	7.206	7.199	0.007	10:50:39 AM	12.351	12.392	-0.041
10:51:39 AM	7.125	7.128	-0.003	10:51:39 AM	12.273	12.305	-0.032
10:52:39 AM	7.098	7.085	0.013	10:52:39 AM	12.201	12.239	-0.038
10:53:39 AM	7.031	7.048	-0.017	10:53:39 AM	12.124	12.161	-0.037
10:54:39 AM	7.060	7.047	0.013	10:54:39 AM	12.106	12.131	-0.025
10:55:39 AM	7.028	7.032	-0.004	10:55:39 AM	12.100	12.129	-0.029
10:56:39 AM	7.021	7.013	0.008	10:56:39 AM	12.122	12.148	-0.026
Average	7.138	7.136	0.003	Average	12.508	12.537	-0.030
			Passed				Passed

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
11:03:27 AM	29.009	29.029	-0.020	11:03:27 AM	33.912	33.879	0.033
11:04:27 AM	29.012	29.029	-0.017	11:04:27 AM	33.907	33.876	0.031
11:05:27 AM	29.012	29.041	-0.029	11:05:27 AM	33.904	33.867	0.037
11:06:27 AM	29.009	29.043	-0.034	11:06:27 AM	33.910	33.874	0.036
11:07:27 AM	29.007	29.041	-0.034	11:07:27 AM	33.902	33.864	0.038
11:08:27 AM	29.007	29.032	-0.025	11:08:27 AM	33.906	33.862	0.044
11:09:27 AM	28.999	29.017	-0.018	11:09:27 AM	33.867	33.840	0.027
11:10:27 AM	29.001	29.025	-0.024	11:10:27 AM	33.858	33.826	0.032
11:11:27 AM	29.003	29.021	-0.018	11:11:27 AM	33.841	33.806	0.035
11:12:27 AM	28.994	29.021	-0.027	11:12:27 AM	33.818	33.781	0.037
11:13:27 AM	29.001	29.034	-0.033	11:13:27 AM	33.801	33.764	0.037
11:14:27 AM	29.012	29.042	-0.030	11:14:27 AM	33.780	33.744	0.036
11:15:27 AM	29.016	29.031	-0.015	11:15:27 AM	33.767	33.729	0.038
11:16:27 AM	29.011	29.025	-0.014	11:16:27 AM	33.746	33.709	0.037
11:17:27 AM	29.007	29.028	-0.021	11:17:27 AM	33.734	33.696	0.038
11:18:27 AM	29.013	29.038	-0.025	11:18:27 AM	33.706	33.672	0.034
11:19:27 AM	29.001	29.019	-0.018	11:19:27 AM	33.697	33.660	0.037
11:20:27 AM	28.998	29.010	-0.012	11:20:27 AM	33.698	33.662	0.036
11:21:27 AM	29.001	29.006	-0.005	11:21:27 AM	33.712	33.670	0.042
11:22:27 AM	28.995	28.997	-0.002	11:22:27 AM	33.718	33.681	0.037
11:23:27 AM	28.993	28.998	-0.005	11:23:27 AM	33.718	33.679	0.039
11:24:27 AM	28.997	29.007	-0.010	11:24:27 AM	33.699	33.658	0.041
11:25:27 AM	28.999	29.009	-0.010	11:25:27 AM	33.679	33.642	0.037
11:26:27 AM	29.003	29.009	-0.006	11:26:27 AM	33.648	33.615	0.033
11:27:27 AM	29.007	29.023	-0.016	11:27:27 AM	33.628	33.586	0.042
11:28:27 AM	29.018	29.040	-0.022	11:28:27 AM	33.611	33.564	0.047
11:29:27 AM	29.016	29.046	-0.030	11:29:27 AM	33.568	33.535	0.033
11:30:27 AM	29.023	29.054	-0.031	11:30:27 AM	33.549	33.511	0.038
11:31:27 AM	29.027	29.065	-0.038	11:31:27 AM	33.498	33.463	0.035
11:32:27 AM	29.022	29.062	-0.040	11:32:27 AM	33.496	33.462	0.034
Average	29.007	29.028	-0.021	Average	33.743	33.706	0.037
			Passed				Passed

Table 12: Verification of temperature sensors

APPENDIX C

Total Cooling System Efficiency (Example)

Average reading	Period		Unit
	Daytime[See Note 2]	Night-time[See Note 3]	
Overall air-side efficiency [See note 1]			kW/RT
Overall water-side efficiency			kW/RT
Total cooling system efficiency			kW/RT

Table 13: Total Cooling System Efficiency (including airside system)

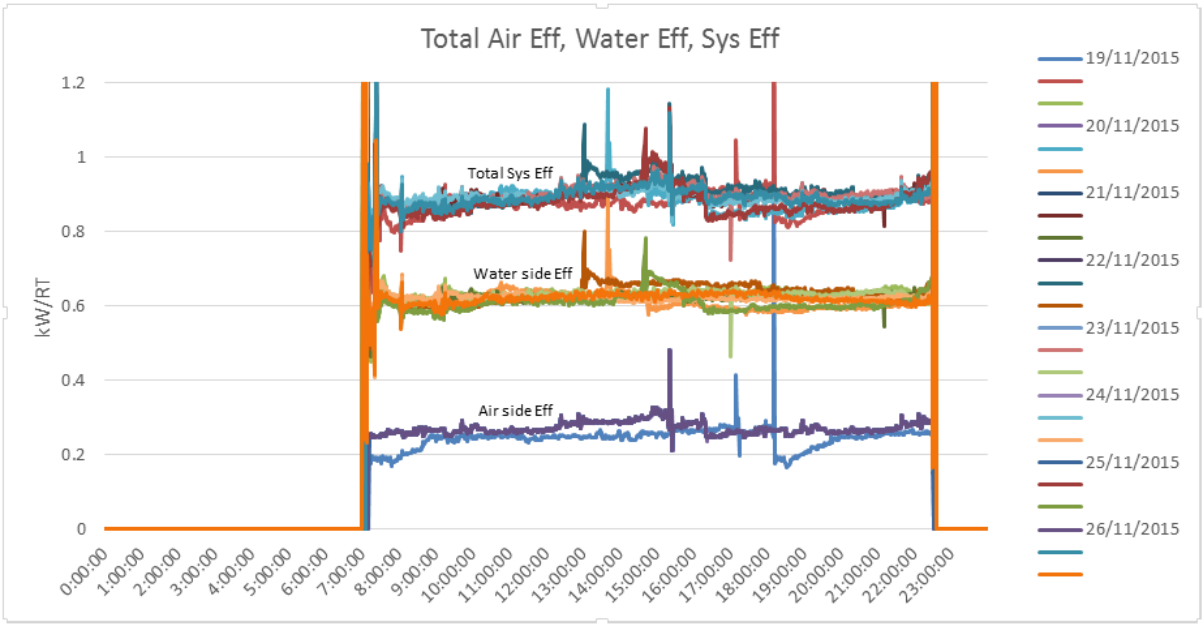

Figure 21: Super-imposed plot of daily total cooling system efficiency kW/RT (Example)

Note (1)The computation of the air-side efficiency is applicable to :

(a) buildings for which the design score submission under the ESM Regulations 2013 were made on or after 1 June 2022;

(b) buildings where the applications for planning permission were submitted to the competent authority under the Planning Act 1998 on or after 1 December 2021 under ES Regulations 2008; and

(c) buildings wholly or partly on land sold on or after 30 June 2022 under the GLS Programme and subject to the ES Regulations 2008.

Note (2) - For hotels and other developments with 24-hour operations, day-time shall refer to the period from 7am – 11pm; for all other developments, daytime shall refer to the normal operating hours stipulated in subsection 4.1.1 of the Energy Audit Code.

Note (3) - For hotels and other developments with 24-hour operations only; Night-time shall refer to the period from 11pm – 7am.