78065

ENERGY EFFICIENCY THROUGH MANAGEMENT AND AUDIT

Organised by:

BCA ACADEMY
of the built environment

200 Braddell Road
Singapore 579700
Tel: 6248 9999
Website: http://www.bcaa.edu.sg
Email:bca_academy@bca.gov.sg

GMFP Core and GMP Group 2 Elective Module:
2-Day Course for Energy Efficiency Through Management and Audit

Trainers:
- **Ahmad Sulaiman**
- **Benjamin Lai**

Day 1	
Time	**Topic**

9.00am	• Energy Management Overview
	  • Energy management concept
	  • Tools for appraising energy management performance
	  • Setting energy target and plan

11.00am	• Energy Economic Analysis
	  • Life cycle cost concept in economic and analysis
	  • Time value of money concept

12.00pm	Lunch

1.00pm	• Energy Economic Analysis
	  • Project measures of worth
	  • Economic models of optimal energy use
	  • Energy policies (e.g. tax refunding etc.)

2.00pm	• Budget planning and procurement Procedures
	  • Setting of the budget planning for improving energy performance
	  • Financial analysis and cost prediction for energy saving assessment
	  • Preparing the checklists for procurement procedures
	  • Energy performance contract case studies

4.00pm	• Introduction and definition of different Energy Audit Levels
	• Differences between these three (3) levels:
	  • Level I Audit - Preliminary
	  • Level II Audit - Standard
	  • Level III Audit - Detailed

5.00pm	End

Day 2	
Time	**Topic**
9.00am	• Scope of works and report requirements of the three (3) audit levels • Energy audit at level I and II – Case Studies

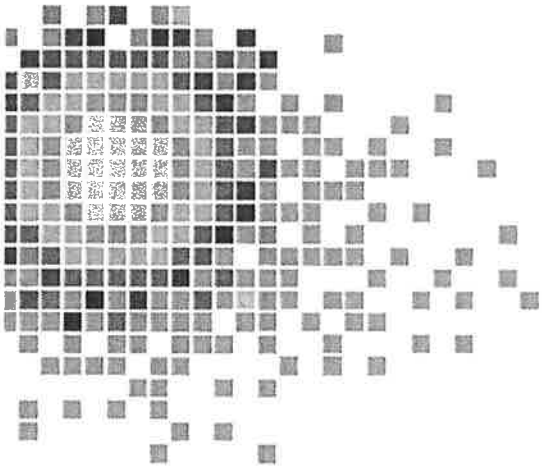
10.00am	• Energy Measurement and Verification (M&V)
	  • International Performance Measurement and Verification
	  • Setup of M&V processes and planning
	  • Different M&V methods and basic framework for M&V

12.00pm	Lunch

1.00pm	• Analysis methodology and accuracy for energy consumption
	  • Energy-use & performance profiling/benchmarking
	  • Baseline Modelling and saving prediction

3.00pm	• Audit report
	  • Self-evaluation checklists
	  • Determine the major factors of energy consumption in different audit levels(overall or specialized)
	  • Discover transferable techniques for saving energy
	  • Provide guidance to pinpoint modifications to reduce energy

	consumption • Identify areas where constructive suggestions welcome • Guideline and the contents for report writing
4.30pm	Assessment



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1. Energy Management Overview

Energy Management Concept

Outline

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- Energy Management Concept
- Energy Management Appraising Tools
- Setting Energy Target and Plan

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Outline

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- Energy Management Concept
- Energy Management Appraising Tools
- Setting Energy Target and Plan

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Definition

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"Energy Management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives"

Ref: VDI-Guideline VDI 4602, page 3, Beuth Verlag, Berlin 2007

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Why Energy Management?

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Proactive

- Impact of energy cost to your business?
- Corporate environmental responsibility?

Motivation

- Interests
- Purpose

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S$3.98b
Group Revenue

For the year ended 31 December 2013, the Group posted revenue of S$3.98 billion, EBIT of S$1.80 billion, and a 43% increase in operating PATMI to S$527.7 million

Energy and Water Usage Reduction: For the first nine months of 2013, the reduction in energy usage in KWh/m² was 10% and the reduction in water usage in m³/m² was 19% from the 2008 baseline. CapitaLand will continue to implement energy and water conservation measures to ensure efficient operations and minimise resource wastage.

	Note	The Group 2013 $'000	2012 $'000
Revenue	25	3,977,487	3,301,363
Cost of sales		(2,891,707)	(2,073,289)
Gross profit		1,085,780	1,228,074
Other operating income	26(a)	381,127	586,949
Administrative expenses		(517,627)	(580,251)
Other operating expenses		(198,637)	(52,122)
Profit from operations		750,643	1,182,650
Finance costs	26(d)	(444,490)	(498,953)
Share of results (net of tax) of:			
– associates		863,887	699,197
– joint ventures		183,481	135,584
		1,047,368	834,781
Profit before taxation	26	1,353,521	1,518,478
Taxation	27	(168,908)	(201,907)
Profit for the year		1,184,613	1,316,571

What is the impact of energy cost to a REIT?

CapitaLand Limited Annual Report 2013 *Ref: http://media.corporate-ir.net/media_files/IROL/13/130462/CapitaLand_Limited_AR13.pdf*

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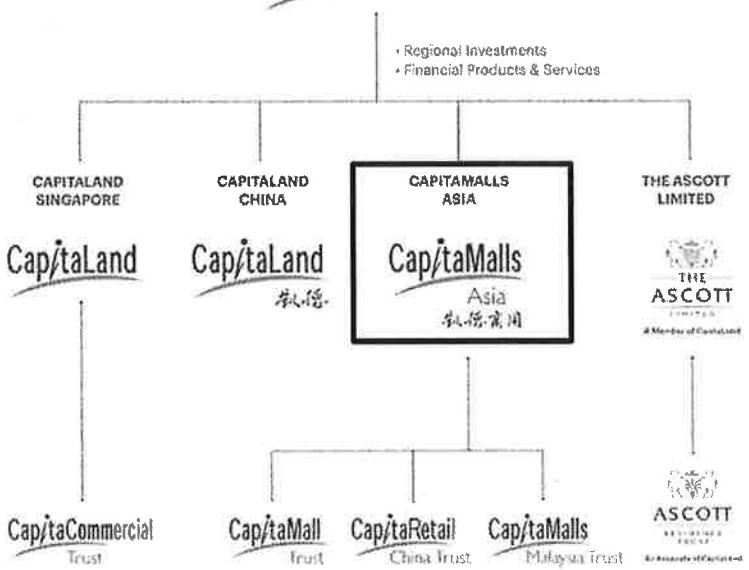
CapitaLand



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~ 400 kWh/m²/year

CapitaMalls Asia 凱德商用

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105

Shopping Malls

Across 53 cities in Singapore, China, Malaysia, Japan and India, with a total property value of approximately S$34.3 billion and a total gross floor area (GFA) of approximately 98.5 million square feet

Of these, 85 malls are operational while the other 20 are under development.

400 kWh/m2/year
x
9.15 Mil m2
x
85/125 in operation
x
Landlord's Consumption 60%

= 1,778 GWh

= SGD 270 Mil

Ref: http://media.corporate-ir.net/media_files/IROL/13/130462/CapitaLand_Limited_AR13.pdf

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Offices : 218
Hotels : 292
Retails : 405
Mixed Development : 264

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>S$ 300 Mil
Energy Costs

Energy Costs
>8%
Over Revenue

Ref: http://media.corporate-ir.net/media_files/IROL/13/130462/CapitaLand_Limited_AR13.pdf

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Why Energy Management?

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Proactive | **Motivation**

Impact of energy cost to your business?	Interests
Corporate environmental responsibility?	Purpose

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>S$ 300 Mil
Energy Costs

Energy Costs
>8%
Over Revenue

Are there INTERESTS to implement ENERGY MANAGEMENT Proactively?

Ref: http://media.corporate-ir.net/media_files/IROL/13/130462/CapitaLand_Limited_AR13.pdf

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Why Energy Management?

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Proactive → Impact of energy cost to your business? → Corporate environmental responsibility?

Motivation → Interests → Purpose

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>S$ 300 Mil
Energy Costs

Energy Costs
>8%
Over Revenue

>1,778
GWH
Energy Consumption

> 3.6 Mil
Annual Tons
CO2 Emission

Is there enough MOTIVATION to implement ENERGY MANAGEMENT Proactively to save the environment?

Ref: http://media.corporate-ir.net/media_files/IROL/13/130462/CapitaLand_Limited_AR13.pdf

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S$3.98b
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> **3.6** Mil
Annual Tons CO2 Emission

> **178** Mil
Trees to Offset Annually

Is there enough MOTIVATION to implement ENERGY MANAGEMENT Proactively to save the environment?

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Why Energy Management?

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Organized

- Who is responsible?
- Is accountability defined?

Objectives

- Common Goals, Objectives & Targets
- Incentive, penalty, performance contracting

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Organized

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- Who is responsible?
  - Energy Manager
  - Operations Manager
  - Engineering Director
  - Building Manager
- One leader appointed to be responsible for Energy Management
- Reports to CEO, COO or Operations Director
- Accountability must be defined using Management by Objectives (MBO)
- Use incentives, penalty and performance bonus to promote accountability

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Organized

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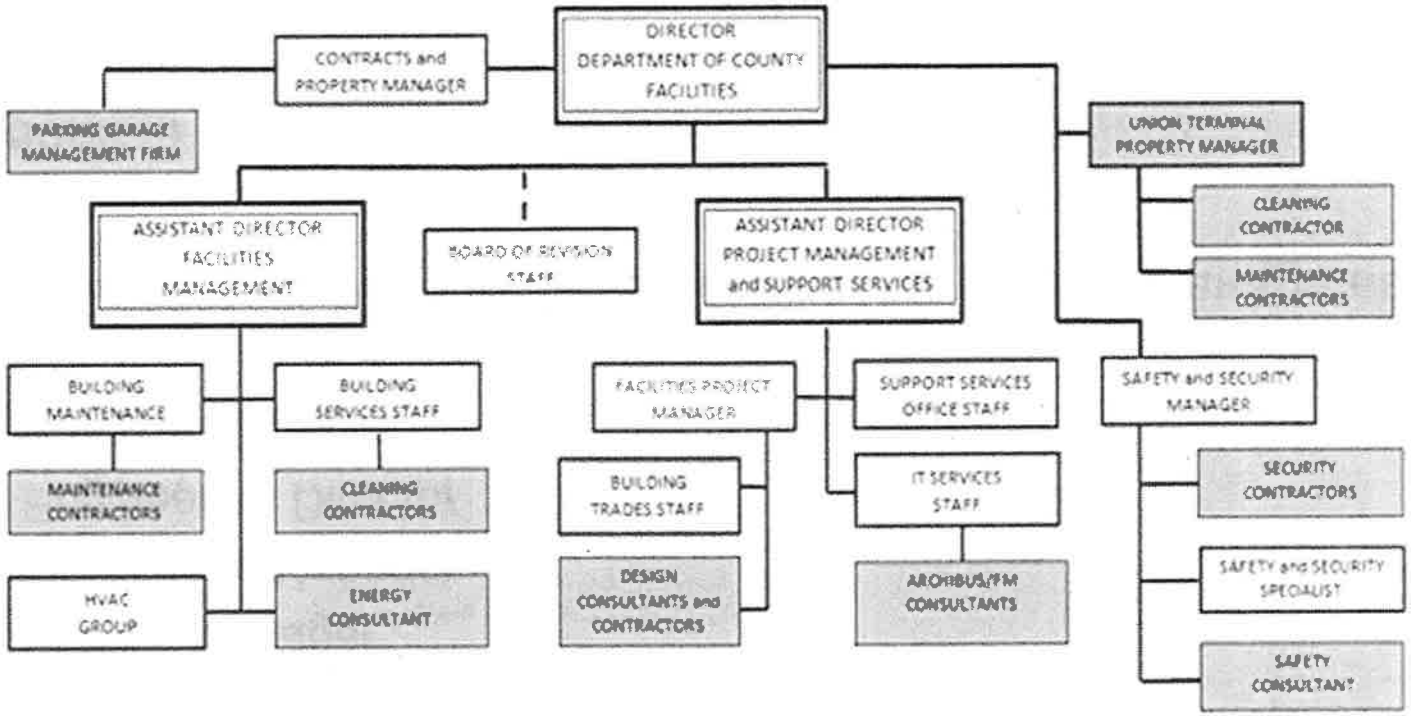
- Sample organization chart



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Why Energy Management?

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Systematic Coordination	Management System
Policy? Baseline? Review? System	SS ISO 50001
Process? M&V Tools? Periodic Review?	PDCA

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Why Energy Management?

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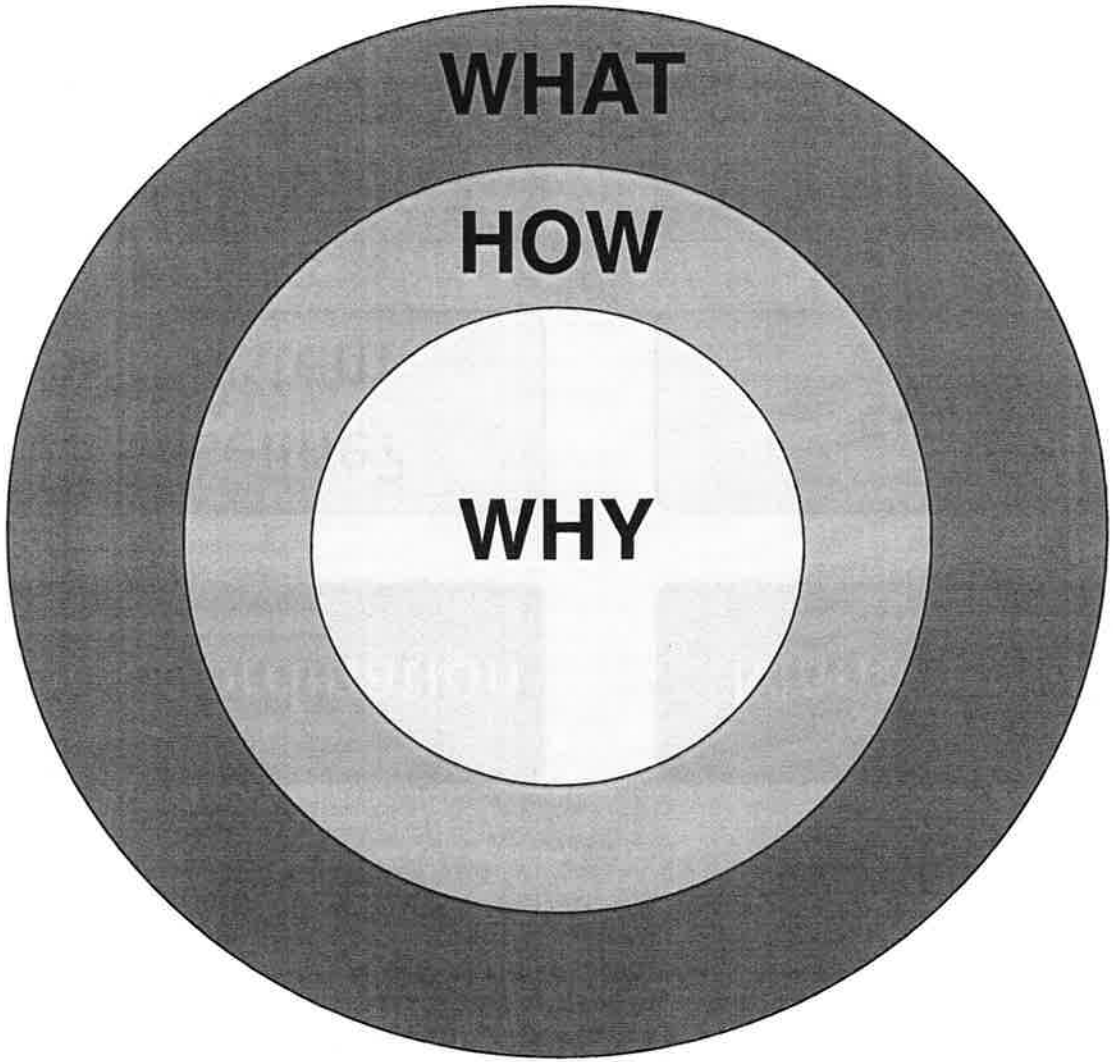

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Class Activity

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- Break up into groups
- Survey impact of energy cost to business of 3 companies
- Time: 10 minutes

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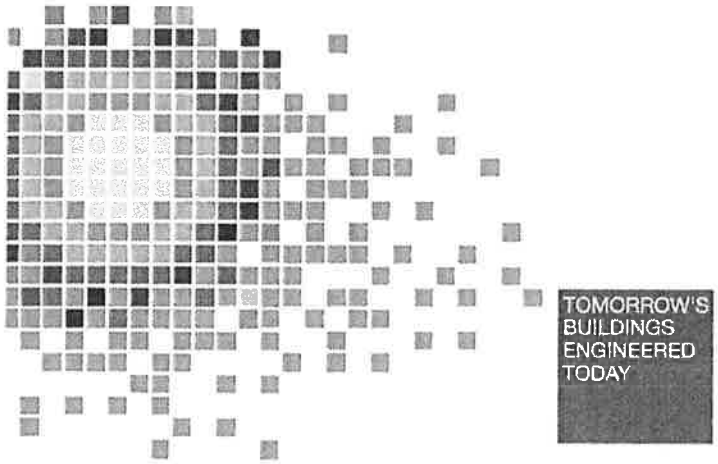

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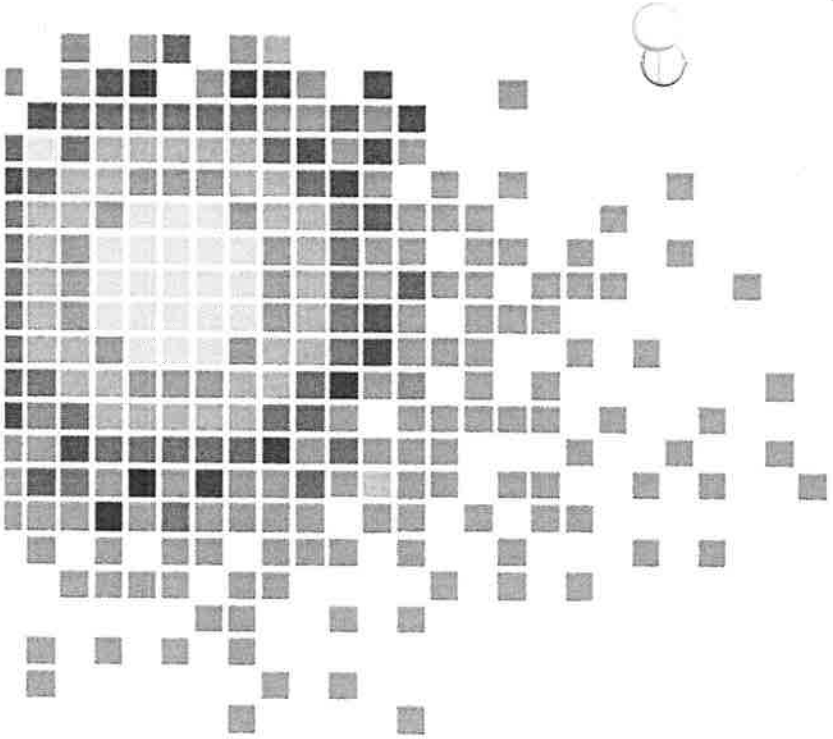
Thank You



TOMORROW'S
BUILDINGS
ENGINEERED
TODAY

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1. Energy Management Overview

Tools for Appraising Energy Management Performance

Outline

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- Energy Management Concept
- Energy Management Appraising Tools
- Setting Energy Target and Plan

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Energy Performance

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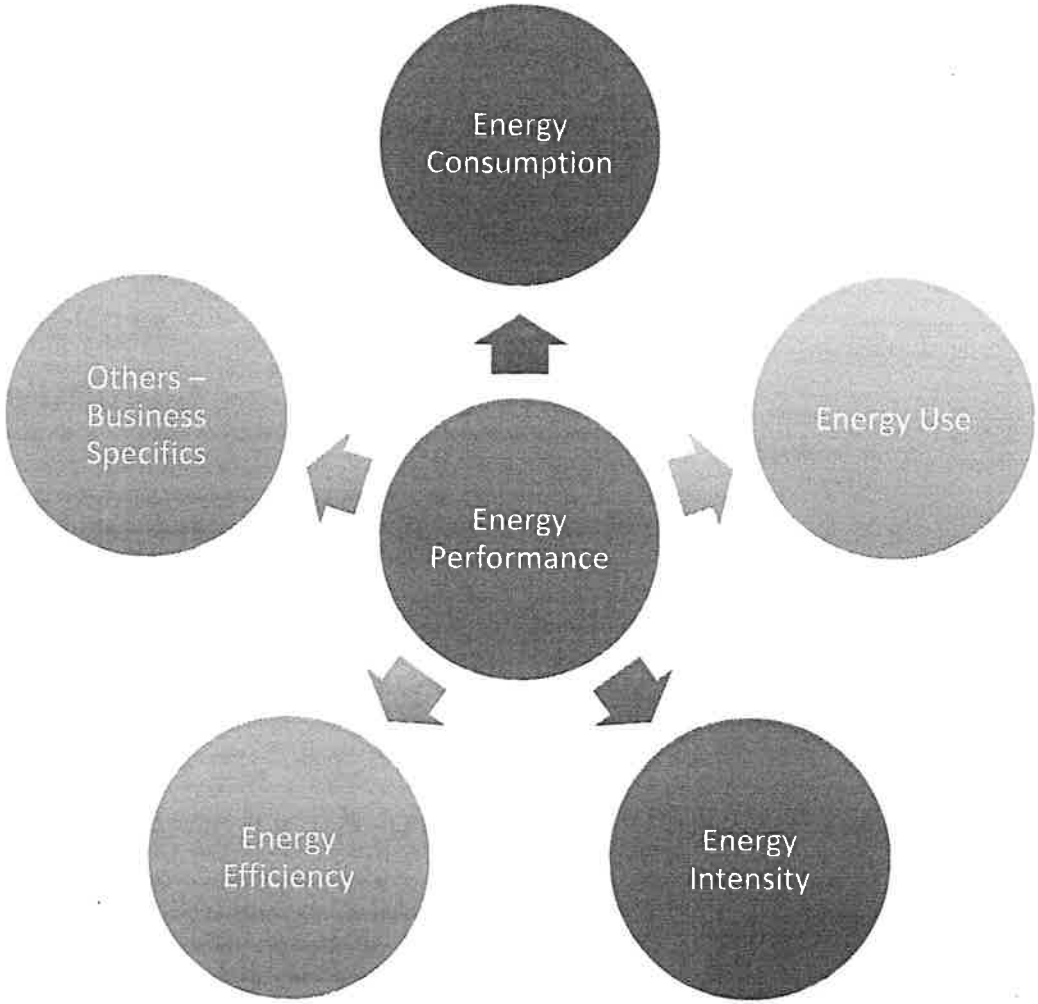

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Energy Consumption



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- Energy includes electricity, fuels (gas, diesel), steam, heat, chilled water, compressed air, etc..
- Energy consumption is quantity of energy procured, harvested and used in the building
- Utility Bills Analysis
  - Past 12 months
  - Electricity, Gas, Diesel, etc.
- Energy Consumption per Year, kWh/year, commonly used benchmarking

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Energy Consumption



- Electricity Consumption

Account Details	Rates / Basis of Charges		Units		Amount (SGD)
Energy Charges					
Energy Charge (Fixed) - Tier 1	0.2318000	SGD/kWh	884,348.100	kWh	204,991.89
Energy Charge (Fixed) - Tier 2	0.2318000	SGD/kWh	137,433.900	kWh	31,857.18
Energy Charge (Tariff) - Tier 1	0.2337300	SGD/kWh	884,348.100	kWh	206,698.68
Energy Charge (Tariff) - Tier 2	0.1482740	SGD/kWh	137,433.900	kWh	20,377.87
	Energy Charges Total		2,043,564.000	kWh	463,925.62
Transmission Charges					
UOS - Peak Charge	0.0074000	SGD/kWh	1,768,696.200	kWh	13,088.35
UOS - Off Peak Charge	0.0008000	SGD/kWh	274,867.800	kWh	219.89
Maximum Demand			4,783.200	kW	
Contracted Capacity Charge	7.4900000	SGD/kW	4,760.000	kW	35,652.40
Un-contracted Capacity Charge	11.2400000	SGD/kW	23.200	kW	260.77
	Transmission Charges Total				49,221.41

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Energy Consumption



- Gas Consumption

SUMMARY OF CHARGES 31 Mar 2012 to 30 Apr 2012	Amount ($)
Balance B/F from Previous Bill	18,905.86
Payment on 23-04-2012 - Thank You	-18,905.86
Outstanding Balance	0.00
Total Current Charges due on 23 May 2012 (Wed)	18,635.32
Total Amount Payable will be deducted from your account with HSBC Ltd on 23 May 2012	**$18,635.32**

SP Services Ltd
Orchard P.O. Box 341
Singapore 912312
Co. Registration No.: 199504470N
GST Reg No. M2-8920920-4
General Enquiries: 1800 2222333
Credit Arrangement: 6671 7100
Fax: 6304 8229
www.spservices.com.sg
spservices@singaporepower.com.sg

Payment received on or after 09.05.2012 may not be included in this bill.

CURRENT MONTH METER READING AND CONSUMPTION	Meter No.	Meter Reading	Total Meter Usage
Gas Services by City Gas Pte Ltd			
Reading taken on 30-04-2012	GM525139	221517	
Reading taken on 30-04-2012	GM9320272	191075	
Reading taken on 30-04-2012	IM750592	355630	
Reading taken on 30-04-2012	KM0117015	854344	87343

CURRENT MONTH CHARGES	Usage	Rate ($)	Amount ($)	Total ($)
Gas Services by City Gas Pte Ltd				
Gas	87343 kWh	0.1994	17,416.19	**17,416.19**
Total Charges			17,416.19	**17,416.19**
Goods & Services Tax	$17,416.19	7%	1,219.13	**1,219.13**
Total Current Charges Inclusive of GST				**$18,635.32**

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Energy Consumption



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- Gas Consumption
  - SCM = "Standard Cubic Meter"
  - 1 SCM refers to one cubic meter at atmospheric pressure and 15.56°C
  - 1 Million BTU (MMBTU) = 26.24 SCM
  - 69,587 SCM =

Current Meter Read	29/02/2012	5,205,222	SCM	
Previous Read	01/02/2012	5,135,635	SCM	
	Difference	69,587	SCM	Equivalent to **2,651.6018** MMBTU

Energy Charges	Rate	Quantity	USD Amount
Gas Charges	23.183296	2,651.6018	$61,472.87

Messages

To convert from SCM to MMBtu, the conversion factor = (35.3146 x GHV)/ 1,000,000 .

INDEXES

HSFO	732.1462
GHV	1,079.0110

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Energy Consumption



- Diesel Consumption
  - Purchased in litres or gallons
  - Energy Content, 10 kWh/litre

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Energy Use



- Energy Use is defined as manner or kind of application of energy

- Cooling (Chiller Plant, Airside Systems), Mechanical Ventilation, Lighting, Lifts/Escalators, Receptacle Loads, Hot Water, Production Facilities

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Energy Use



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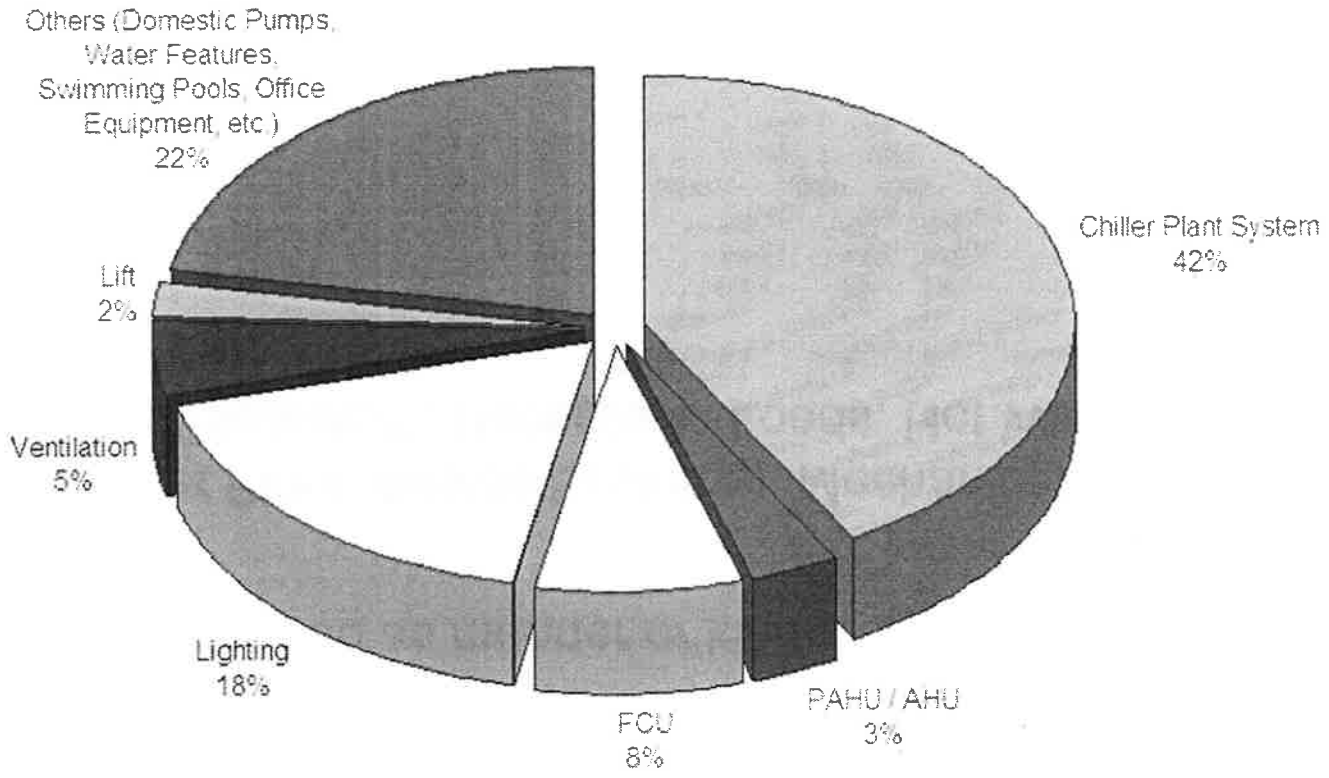
- Typical energy use of various types of buildings



Hotel

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Energy Use



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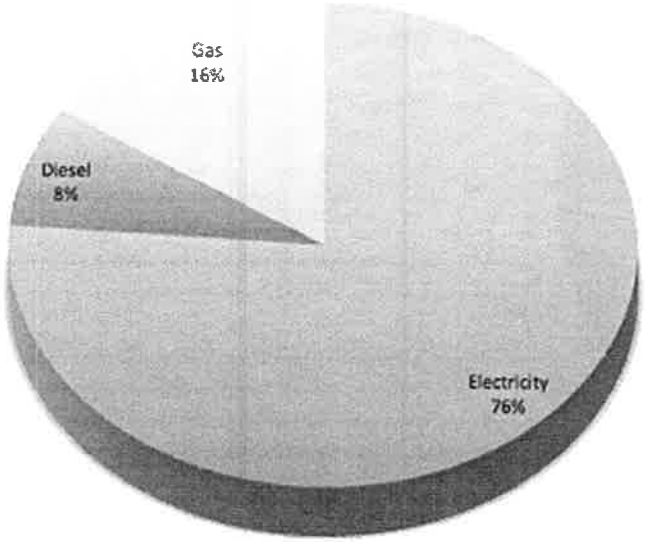
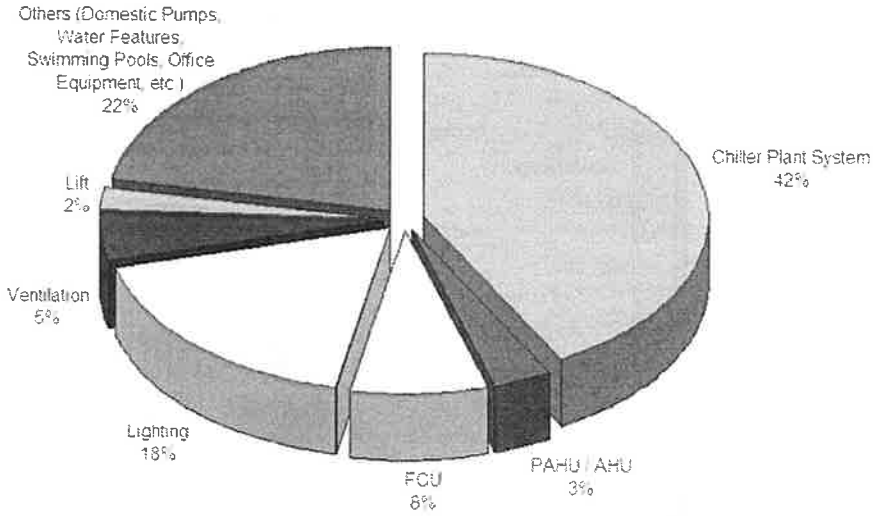
- Typical energy use of various types of buildings





Hotel

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Energy Use



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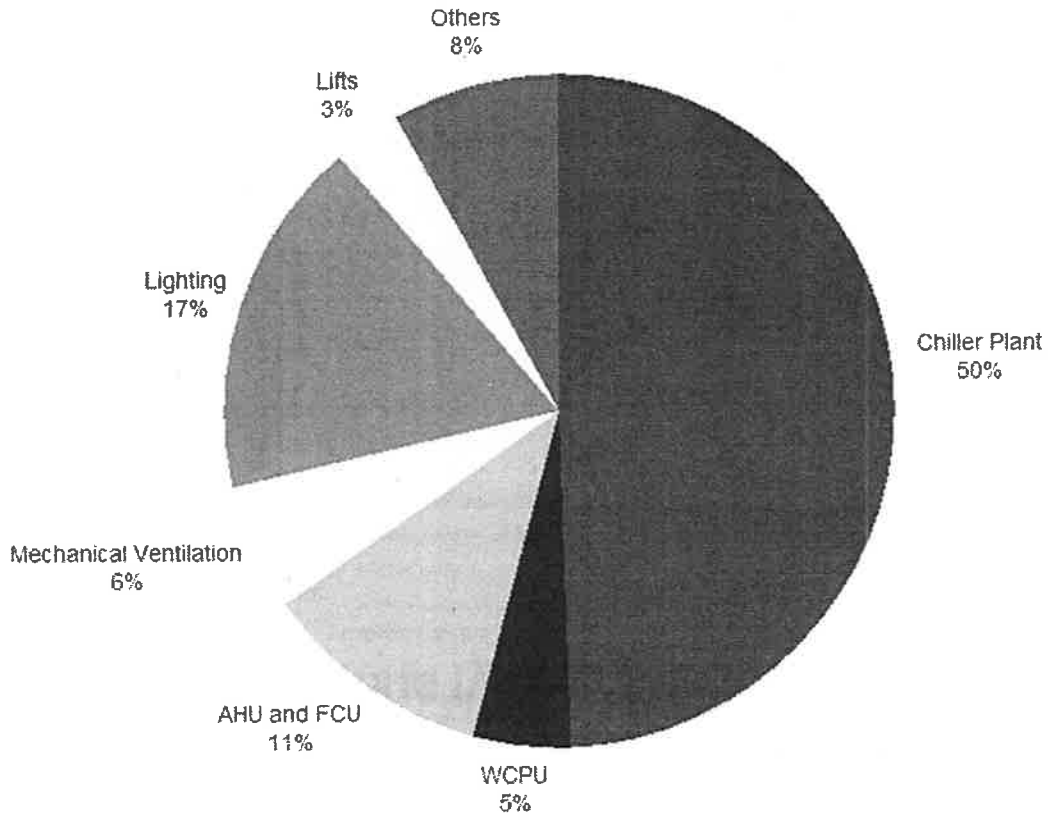

Office

Landlord Only

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Energy Use



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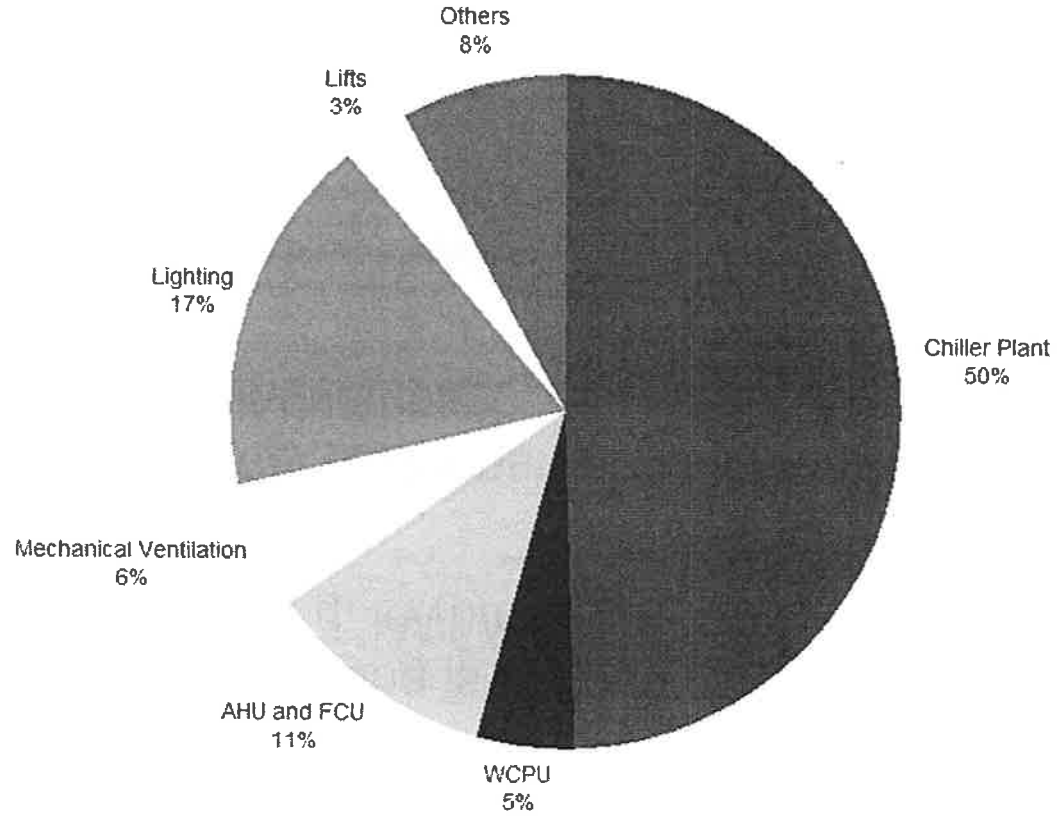
- Understanding of energy use in a building allows the energy manager to prioritize areas of improvement within a building



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Energy Intensity



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- Energy Intensity of a building is defined as energy consumption per floor area per annum, e.g. kWh/m2/year
- Simplest form of energy performance benchmarking among similar types of buildings or industries
- EUI (Energy Usage Index), kWh/m2/year
- EEI (Energy Efficiency Index), normalized kWh/m2/year

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Energy Intensity



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- EEI (Energy Efficiency Index), normalized kWh/m2/year

Calculation of EEI:
EEI = (TBEC - DCEC)/ (GFA excluding carpark - DCA - GLA*VCR)*(55/OH)

where:

a) TBEC :	Total building energy consumption (kWh/year)
b) DCEC :	Data centre energy consumption (kWh/year)
c) GFA excluding carpark :	Gross floor area exclusive of car park area (m2)
d) DCA :	Data centre area (m2)
e) GLA :	Gross lettable area (m2),
f) VCR :	Weighted floor vacancy rate of gross lettable area (%)
g) 55 :	Typical weekly operating hours of office buildings in Singapore (hrs/week)
h) OH :	Weighted weekly operating hours of gross lettable area exclusive of data centre area (hrs/week)

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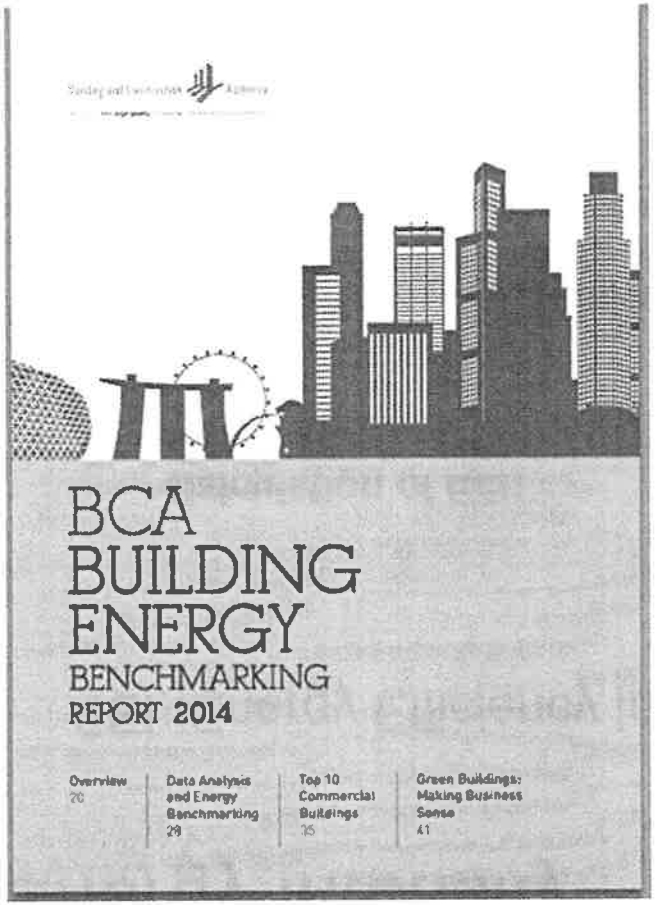
Energy Intensity

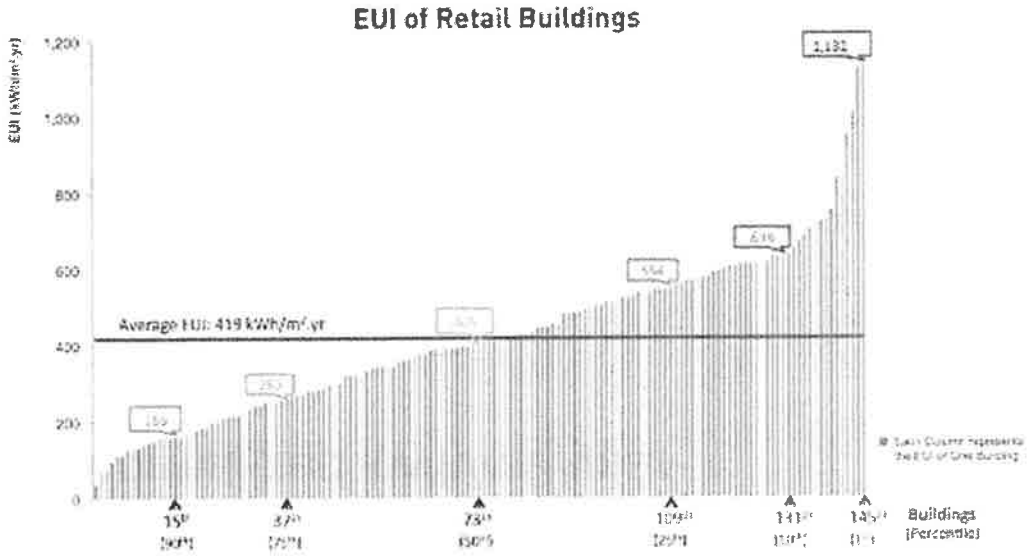


- EUI (Energy Utilization Index), normalized kWh/m2/year



Energy Utilisation Index (EUI) of Retail Buildings

Of the 145 retail buildings analysed, 51% were smaller retail buildings with GFA less than 15,000 m². It was observed that retail buildings with higher EUI were smaller-sized buildings with long operating hours and using split-unit air-conditioning or air cooled centralised chiller systems. However, this does not result in an energy inefficient building.



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Energy Efficiency



- Energy Efficiency is the ratio between an output of performance, service, goods or energy to an input of energy

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Energy Efficiency



- Energy Efficiency is the ratio between an output of performance, service, goods or energy to an input of energy

- Energy Efficiency is measured and evaluated at building system and sub-system levels, e.g.

  - Lighting System, lumen/watt (efficacy)
  - Chiller System, kW/RT or COP
  - Airside Systems, W/CMH or kW/RT
  - Boilers, COP
  - Heat Pumps, COP
  - Compressed Air System, CFM/W
  - Motors, efficiency%
  - Pumps, efficiency% or l/s/kW
  - Refrigeration System, COP

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Energy Efficiency



- Lighting Efficacy, Lumens/W

$$COP = \frac{\text{Output of Performance in Energy Unit}}{\text{Input of Energy in identical Energy Unit}}$$

- Higher Efficacy = Higher Efficiency

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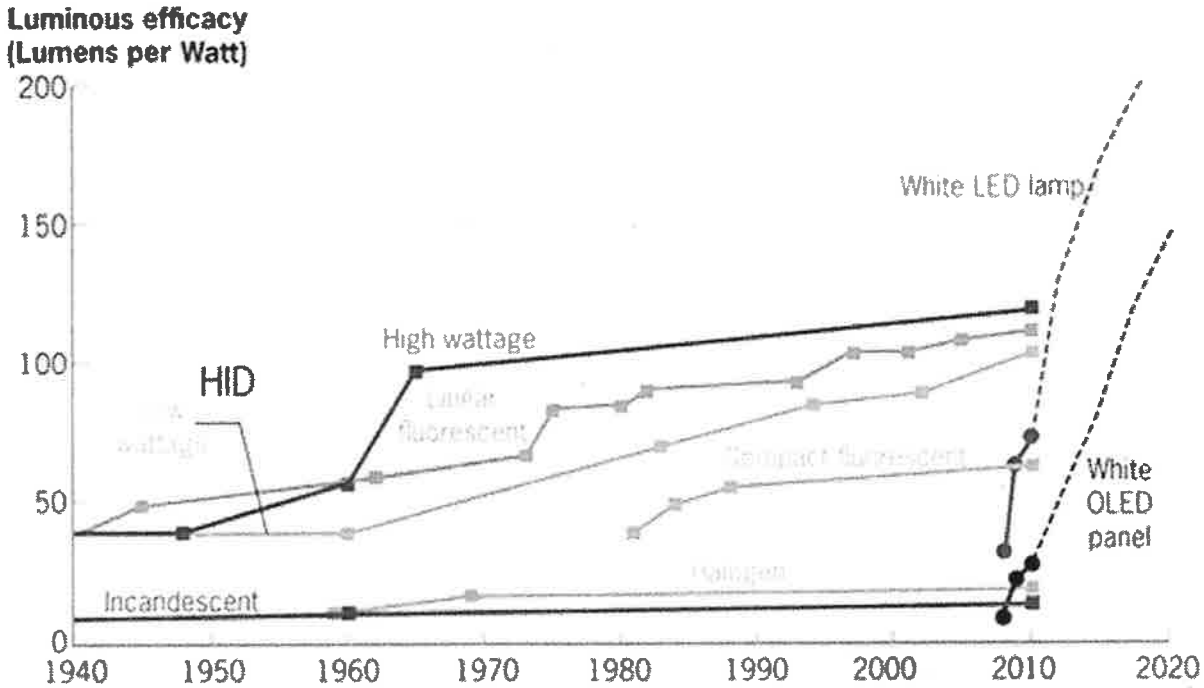
Energy Efficiency



- Lighting Efficacy, Lumens/W



http://energy.gov/eere/ssl/why-ssl

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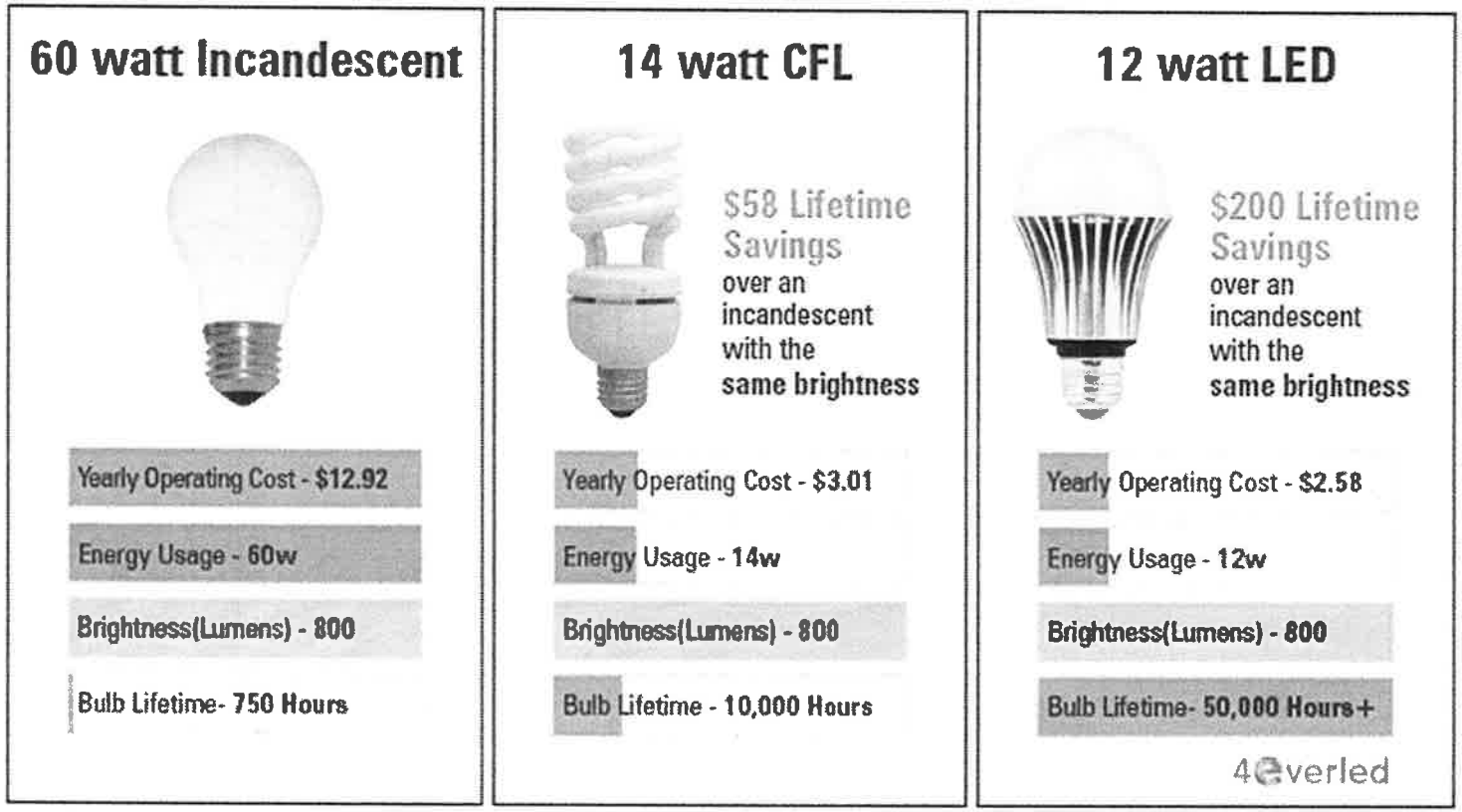
Energy Efficiency



- Lighting Efficacy, Lumens/W



http://facweb.cs.depaul.edu/sgrais/color_temperature.htm

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Energy Efficiency



- COP, Coefficient of Performance

$$\text{COP} = \frac{\text{Output of Performance in Energy Unit}}{\text{Input of Energy in identical Energy Unit}}$$

- Higher COP = Higher Efficiency

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Energy Efficiency



- COP, Coefficient of Performance
- Air-Conditioning System, e.g. VRF system, chillers

$$COP = \frac{\text{Output of Performance in Energy Unit}}{\text{Input of Energy in identical Energy Unit}}$$

$$COP = \frac{\text{Cooling Production in kWr}_{\text{(refrigeration)}}}{\text{Electrical Power Input in kWe}_{\text{(electric power)}}}$$

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Energy Efficiency



- COP, Coefficient of Performance

Examples to be inserted

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Energy Efficiency



- kW/RT, e.g. chillers, chiller plant system, chilled water pumps, condenser water pumps, cooling tower fans, airside fans

$$\text{kW/RT} = \frac{\text{Electric Power Input in kW}}{\text{Cooling Production in Refrigeration Tons (RT)}}$$

- Lower kW/RT = Higher Efficiency

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Energy Efficiency

- One Refrigeration Ton

= Heat required to melt 1 metric ton (1000 kg) of ice in 24 hours



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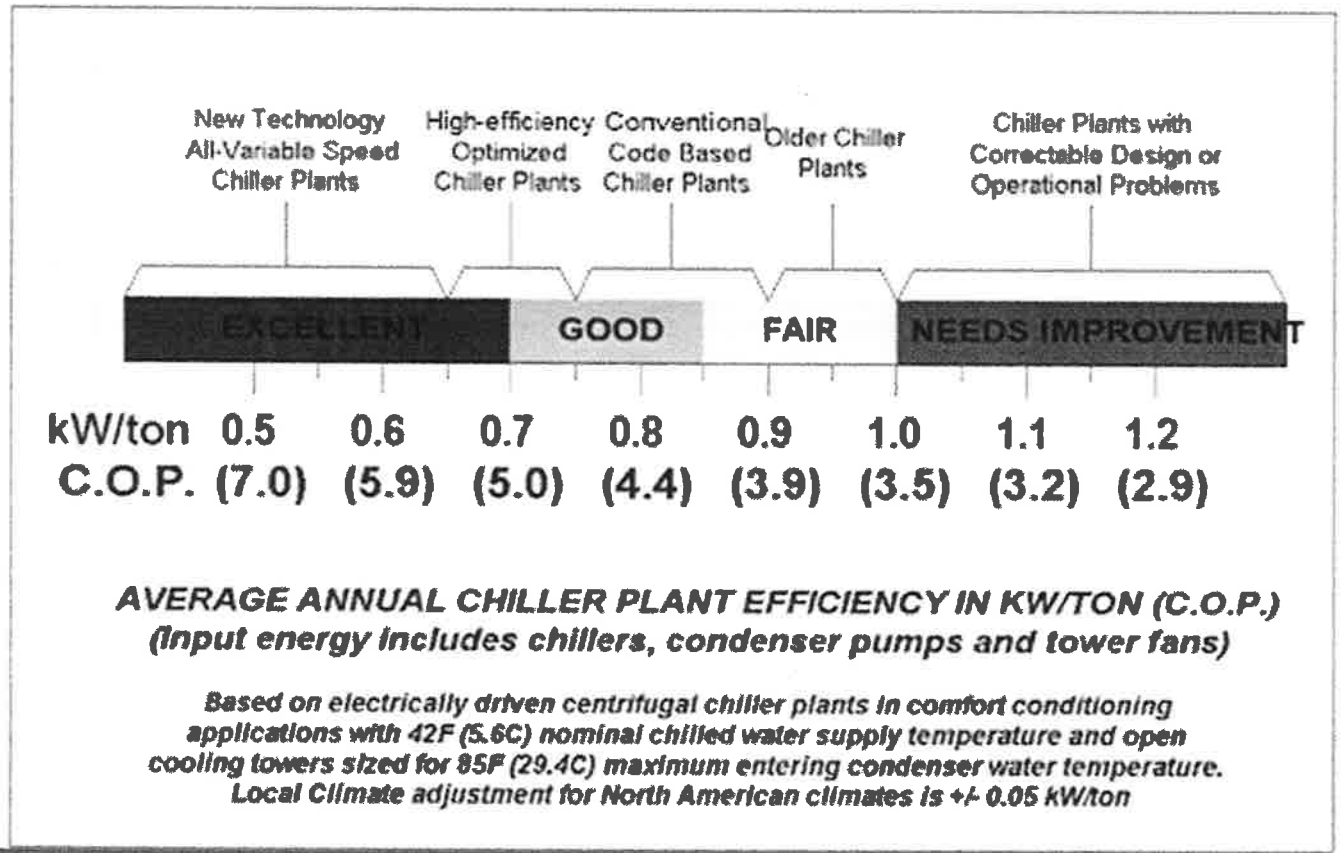
Energy Efficiency



- kW/RT, e.g. chillers, chiller plant system, chilled water pumps, condenser water pumps, cooling tower fans, airside fans



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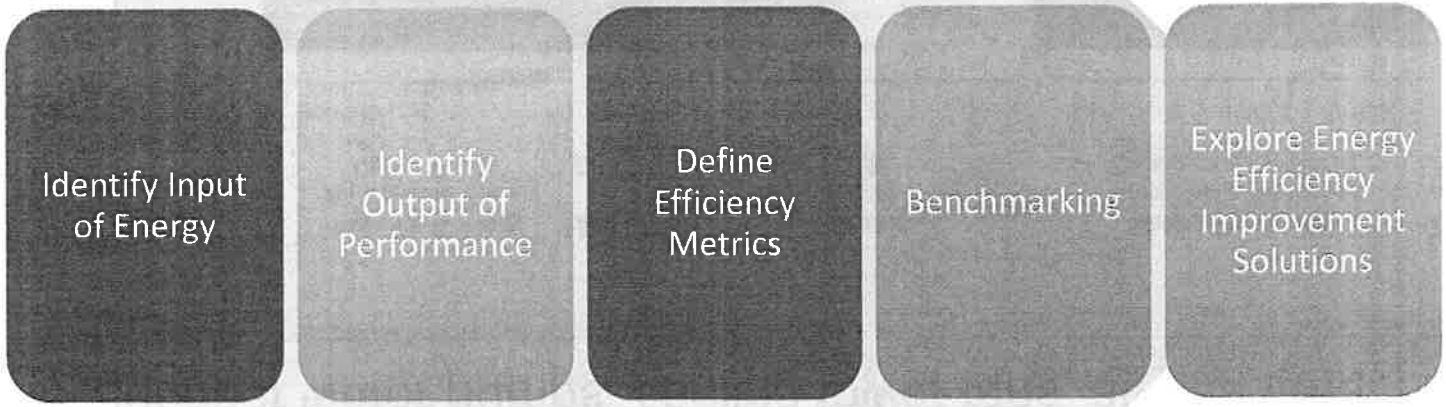
Energy Efficiency



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Others - Business Specifics



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- Industrial, process or business specific performance/output
- Examples
  - Manufacturing industry, kWh per unit of finished good produced
  - Hotel industry, kWh per room night
  - PV energy production, %generation/total energy consumption

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Energy Performance

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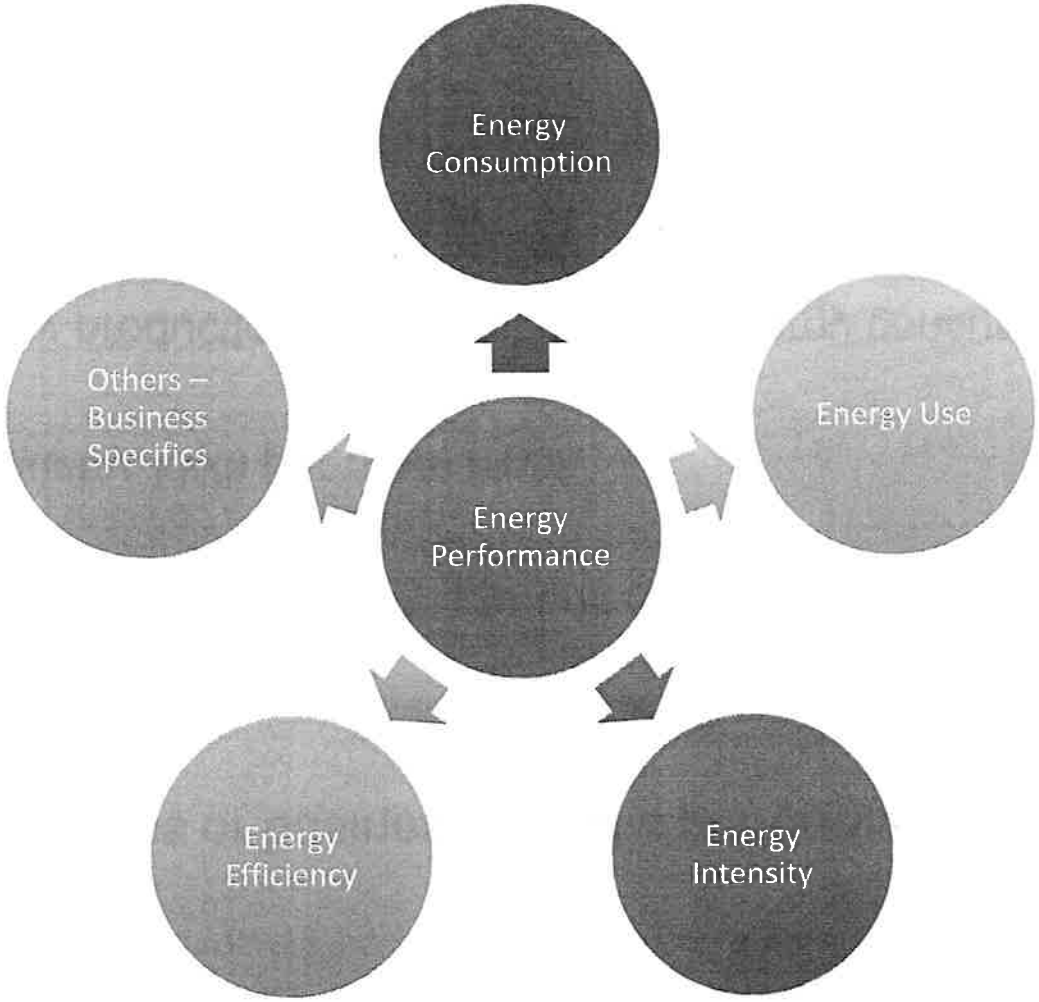

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Others - Business Specifics

Others – Business Specifics

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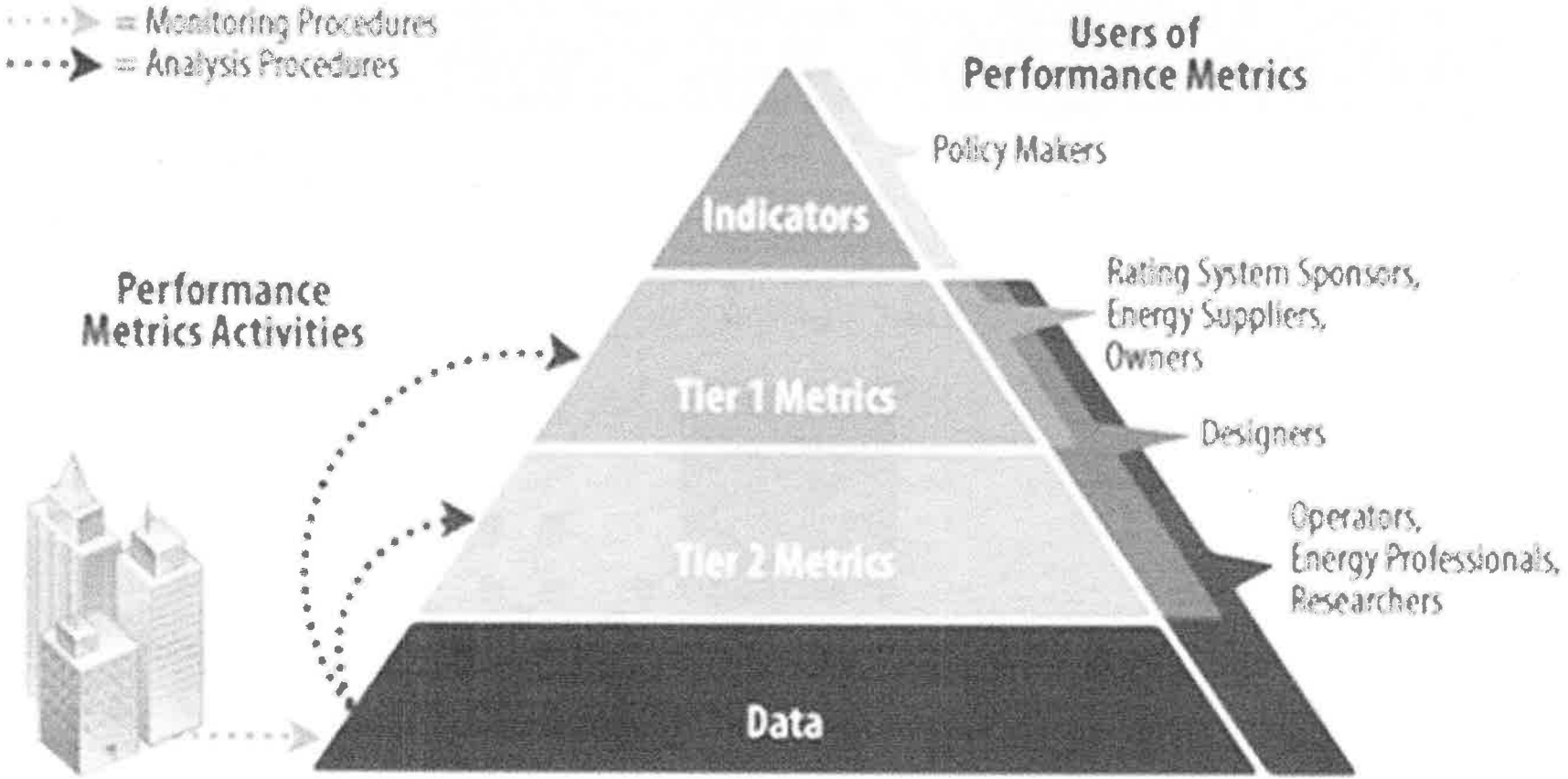

http://energy.gov/eere/buildings/performance-metrics-tiers

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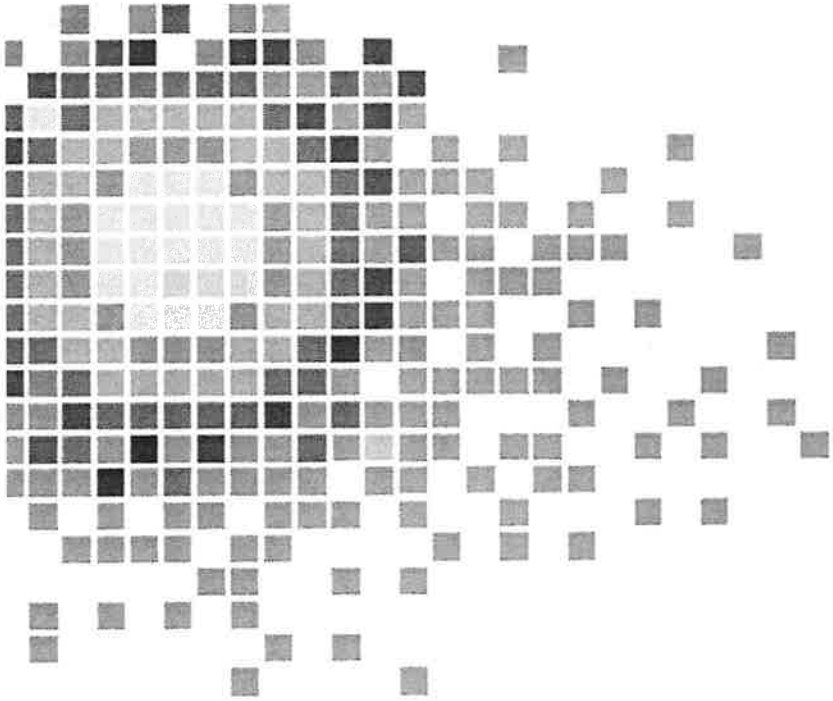

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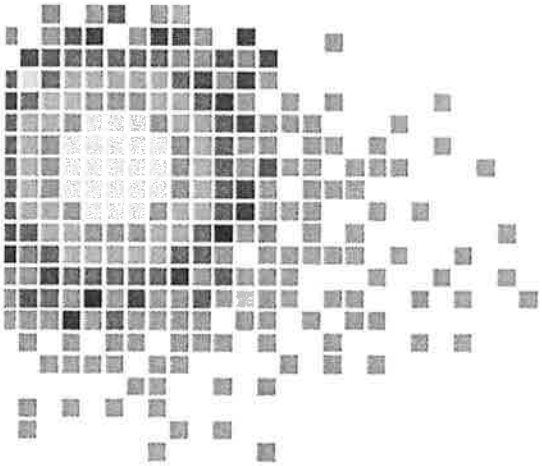
TOMORROW'S
BUILDINGS
ENGINEERED
TODAY

Thank You



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1. Energy Management Overview

Setting Energy Target and Plan

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Outline

- Energy Management Concept
- Energy Management Appraising Tools
- Setting Energy Target and Plan

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Strategic Energy Management

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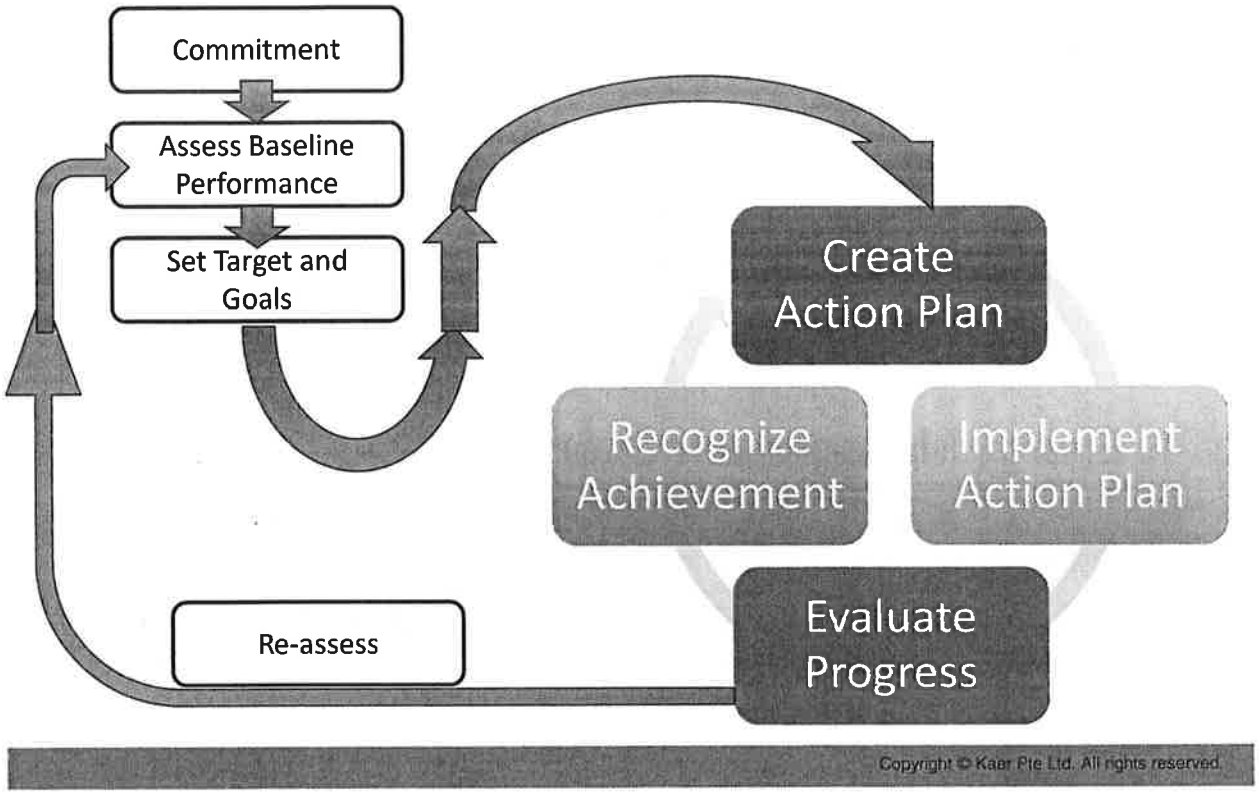

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Strategic Energy Management

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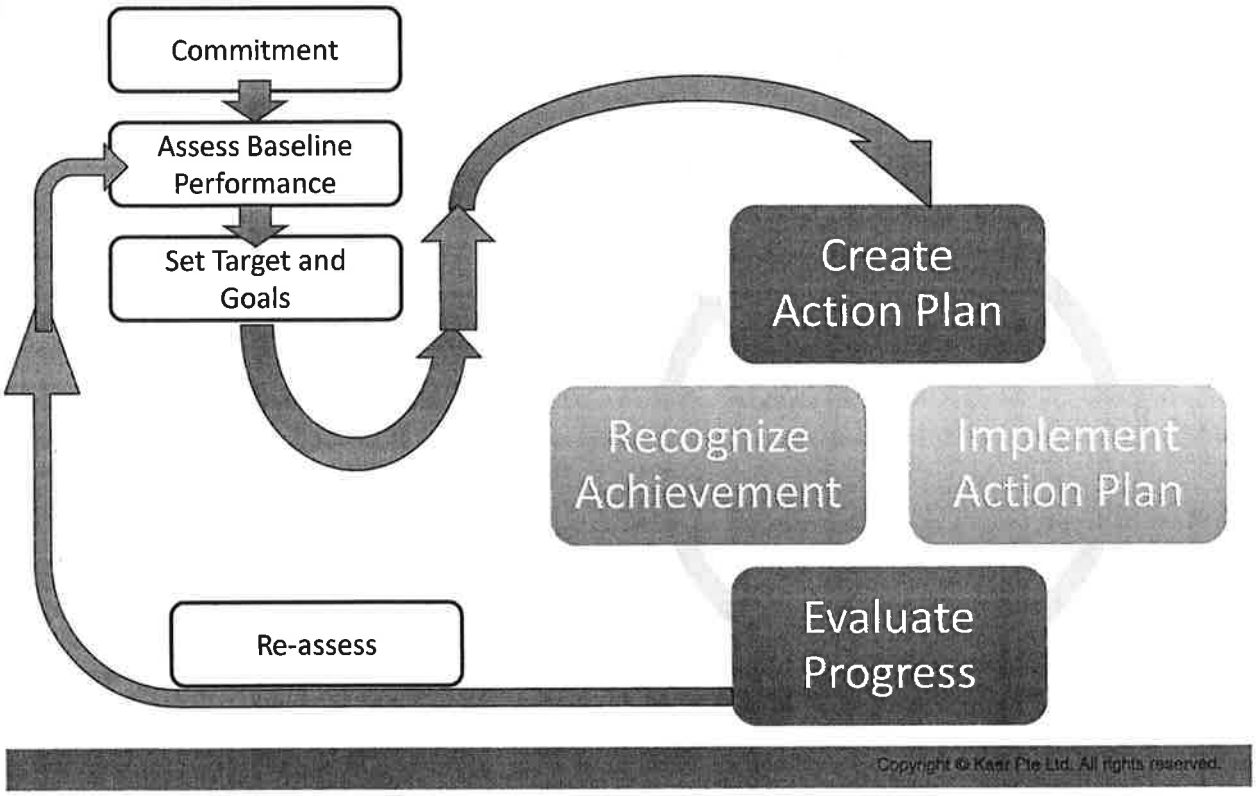

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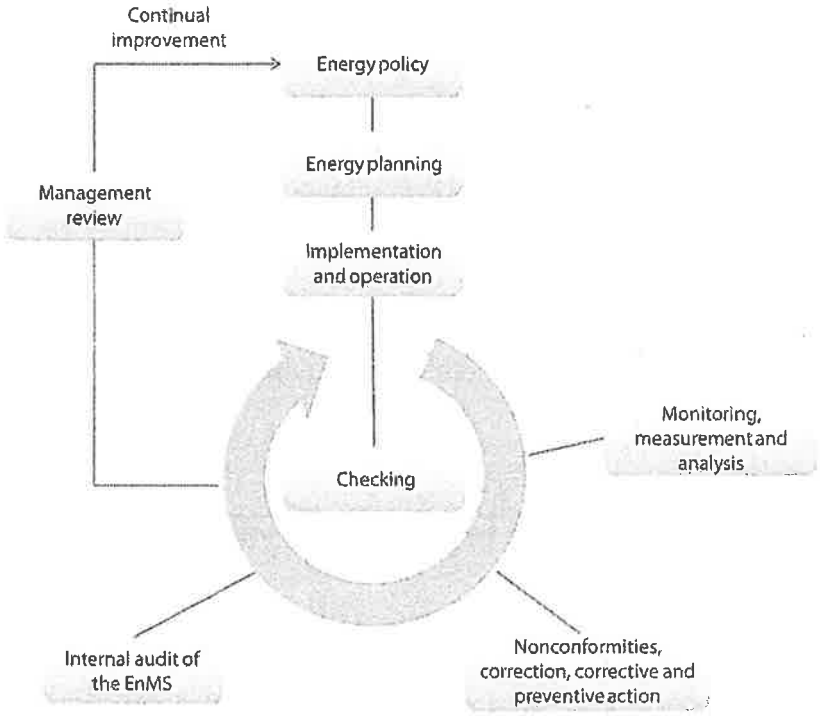

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Commitment

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- Commit to make "Energy Management" a continuous process
- Make "Energy Management" a function of business
- Appoint an Energy Manager
- Form an Energy Management Committee
- Formulate an Energy Policy

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Commitment - Energy Policy

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Insert Singapore's energy policy

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Commitment - Energy Policy

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Examples of energy policy by large MNCs to be inserted

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Commitment
Accountability and Ownership

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- Energy Management Committee

Examples of energy management organization structure

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Strategic Energy Management

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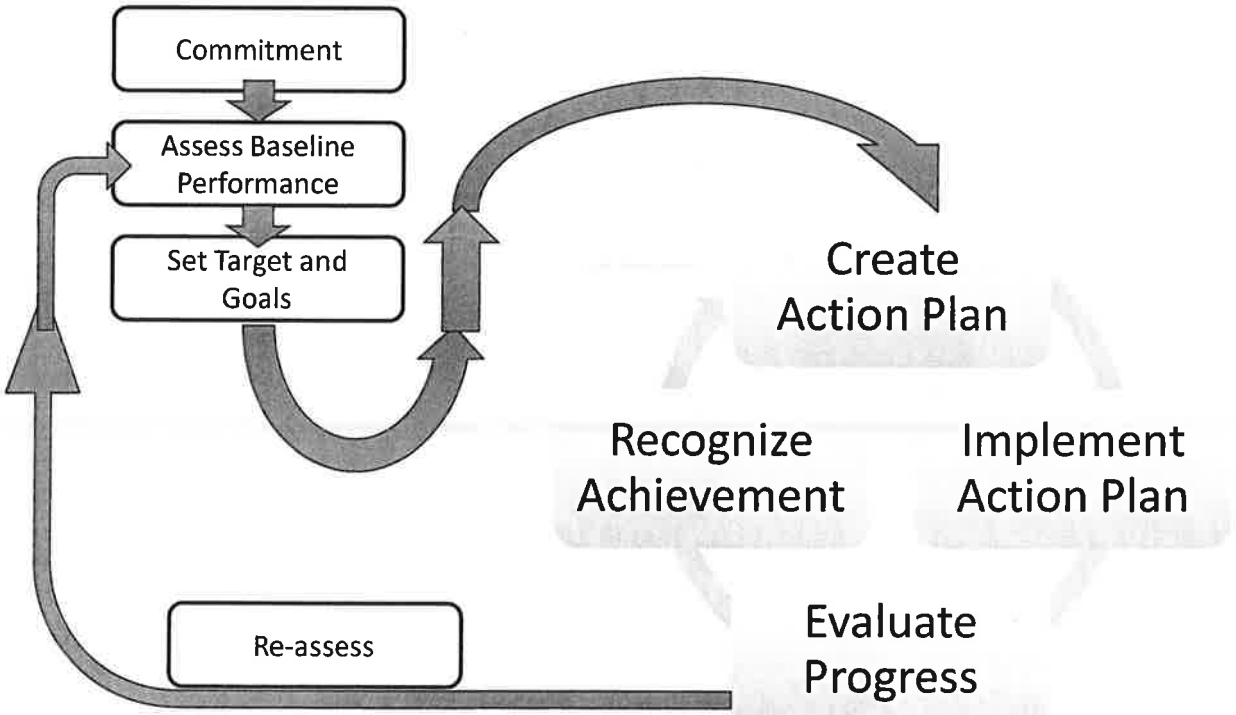

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Baseline Performance

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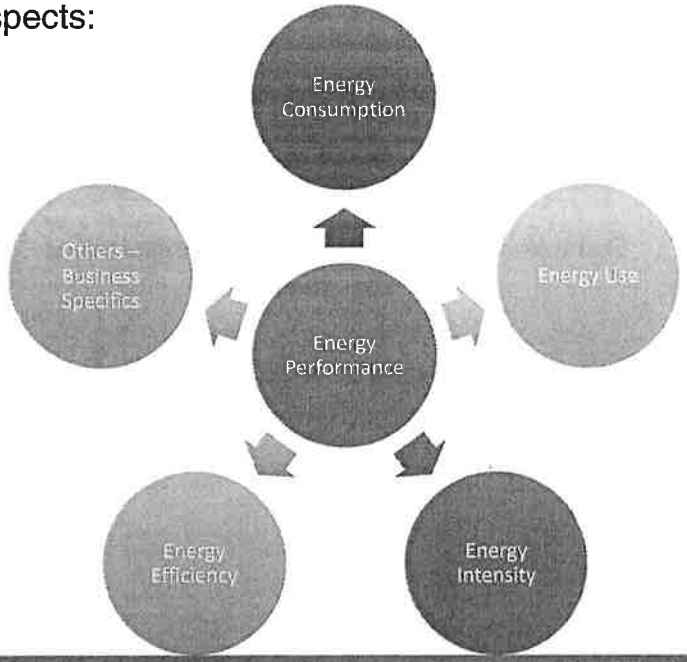
- Assess baseline building energy performance in terms of the following aspects:



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Baseline Performance

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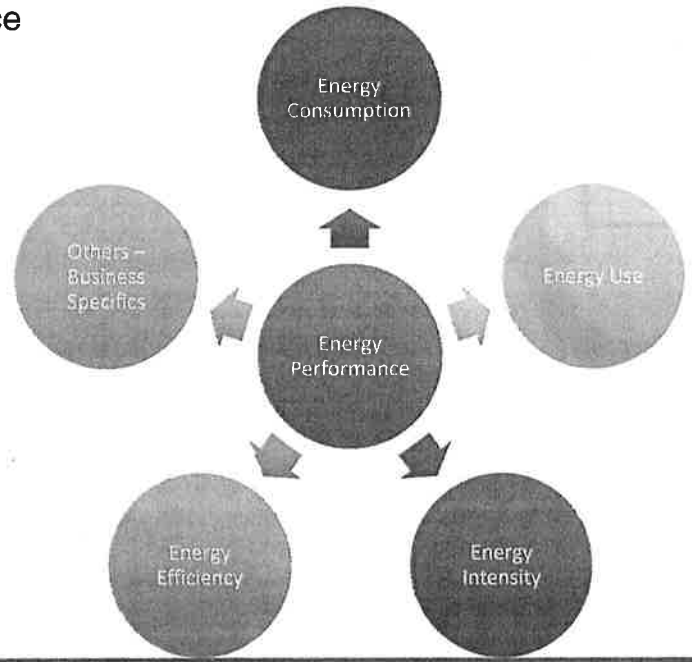
- Conduct energy audit level I **and** II or III to ascertain baseline energy performance



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Baseline Performance

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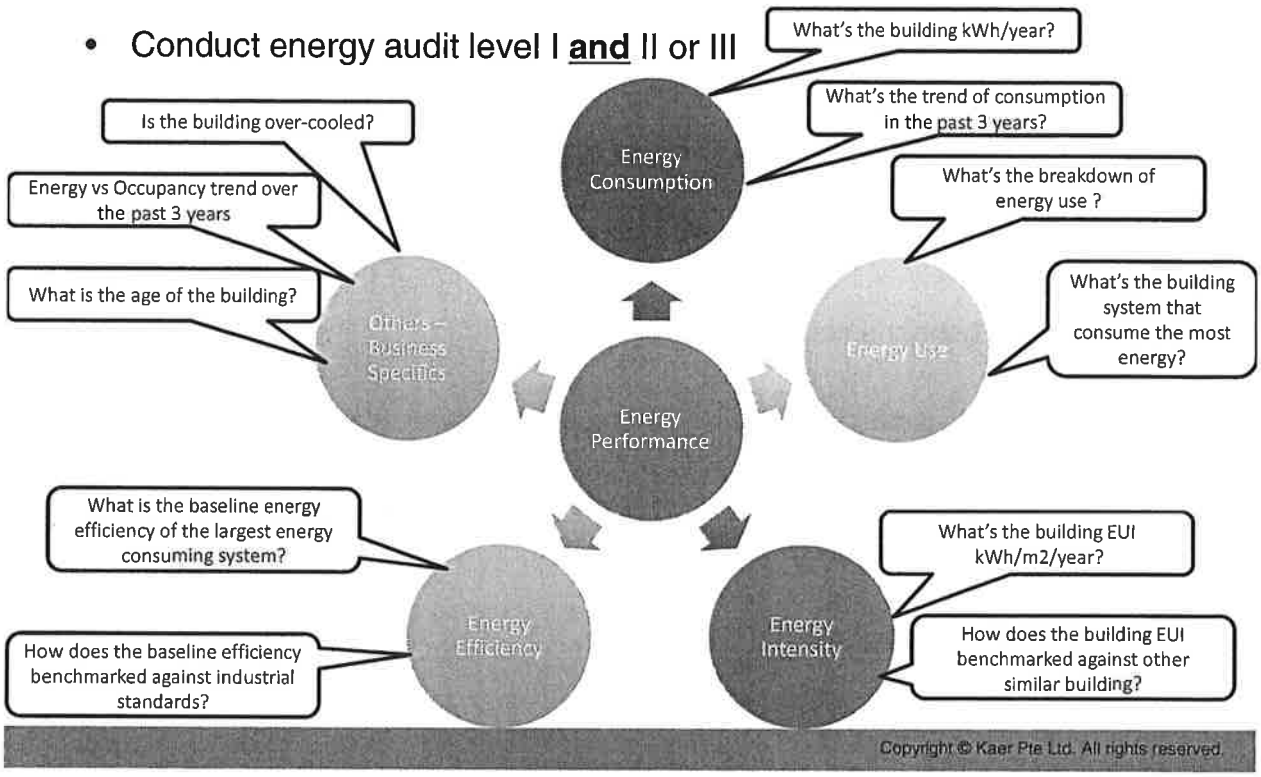
- Conduct energy audit level I **and** II or III



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Strategic Energy Management

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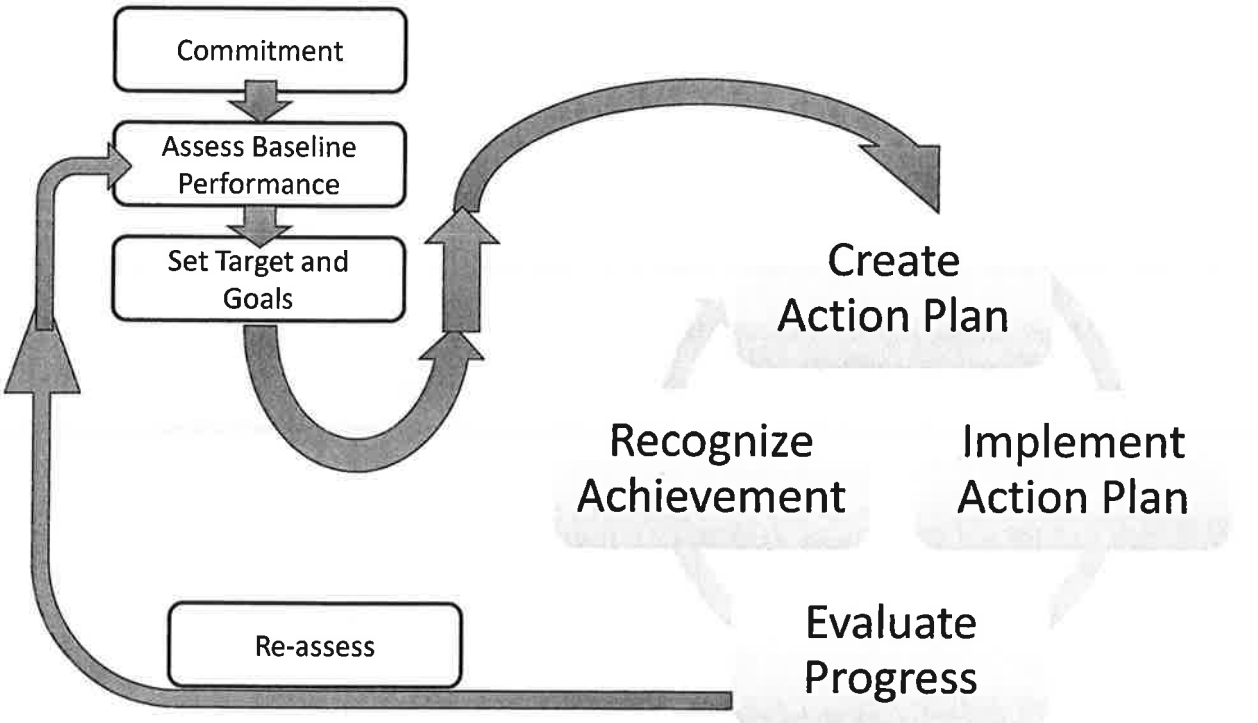

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Set Target and Goals

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- Benchmark Baseline Performance against
  - Historical energy consumption or energy intensity
  - Similar buildings in terms of EEI or EUI
  - Industrial energy efficiency standards
  - Alternative building systems, technologies, services or solutions, e.g.
    - heat recovery system in place of existing boiler system
    - Performance based service & maintenance in place of existing preventive service maintenance
  - Green Building standards

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Set Target and Goals

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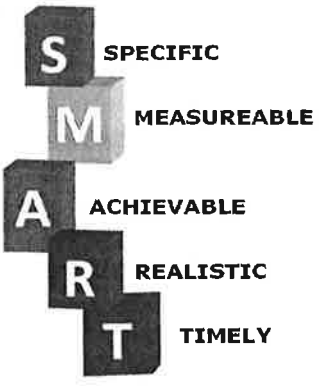
- Set SMART target and goals

- S = Specific rather than general
- M = Measurable in quantity, quality or results
- A = Achievable within the review period
- R = Relevant/Result oriented
- T = Time bound



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Set Target and Goals

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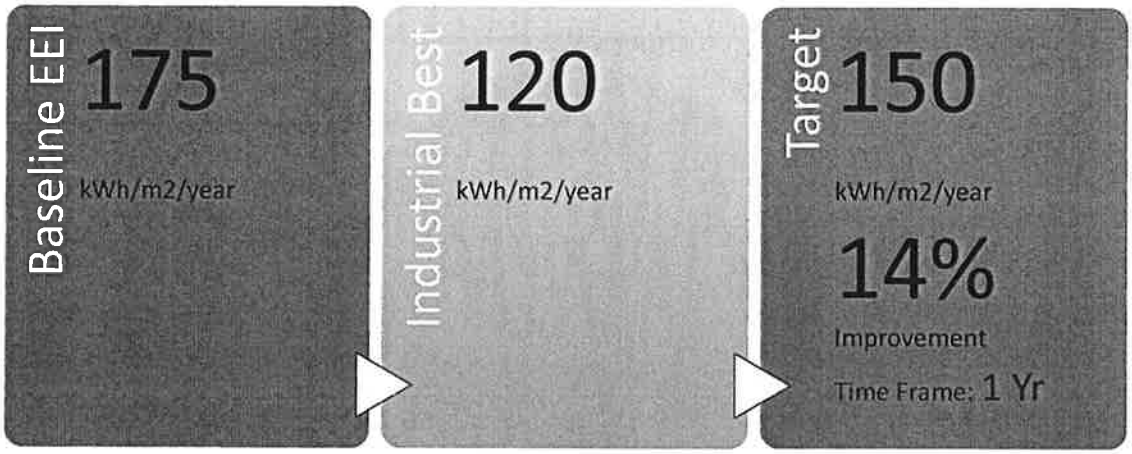
- Commercial Office Building



- Near Term Goal:
- **achieve 150 kWh/m2/year within one year period**

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Set Target and Goals

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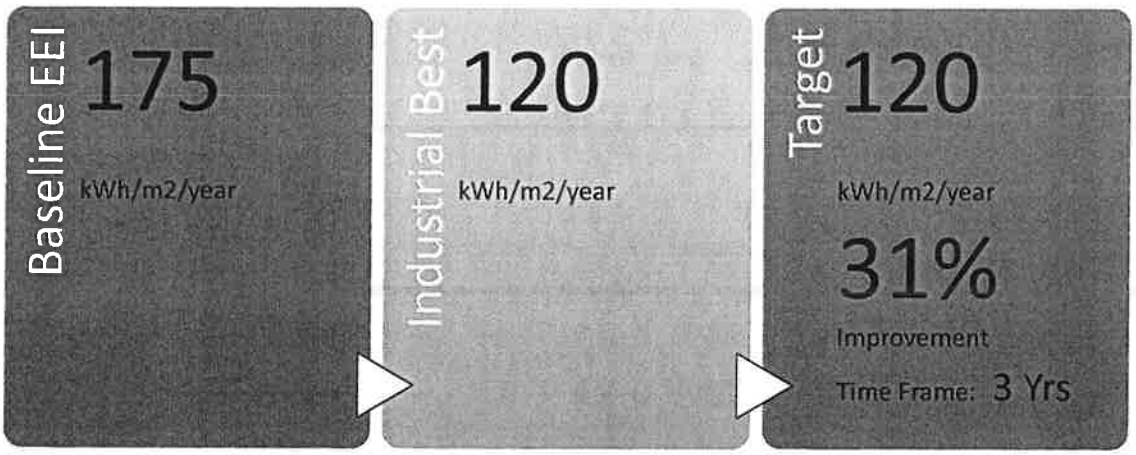
- Commercial Office Building



- Long Term Goal:
- **achieve 120 kWh/m2/year in three years**

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Set Target and Goals

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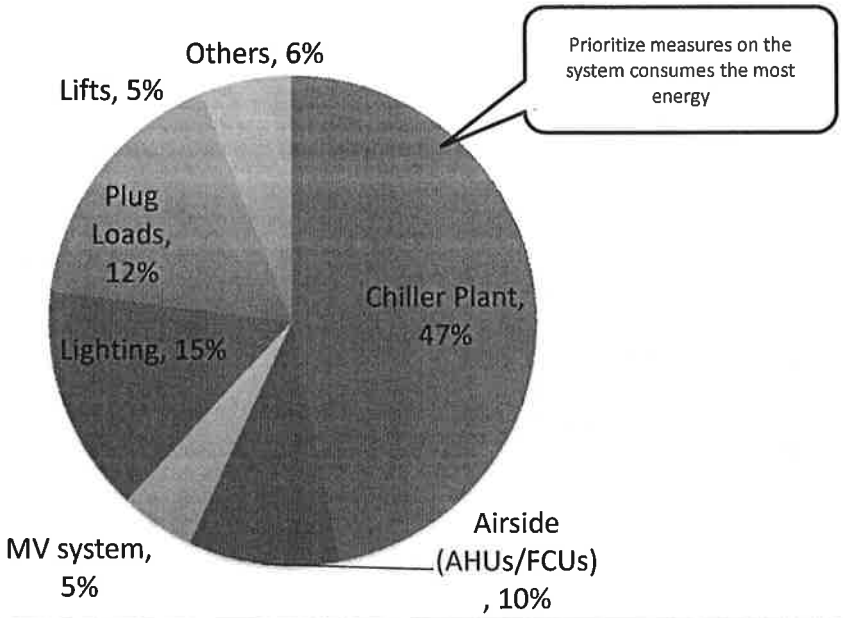
- Commercial Office Building, evaluate Energy Use



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Set Target and Goals

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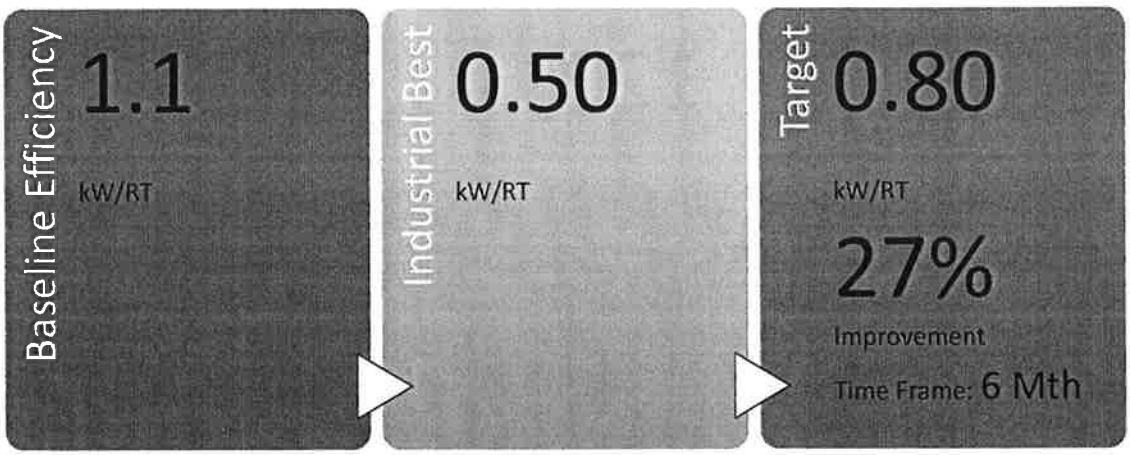
- Commercial Office Building, largest energy use: chiller plant system



- Viable measure #1: plant optimization with EMS controls

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Set Target and Goals

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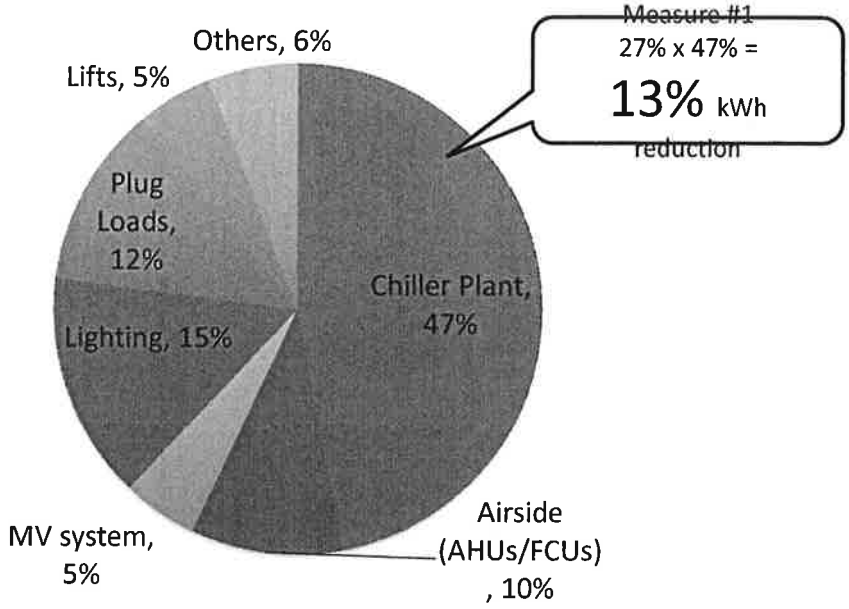
- Commercial Office Building, evaluate Energy Use



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Set Target and Goals

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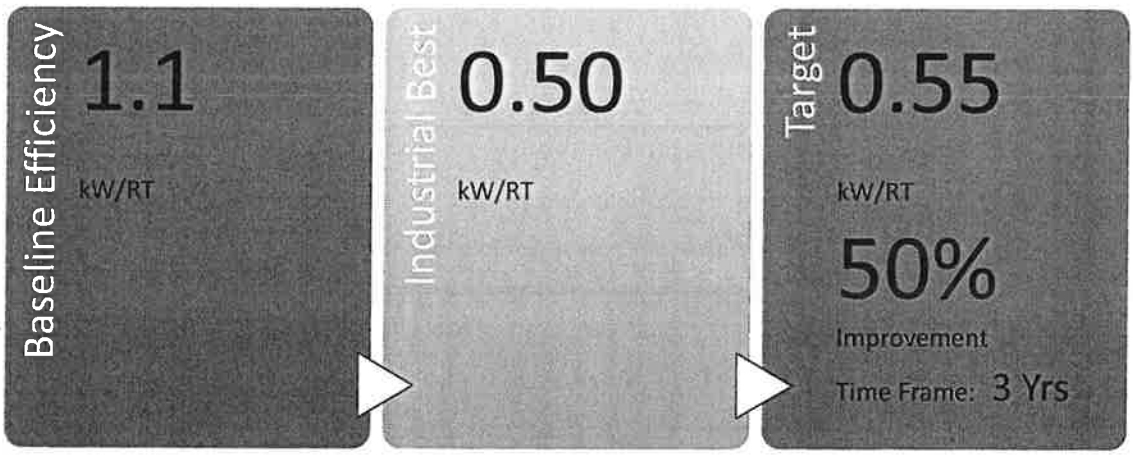
- Commercial Office Building, largest energy use: chiller plant system



- Viable measure #2: retrofit existing chiller plant

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Set Target and Goals

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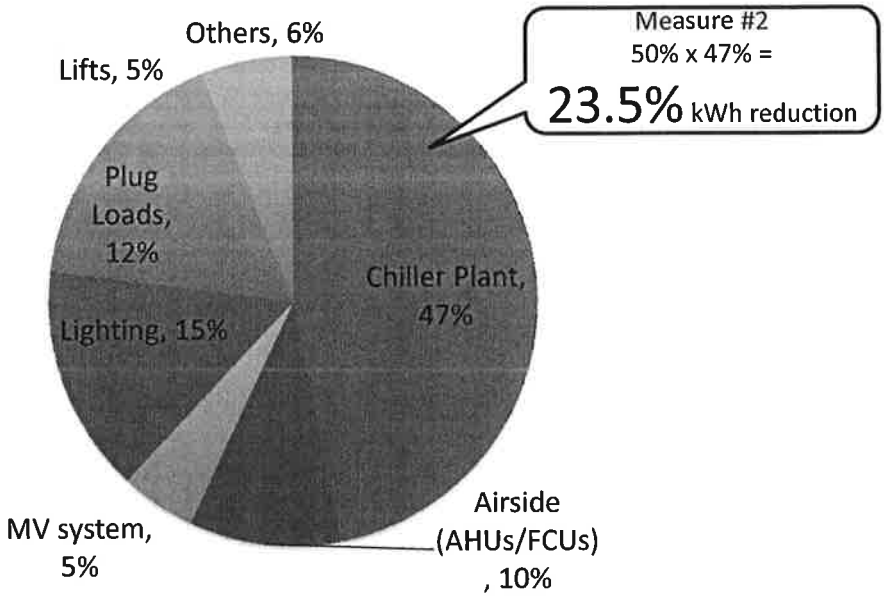
- Commercial Office Building, evaluate Energy Use



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Set Target and Goals

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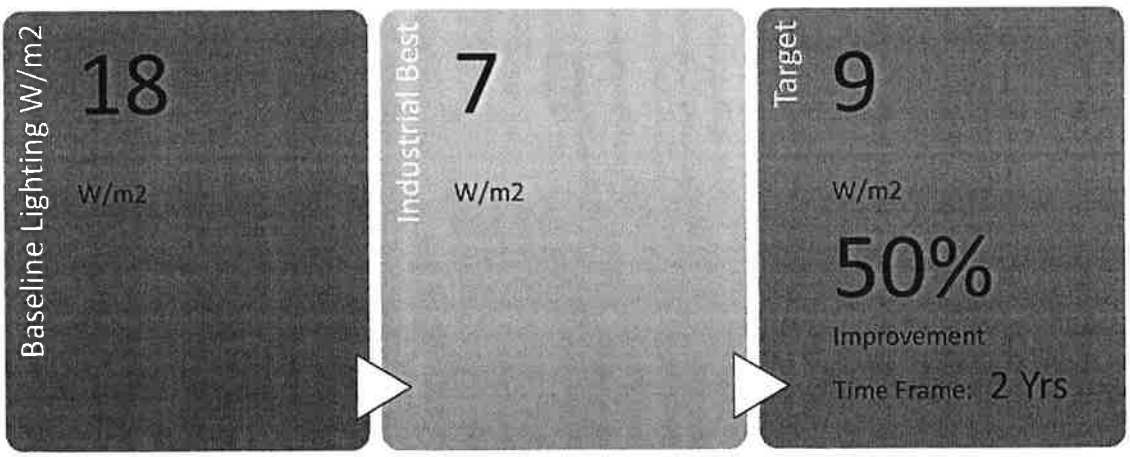
- Commercial Office Building, 2nd largest energy use: lighting system



- Viable measure #3: retrofit existing T8 lightings with T5

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Set Target and Goals

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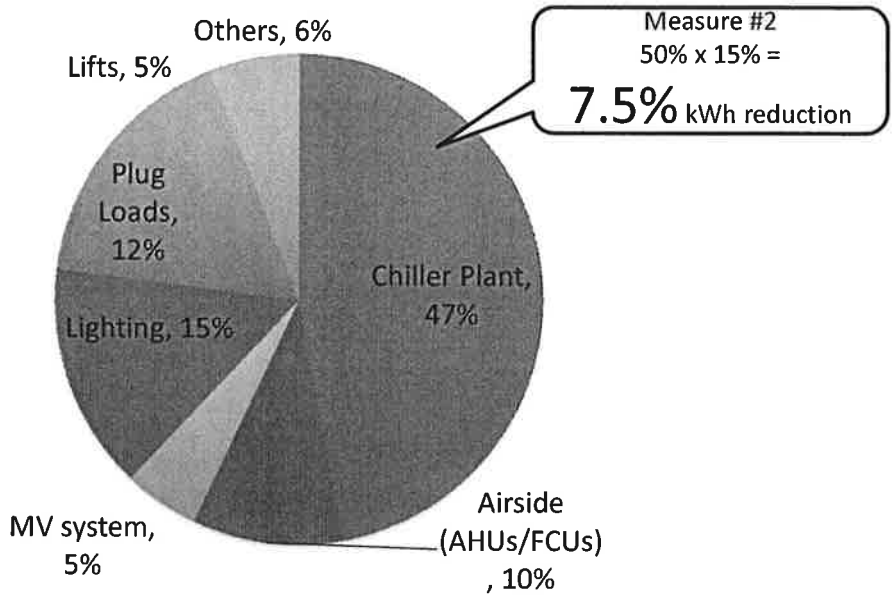
- Commercial Office Building, evaluate Energy Use



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Strategic Energy Management

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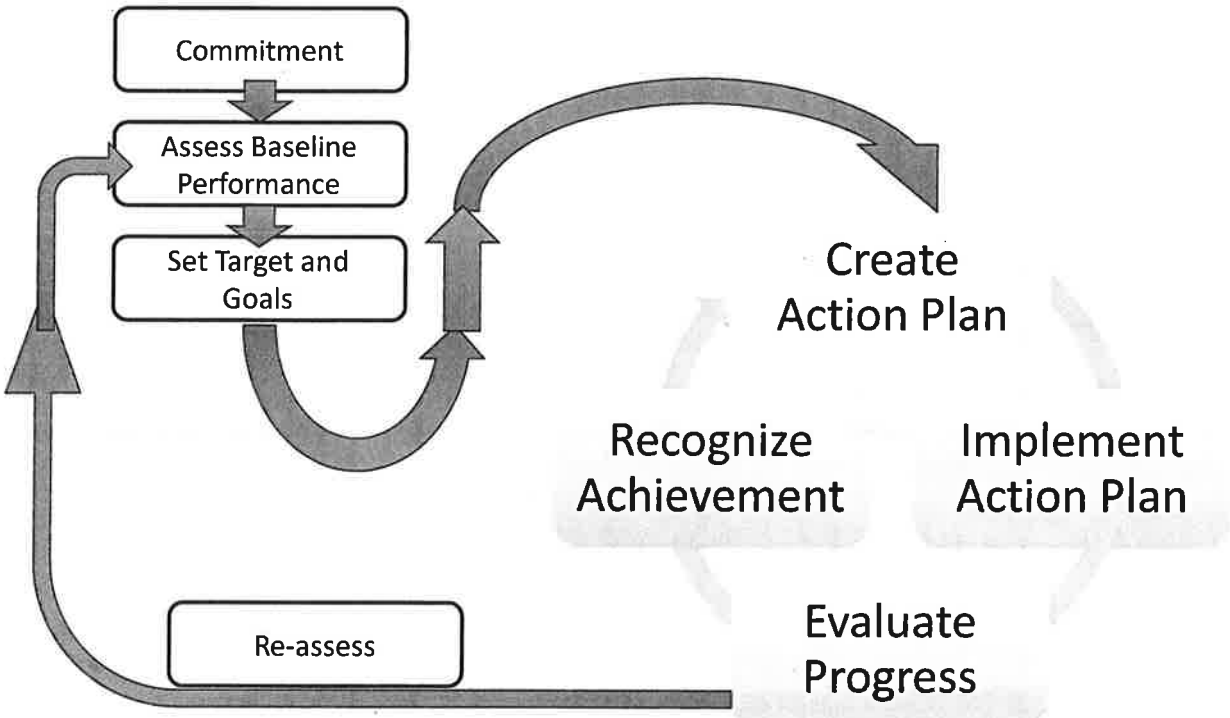

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Create Action Plan

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Economic Analysis
- Evaluate Return on Investment (ROI) of all viable measures
- Conduct lifecycle cost analysis

Roadmap
- Shortlist and finalize energy savings measures (ESMs)
- Formulate 3 to 5-year Energy Savings Roadmap

Approval
- Obtain management approval to implement finalized ESMs

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Strategic Energy Management

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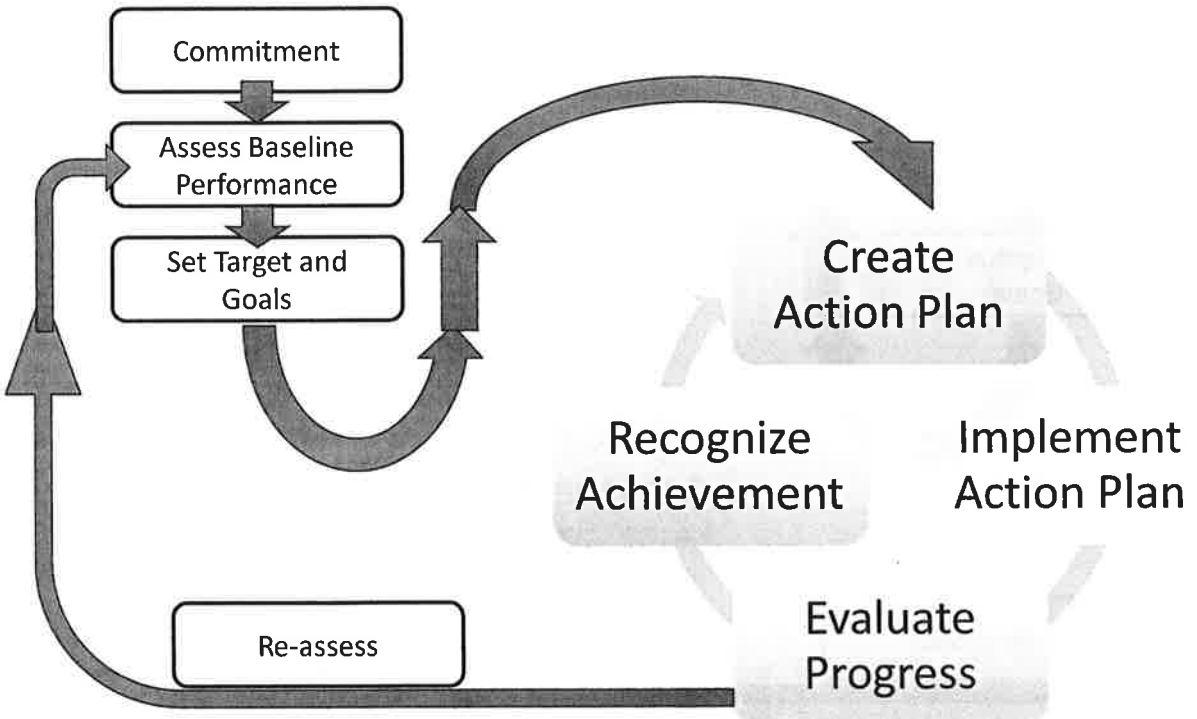

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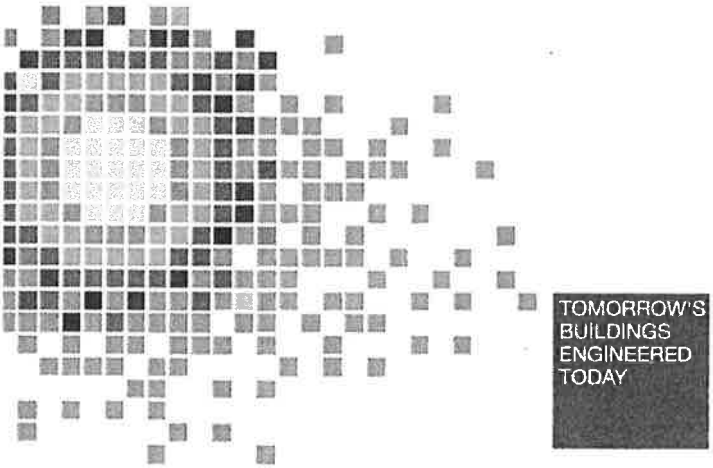

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2. Energy Economic Analysis

2.1 Life Cycle Cost Analysis
2.2 Time Value of Money Concept

Outline

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- Life Cycle Cost Analysis
- Time of Money Concept
- Project Measures of Worth
- Economic Models of Optimal Energy Use
- Energy Policies

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Life Cycle Cost Analysis

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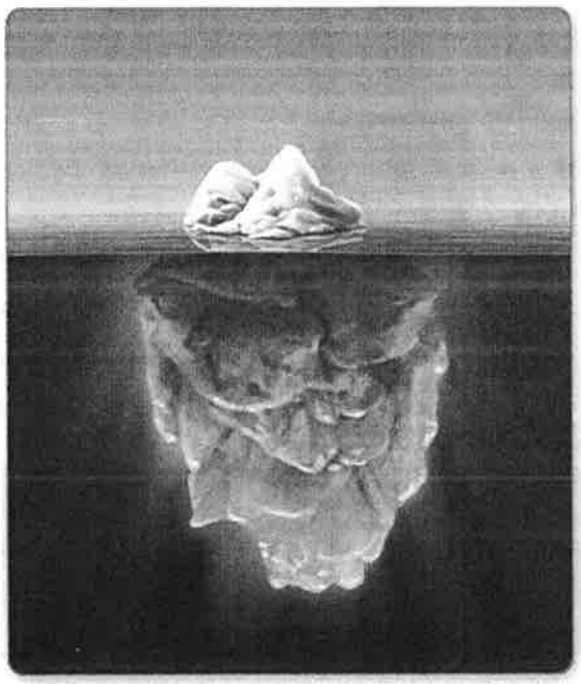

- First Cost
- Capex

- Energy Cost
- Maintenance/service cost
- Repair
- Replacement
- Consumables
- Staff Cost
- Unscheduled Repair
- Environmental Cost
- Demolition Cost

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Life Cycle Cost Analysis

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- Life Cycle Cost Analysis is used to
  - Compare various design alternatives or solutions
  - Project associated costs over the life span of the solutions (or "Life Cycle Period" of the solutions)
  - Consider all costs incurred over the life span of the solutions including first cost, installation costs, operating and maintenance costs
  - Bring all costs, which occur at different times, to a common point of time
  - Facilitate comparison of various design alternatives or solutions to allow selection based on lowest total life cycle cost

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Life Cycle Cost Analysis

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Life Cycle Period

- Length of time of the asset ownership
- Service life span of the building or systems
- Loan repayment period
- Depreciation rules (tax effects)

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Life Cycle Cost Analysis

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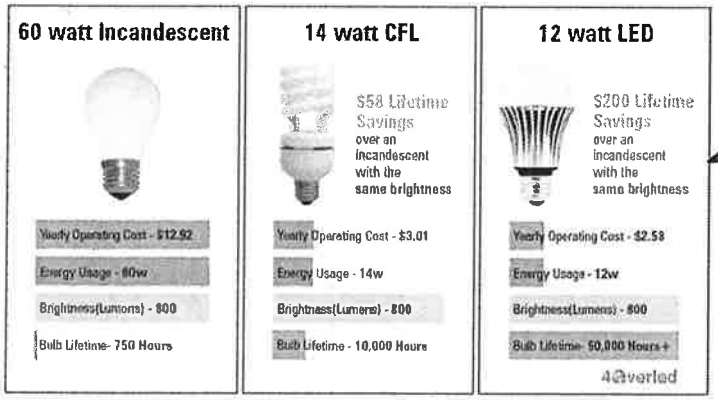
- Life Cycle Cost Analysis method
  - Converting all costs to a **Present Value (PV)**
  - The solution or alternative with the **lowest** Life Cycle Cost is the **best** option



Which solution is the best in terms of Life Cycle Cost?

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Outline

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- Life Cycle Cost Analysis
- Time of Money Concept
- Project Measures of Worth
- Economic Models of Optimal Energy Use
- Energy Policies

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Time Value of Money

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- "A dollar today is worth more than a dollar tomorrow"
- Example: if you deposit SGD 10,000 in a bank today, 10 years later, how much the value of SGD 10,000 will worth?
- 1st year

$$FV1 = SGD\ 10{,}000 \times (1 + 3\%)$$

$$= SGD\ 10{,}300$$

- 2nd year

$$FV2 = SGD\ 10{,}300 \times (1 + 3\%)$$

$$= \{SGD\ 10{,}000 \times (1 + 3\%)\} \times (1 + 3\%)$$

$$= SGD\ 10{,}609$$

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Time Value of Money

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- "A dollar today is worth more than a dollar tomorrow"
- Example: if you deposit SGD 10,000 in a bank today, 10 years later, how much the value of SGD 10,000 will worth?

$$FV10 = SGD\ 10{,}000 \times (1 + 3\%)^{10}$$

$$= SGD\ 13{,}439$$

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Time Value of Money

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PV = Present Value

i = interest rate

FV = Future Value

N = Number of Periods

$$FV = PV \times (1+i)^{N}$$

$$= SGD\ 10{,}000 \times (1 + 3\%)^{10}$$

$$= SGD\ 13{,}439$$

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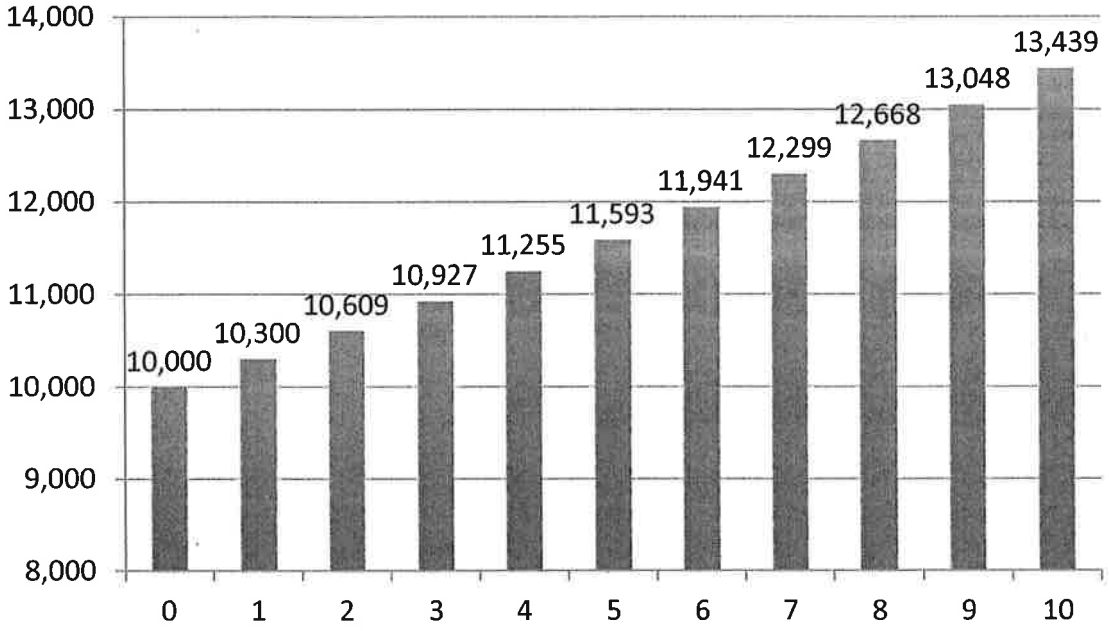
Time Concept of Money



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Time Concept of Money

- **Present Value (PV)**
  - The value of a future amount of money discounted to reflect its current value
- **Future Value (FV)**
  - The value of an asset or cash at a specific date in the future
- **Annuity Payment**
  - A continuing payment or income at stated intervals over a specified period of time
- **Interest Rate (i)**
  - The growth rate of a sum of money over the life of the investment
- **Number of Periods (N)**
  - The number of time intervals over the life of the investment (e.g. 10 years, 40 quarterly years, 120 months)

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Time Concept of Money

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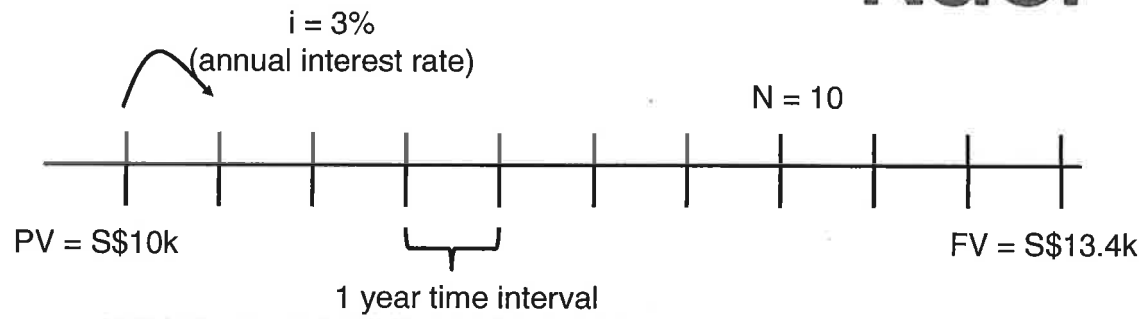
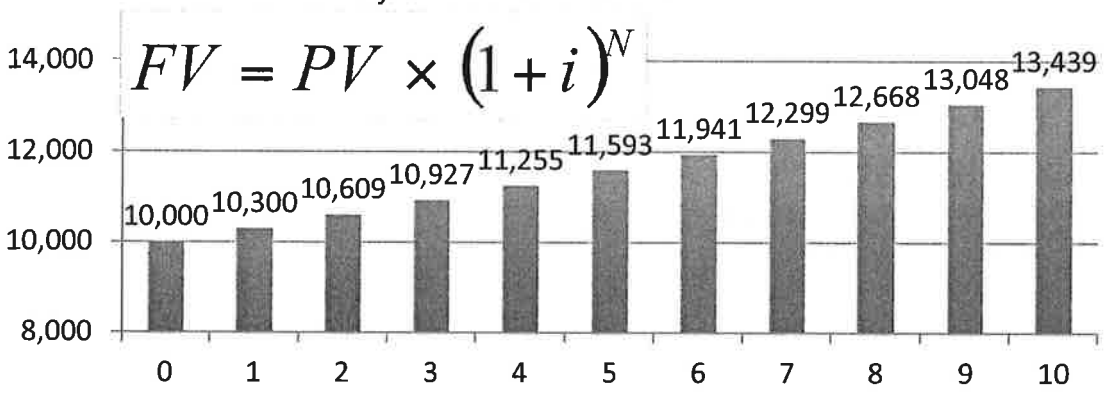


$$FV = PV \times (1+i)^N$$



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Time Concept of Money

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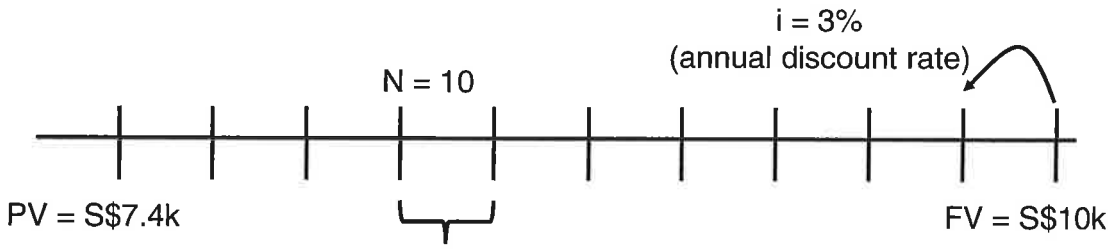
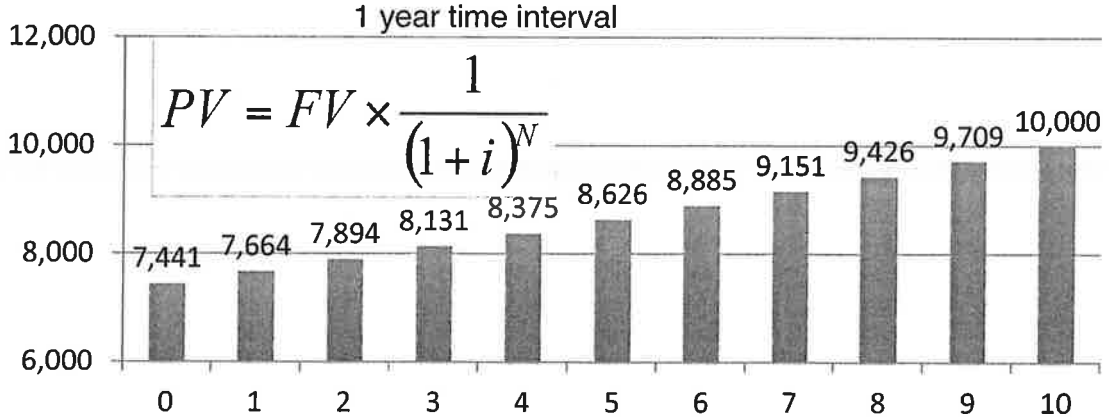


$$PV = FV \times \frac{1}{(1+i)^N}$$



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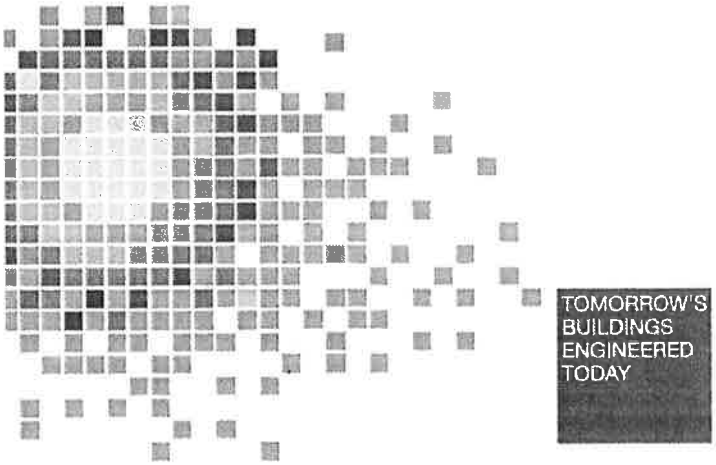

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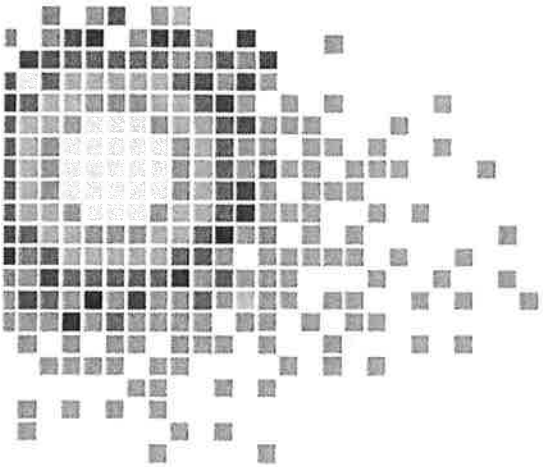

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3. Energy Economic Analysis Part 2

3.1 Project Measures of Worth
3.2 Economic Models of Optimal Energy Use
3.3 Energy Policies

Outline

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- Life Cycle Cost Analysis
- Time of Money Concept
- Project Measures of Worth
- Economic Models of Optimal Energy Use
- Energy Policies

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Project Measures of Worth

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- **Simple Payback vs Time Concept of Money**
- Example: Is it viable to invest SGD 1,000,000 on an Energy Savings Initiative that projects SGD 250,000 energy cost savings per annum?

Simple Payback Analysis

$$\text{Simple Payback} = \frac{\text{SGD } 1{,}000{,}000}{\text{SGD } 250{,}000}$$

$$= 4 \text{ years}$$

$$\text{ROI} = 1 / 4$$

$$= 25\%$$

Simple Payback is unable to provide comparison "Measures of Worth"

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Project Measures of Worth

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- **Simple Payback is unable to answer the following questions:**
- What if there is an alternative solution, also incurs SGD 1 Mil investment but gives 4-year simple payback with decreasing annual energy cost savings over time, e.g
  - 1st year, SGD 500k
  - 2nd year, SGD 300k
  - 3rd year, SGD 200k
  - 4th year, SGD 100k, which solution will give higher "Measures of Worth"?
- Is 4-year payback better than an alternative investment opportunity that gives return of 22% per annum?

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Project Measures of Worth

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- **Simple Payback vs Time Concept of Money**
- Assuming the Energy Savings Measure gives SGD 250,000 savings per year over 10 years period, let's analyze Present Value by discounting the future energy cost savings by 7% interest:

VIABLE vs an investment with 7% return per annum

Present Value Analysis

		i =	7%
Year	FV	PV	
1	250,000	233,645	
2	250,000	218,360	
3	250,000	204,074	
4	250,000	190,724	
5	250,000	178,247	
6	250,000	166,586	
7	250,000	155,687	
8	250,000	145,502	
9	250,000	135,983	
10	250,000	127,087	
		1,755,895	

$$PV = FV \times \frac{1}{(1+i)^N}$$

VIABLE as compared to what investment?

PV of SGD 1.76 Mil > SGD 1 Mil investment, VIABLE!

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Project Measures of Worth

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- **Application of Present Value and Future Value**
- Example: Is it viable to invest SGD 1,000,000 on an Energy Savings Measure that projects SGD 250,000 energy cost savings per annum?

Comparing to an investment with 25% return/year

Present Value Analysis

		i =	25%
Year	FV	PV	
1	250,000	200,000	
2	250,000	160,000	
3	250,000	128,000	
4	250,000	102,400	
5	250,000	81,920	
6	250,000	65,536	
7	250,000	52,429	
8	250,000	41,943	
9	250,000	33,554	
10	250,000	26,844	
		892,626	

$$PV = FV \times \frac{1}{(1+i)^N}$$

What if there's another investment giving 25% return?

PV of SGD 0.89 Mil < SGD 1 Mil investment, NOT VIABLE!

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Project Measures of Worth

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- **Internal Rate of Return (IRR)**
  - the interest rate at which the **Net Present Value** of all the cash flows from a project or investment equal **Zero**
- **Net Present Value (NPV)**
  - the Present Value of an investment's expected cash inflows minus the costs of acquiring the investment

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Project Measures of Worth

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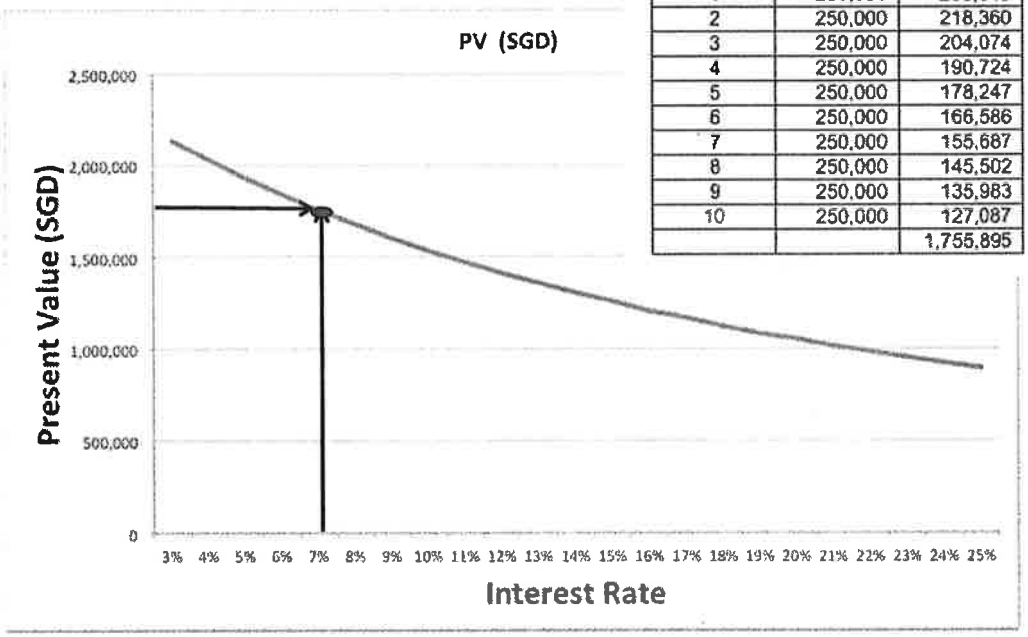
- **Internal Rate of Return**

		i =	7%
Year	FV	PV	
1	250,000	233,645	
2	250,000	218,360	
3	250,000	204,074	
4	250,000	190,724	
5	250,000	178,247	
6	250,000	166,586	
7	250,000	155,687	
8	250,000	145,502	
9	250,000	135,983	
10	250,000	127,087	
		1,755,895	



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Project Measures of Worth

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- **Internal Rate of Return**

	i =	25%
Year	FV	PV
1	250,000	200,000
2	250,000	160,000
3	250,000	128,000
4	250,000	102,400
5	250,000	81,920
6	250,000	65,536
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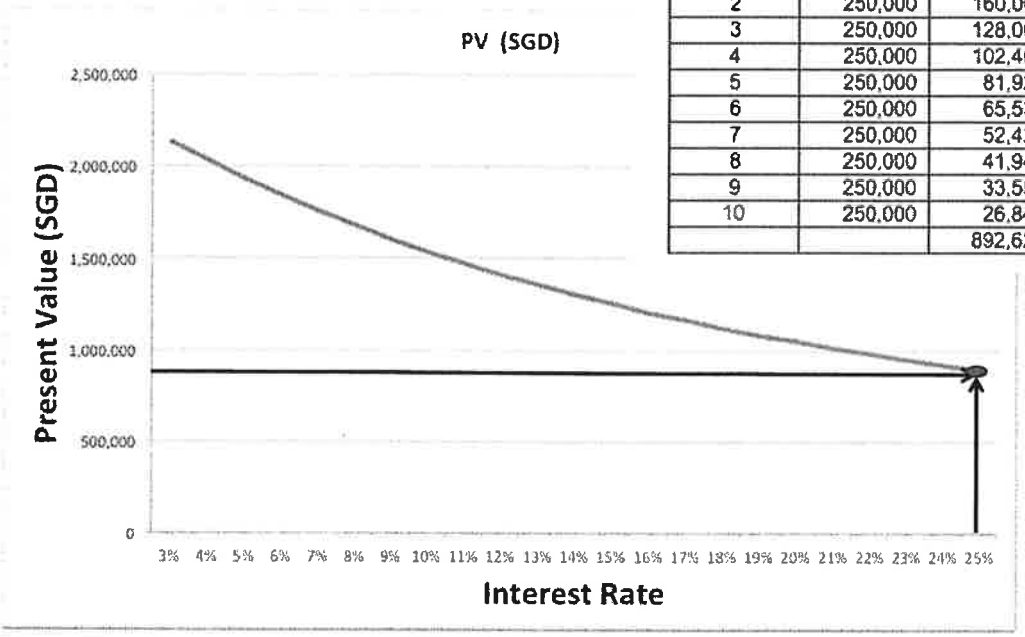

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Project Measures of Worth

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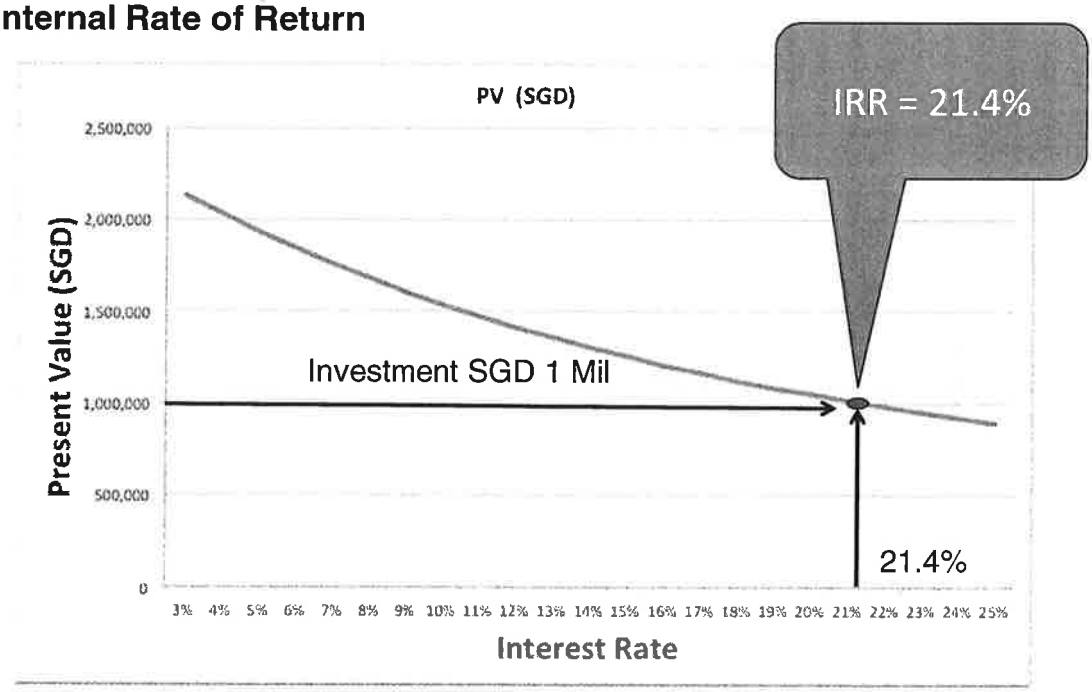
- **Internal Rate of Return**



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Project Measures of Worth

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- **Internal Rate of Return (IRR)**
- If the IRR of an investment in an Energy Savings Measure (ESM) is **higher** than the target or **required return**, it is VIABLE
- If the IRR of an investment in an Energy Savings Measure (ESM) is **higher** than the IRR of all the **other alternative ESMs** or **other investment options**, it is VIABLE

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Project Measures of Worth

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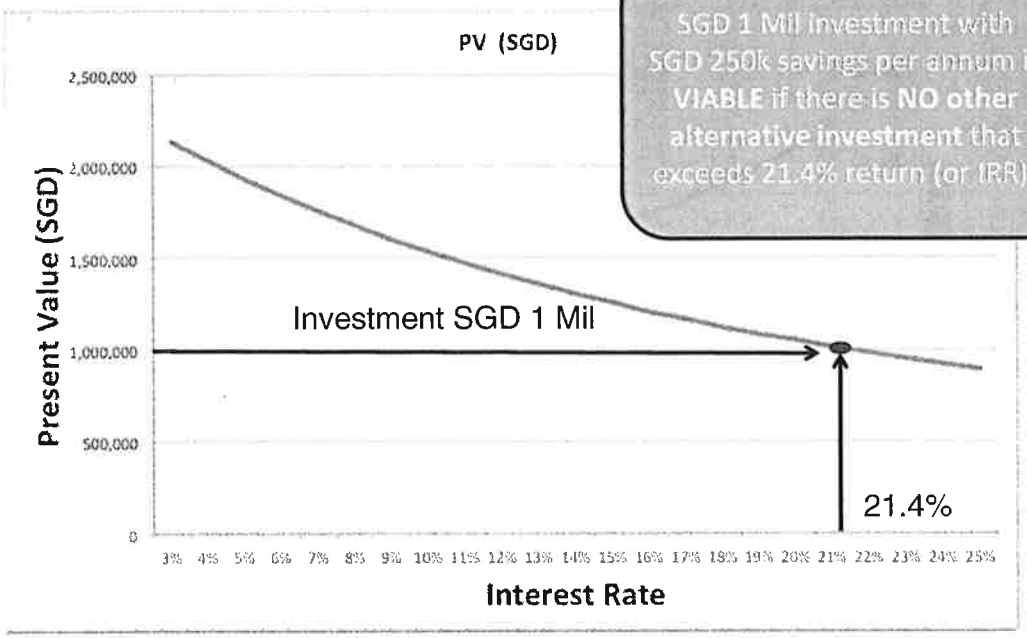
- **Internal Rate of Return**



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Project Measures of Worth

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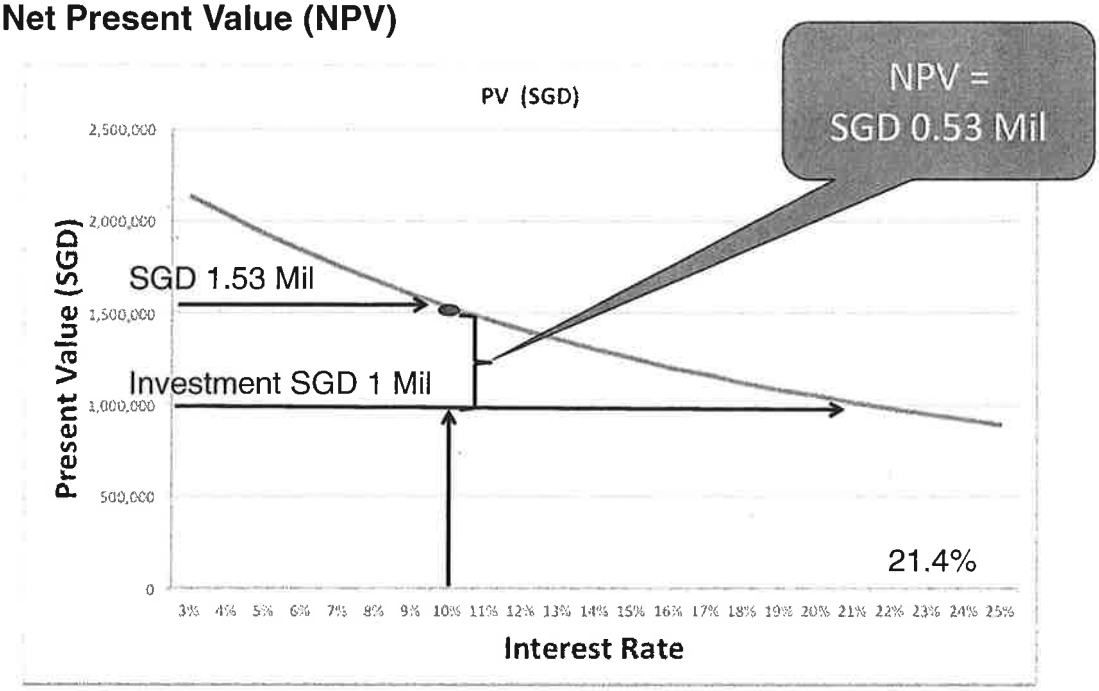
- **Net Present Value (NPV)**



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Project Measures of Worth

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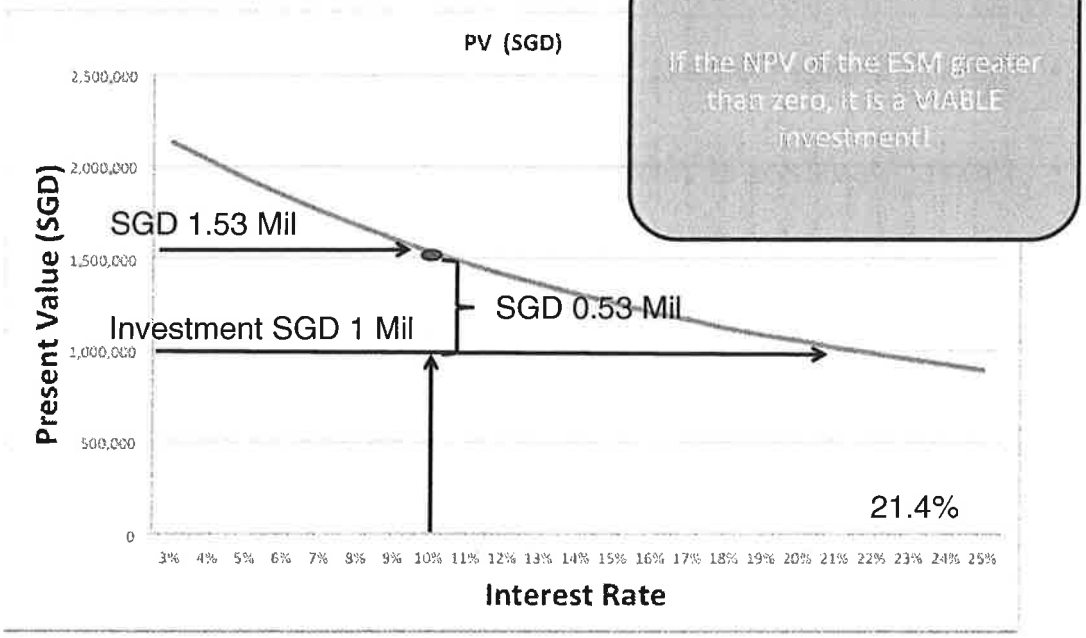
- **Net Present Value (NPV)**



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Project Measures of Worth

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- **Net Present Value (NPV)**
- If NPV > 0, project is VIABLE
- If NPV < 0, project is NOT VIABLE
- If NPV = 0, project is breakeven as the PV of future savings matches the cost of initial investment

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Outline

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- Life Cycle Cost Analysis
- Time of Money Concept
- Project Measures of Worth
- Economic Models of Optimal Energy Use
- Energy Policies

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Life Cycle Cost Analysis

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- Purpose of LCCA is to estimate the overall costs of various Design Alternatives or Solutions, select the design that provides the **LOWEST OVERALL COST** of **OWNERSHIP**

- Building related costs include:
  - Initial costs – Purchase, Acquisition, Construction Costs
  - Fuel costs
  - Operation, Maintenance and Repair costs
  - Replacement Costs
  - Residual Values – Resale or Salvage Values or Disposal Costs
  - Finance Charges – Loan Interest Payments
  - Non-Monetary Benefits or Costs

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Life Cycle Cost Analysis

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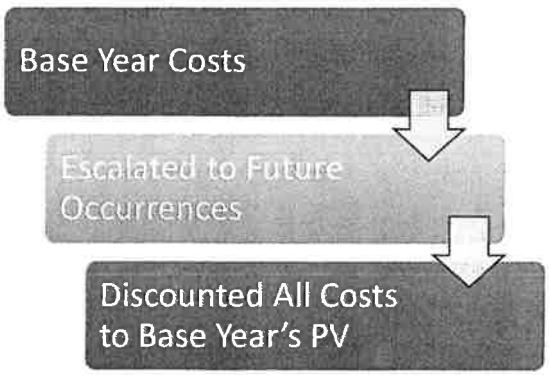
- Costs are entered as base-year amounts in today's dollar

- All costs are populated in future occurrence

- All future costs are then being discounted back to the base date to covert them to Present Values (PV)



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Life Cycle Cost Analysis

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LCC Components	Definition
LCC	Total LCC in present-value (PV) dollars of a given alternative
I	PV investment costs (if incurred at base date, they need not be discounted)
Repl	PV capital replacement costs
Res	PV residual value (resale value, salvage value) less disposal costs
E	PV of energy costs
W	PV of water costs
OM&R	PV of non-fuel operating, maintenance and repair costs
O	PV of other costs (e.g., contract costs for ESPCs or UESCs)

Ref.: http://www.wbdg.org/resources/lcca.php

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Life Cycle Cost Analysis

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One example of LCCA to be inserted

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Life Cycle Cost Analysis

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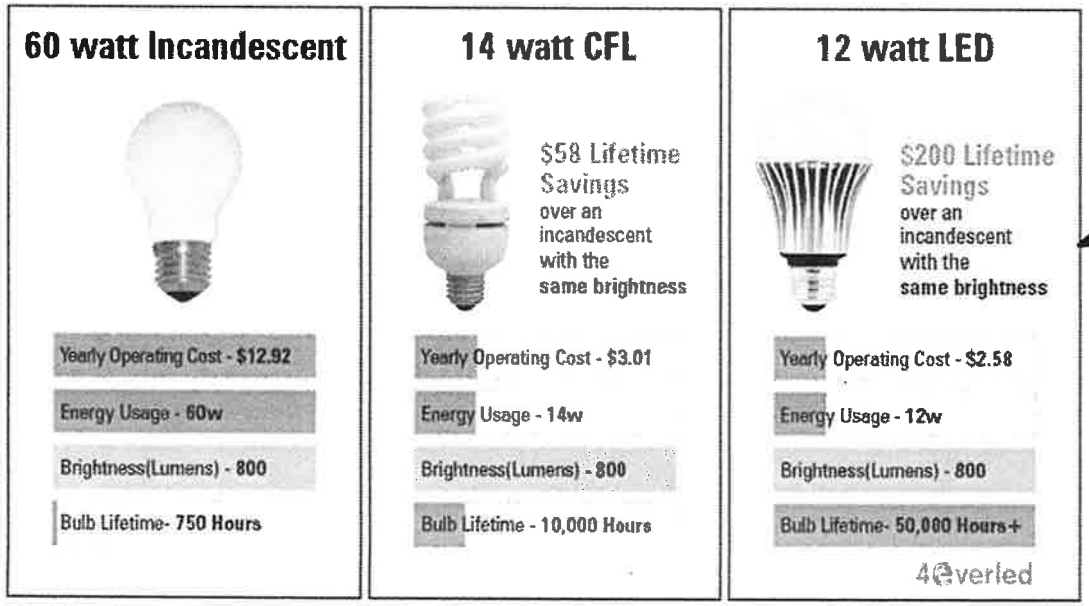
- Life Cycle Cost Analysis method
  - Converting all costs to a **Present Value (PV)**
  - The solution or alternative with the **lowest** Life Cycle Cost is the **best** option



Which solution is the best in terms of Life Cycle Cost?

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Outline

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- Life Cycle Cost Analysis
- Time of Money Concept
- Project Measures of Worth
- Economic Models of Optimal Energy Use
- Energy Policies

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Economic Models of Optimal Energy Use

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- Economic models are used to assess the costs of various policies to address climate change issues

- Typically, these models are
  - Complex mathematical representations of the economy
  - Designed to
    - give insight into economic relationship
    - assess the importance of key variables
    - explore sensitivity of various outcome measures to different policy options

- These models were unable to predict the future as widely diverging modeling results were produced over the years by the governments, industries, academic institutions and NGO

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Outline

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Energy Policies

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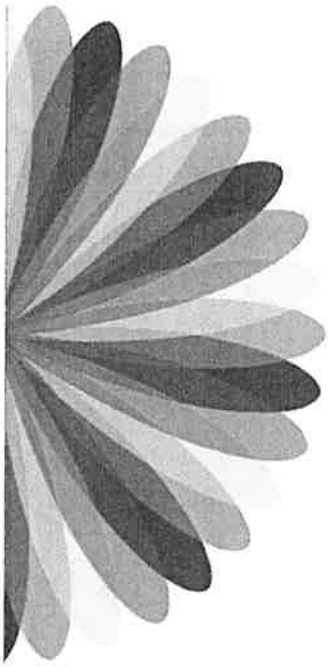

energyforgrowth
National Energy Policy Report

Ref: http://www.mti.gov.sg/ResearchRoom/Documents/app.mti.gov.sg/data/pages/885/doc/NEPR%202007.pdf

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Energy Policies

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- Singapore's National Energy Policy Report – Energy for Growth
- It outlines energy policy framework to meet objectives of
  - Economic Competitiveness
  - Energy Security
  - Environmental Sustainability

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Energy Policies

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We have been on the path toward sustainable growth for many years. We have succeeded in growing a strong industrial sector, while keeping our environment clean, green and liveable. We have cleaned up all our waterways, managed traffic congestion and have groomed a city in a garden. To further reduce emissions and energy costs, we need a concerted effort from the public, private and people sectors to achieve a stepped-up improvement in energy efficiency and conservation.

We also have a strong base to capture the global opportunities in energy. There are new and exciting opportunities to pursue in clean energy, such as solar power, fuel cells, biofuels, and in energy efficiency. From these, there will be spin-offs in services and other supporting industries that will give an additional buzz and grow Singapore into a global energy hub.

Energy for Growth outlines the challenges and opportunities that the current energy climate presents to Singapore, and Singaporeans. With a robust national energy policy framework and a comprehensive set of energy strategies, all of us can help achieve our vision of making Singapore an even more vibrant and exciting place to live, work and play.

LIM HNG KIANG
MINISTER FOR TRADE AND INDUSTRY

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Energy Policies

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Strategy 1: Promote Competitive Markets

We are committed to the promotion of competitive markets. This will help keep energy affordable and ensure our economic competitiveness. We have liberalised our electricity and gas markets, and are looking into enabling full contestability in the electricity retail market. Where there are market failures, we will correct them by using market-based instruments or imposing standards and regulations. We will also encourage the private sector to innovate and achieve the energy security and environmental outcomes that we are seeking.

Strategy 2: Diversify Energy Supplies

Energy diversification will help to protect us against supply disruptions, price increases and other threats to the reliability of supply. In competitive markets, companies themselves will have the incentives to diversify, and reduce their own commercial risks. The Government's role is to create an open and flexible framework that allows diversification to take place. For Singapore, there are also practical challenges to fuel diversification due to our limited energy options. Hydro, geothermal and wind power are not available in Singapore, while nuclear energy is not feasible due to our small size. Solar and coal power have some potential, but they face cost and technological barriers, and environmental concerns respectively. Nonetheless, we should not write off any energy option for Singapore. As technology improves, energy sources which are not viable for Singapore today may become feasible options in the future.

Strategy 3: Improve Energy Efficiency

Improving energy efficiency is a key strategy as it can help to achieve all three objectives of our energy policy. Using less energy to obtain the same output will decrease our dependence on energy imports and enhance our energy security, while reducing business costs, pollution and CO_2 emissions. The Government has set up an Energy Efficiency Programme Office (E^2PO) and developed a comprehensive national energy efficiency plan called Energy Efficient Singapore (E^2 Singapore).

Strategy 4: Build Energy Industry and Invest in Energy R&D

We can turn the energy challenges into opportunities by positioning our economy to meet rising global and regional demand for energy. We intend to increase our refining capacity to consolidate our status as Asia's premier oil hub. We will expand the range of energy trading products to include liquefied natural gas (LNG), biofuels and carbon emission credits. We are also pursuing growth opportunities in clean and renewable energy, including solar energy, biofuels and fuel cells. Strong research and development (R&D) capabilities are required to support industry development in these areas, which will also enable us to develop solutions that address our own energy needs.

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Energy Policies

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Strategy 5: Step Up International Cooperation

Given our small size and reliance on energy imports, it is important that our energy policy includes efforts to promote greater regional and international energy cooperation to further our energy interests. To enhance our energy security, Singapore continues to be actively involved in various energy-related initiatives in major fora, including the Association of Southeast Asian Nations (ASEAN), the Asia-Pacific Economic Cooperation (APEC) and the East Asia Summit (EAS). Because effective action against climate change needs to be carried out at an international level, Singapore also participates actively in the United Nations Framework Convention on Climate Change (UNFCCC), as well as international discussions on climate change in other fora.

Strategy 6: Develop Whole-of-Government Approach

The growing complexity and strategic importance of energy policy demands a Whole-of-Government approach. The work of drawing together the different strands of our energy policy began with the formation of the EPG in March 2006. The EPG plays the role of formulating and coordinating Singapore's energy policies and strategies. In addition to the development of a national energy policy framework comprising the six strategies outlined above, the EPG studied a wide range of energy issues which include power and transport sectors; energy efficiency; climate change; energy industry; energy R&D; and engaging international energy partners.

Several organisational changes have also taken place, such as the creation of a new Energy Division in MTI, the expansion of the Energy Market Authority (EMA), and the creation of the Clean Energy Programme Office (CEPO) and the E²PO. The Government has also set up the Energy Studies Institute (ESI) at the National University of Singapore (NUS) to promote and develop policy-oriented research on the economics, environmental and international relations aspects of energy, as well as contribute to energy dialogue and collaboration within the region.

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Energy Policies

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Energy Efficient Singapore
An E²PO Initiative

Singapore Government
Integrity • Service • Excellence

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- Clean Development Mechanism
- Design for Efficiency Scheme
- Energy Efficiency Improvement Assistance Scheme
- Finance Programme for Energy Efficiency Projects
- Grant for Energy Efficient Technologies

Energy Efficiency Improvement Assistance Scheme (EASe)

▼ **Why Conduct an Energy Assessment?**

What is an Energy Assessment?
An energy assessment (or energy audit) is carried out in an existing building or facility with the objective of improving its energy efficiency. It is an investigation involving a detailed analysis of energy flows into and out of a facility. The aim is to identify and quantify areas where energy

http://app.e2singapore.gov.sg

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Energy Policies

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- E^2PO



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Energy Policies

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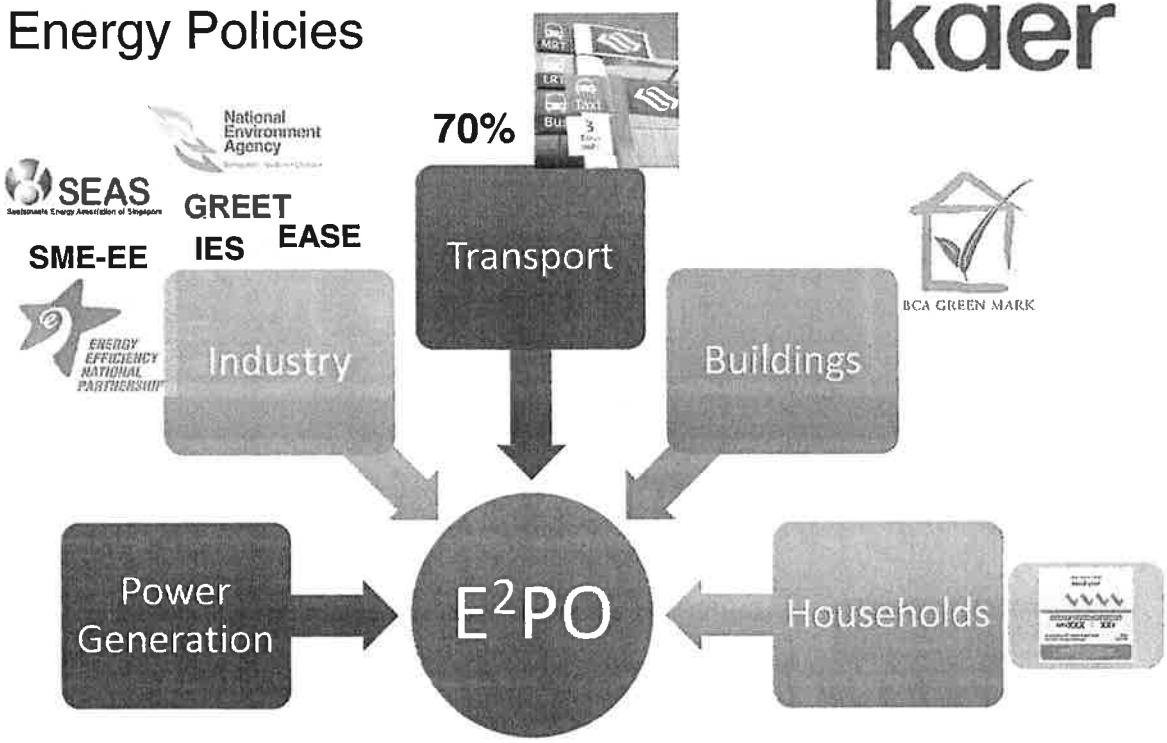

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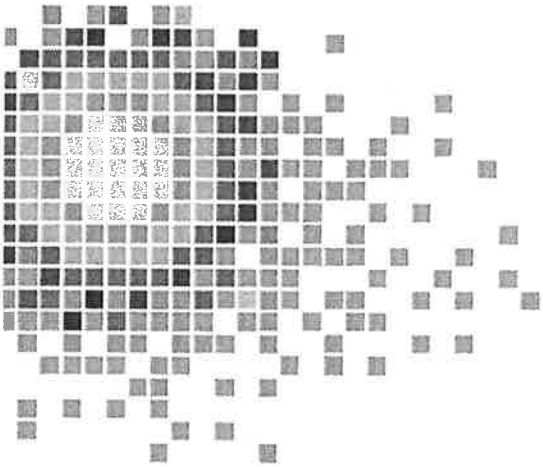

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4. Budget Planning and Procurement Procedure

Outline

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- Budget Planning for Improving Energy Performance
- Financial Analysis and Prediction for Energy Savings Assessment
- Preparing the Checklist for Procurement Procedure
- Case Studies : Energy Performance Contract

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Budget Planning

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- Forming an **Energy Team**
  - Establish the Structure
  - Name Team Members
    - *include members from each key energy-using process*
  - Appoint Energy Team Leader
    - *preferably from Senior Management*
  - Specify Roles and Responsibilities

- Ensure **adequate funding** on energy management initiatives

- Include "Energy Management" as a line item in the **Normal Budget Cycle**

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Budget Planning

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- Prioritization : Energy Monitoring Process and/or System

- **"You can't manage what you don't measure"**

- Stage 1 - Simplest Energy Monitoring:
  - Monthly utility bills and energy consumption data for the past 12 to 24 months
  - Monthly business activities, e.g.
    - Occupancy rates
    - Production volumes

- Stage 2 - More In-depth Energy Monitoring:
  - Energy use by building systems or processes
  - Energy sub-meters may be required

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Budget Planning

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- Prioritization : Energy Monitoring Process and/or System
- **"You can't manage what you don't measure"**
- Stage 3 – Energy Audit
  - Preliminary Energy Audit by ESCOs
  - Detailed Energy Audit (Level II or III) by ESCOs
- Stage 4 – Budget Planning based on Energy Savings Measures recommended by ESCOs

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Outline

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- Budget Planning for Improving Energy Performance
- Financial Analysis and Prediction for Energy Savings Assessment
- Preparing the Checklist for Procurement Procedure
- Case Studies : Energy Performance Contract

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Financial Analysis and Prediction for Energy Savings Assessment

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- Financial Analysis
  - Most ESCOs provide ESM recommendations in terms of investment, simple payback and ROI
  - Building owners can perform Life Cycle Cost Analysis to evaluate various recommended ESMs, or
  - Building owners can provide detailed cost data to ESCOs to perform Life Cycle Cost Analysis

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Financial Analysis and Prediction for Energy Savings Assessment

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- Prediction for Energy Savings Assessment
  - Detailed energy audit is required to establish **"Baseline"** or current energy efficiency of existing system or process
  - Potential of energy savings can be estimated by comparing **"Target"** against **"Baseline"** energy efficiency levels
  - Industry benchmarking can be used as reference to ensure the "Target" energy efficiency is **S.M.A.R.T**



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Financial Analysis and Prediction for Energy Savings Assessment

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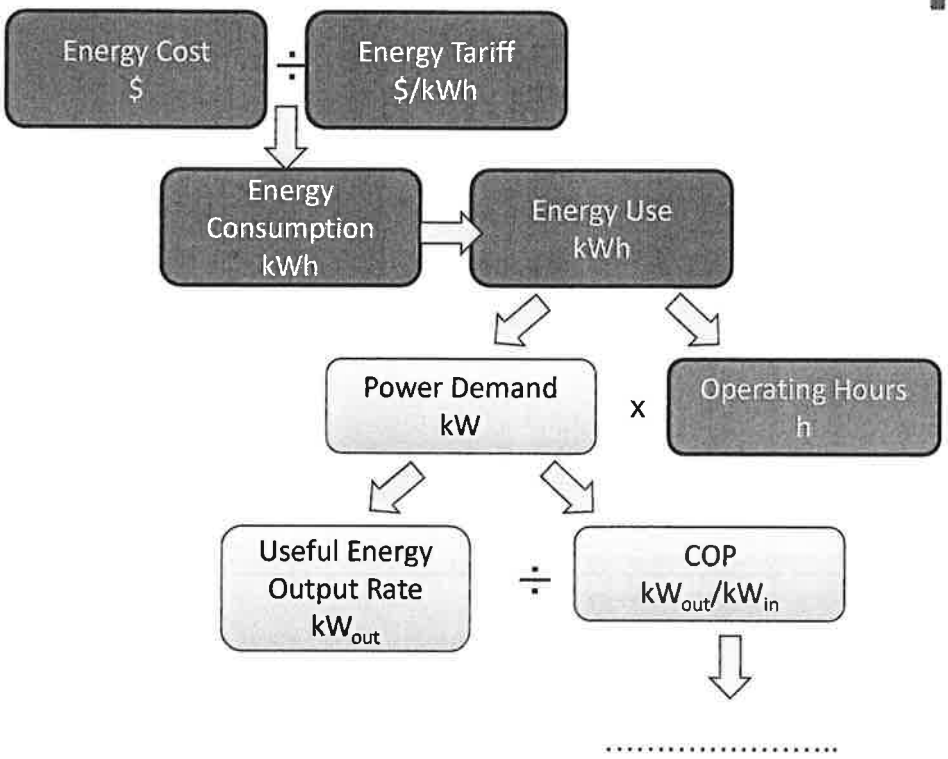

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Financial Analysis and Prediction for Energy Savings Assessment

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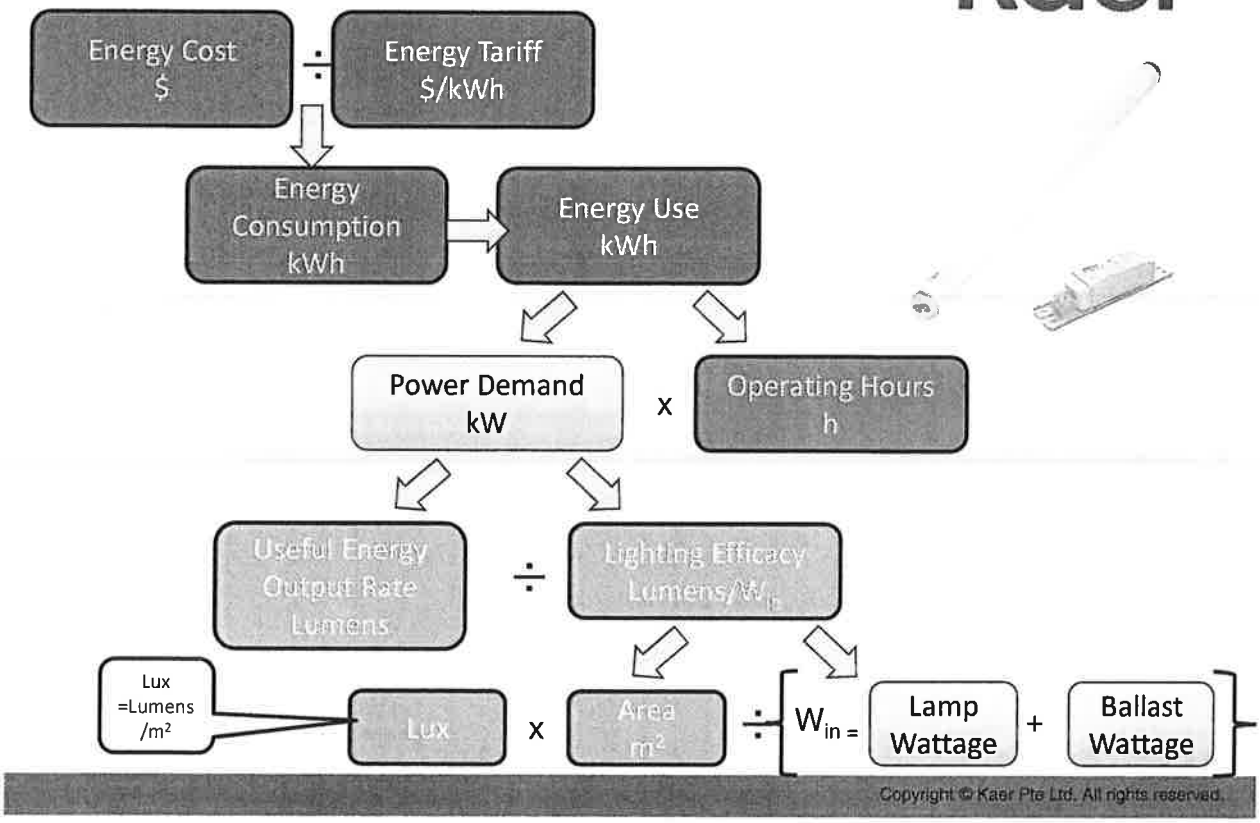

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Financial Analysis and Prediction for Energy Savings Assessment

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Base Case



Lighting Efficacy Lumens/W_{in} = 93 lumens/w

500 Lux x 5000 m2 x Factor = 2,500,000 lumens

W_{in} = Lamp Wattage + Ballast Wattage = 36W + 7 W = 43W per lamp

Number of Lamps = 2,500,000 l ÷ (93 l/w x 36 w/lamp) = 747 lamps

Electrical data	LUMILUX T8
Nominal wattage	36.00 W
Rated lamp efficacy (HF data 25 °C)	Under clarification by authority and standardization body
Rated lamp efficacy (standard condition)	93 lm/W
Rated wattage	36.00 W
Energy consumption	43 kWh/1000h

Note: Assume factor = 1.0; factor specific to an application can be simulated using software

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Financial Analysis and Prediction for Energy Savings Assessment

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Alternative Case #1



Lighting Efficacy Lumens/W_{in} = 82 lumens/w

500 Lux x 5000 m2 x Factor = 2,500,000 lumens

W_{in} = Lamp Wattage + Ballast Wattage = 30.5W + 8.5 W = 39W per lamp

Number of Lamps = 2,500,000 l ÷ (82 l/w x 30.5 w/lamp) = 1,000 lamps

Electrical data	LUMILUX T8 ES
Nominal wattage	30.50 W
Rated lamp efficacy (HF data 25 °C)	Under clarification by authority and standardization body
Rated lamp efficacy (standard condition)	82 lm/W
Rated wattage	30.50 W
Energy consumption	39 kWh/1000h

Note: Assume factor = 1.0; factor specific to an application can be simulated using software

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Financial Analysis and Prediction for Energy Savings Assessment

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Alternative Case #2



Lighting Efficacy Lumens/W_{in} = 94 lumens/w

500 Lux x 5000 m2 x Factor = 2,500,000 lumens

W_{in} = Lamp Wattage + Ballast Wattage = 35.5W + 4.5 W = 40W per lamp

Number of Lamps = 2,500,000 l ÷ (94 l/w x 35.5 w/lamp) = 750 lamps

LUMILUX T5 HE

Electrical data	
Nominal voltage	220 V
Nominal wattage	35.50 W
Rated lamp efficacy (HF data 25 °C)	94 lm/W
Rated wattage	35.50 W
Energy consumption	40 kWh/1000h

Note: Assume factor = 1.0; factor specific to an application can be simulated using software

Ref: http://www.osram.com/osram_com/products/lamps/fluorescent-lamps/fluorescent-lamps-t5/lumilux-t5-he/index.jsp

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Financial Analysis and Prediction for Energy Savings Assessment

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Energy Savings Analysis	Base (T8)	Alternative #1 (T8 ES)	Alternative #2 (T5)
Lamp Wattage (W)	36+7 = 43	30.5+8.5 = 39	35.5 + 4.5
Nos. Lamps	747	1000	750
Total kW	32.1	39.0	30.0
Lighting Power Budget (W/m2)	6.4	7.8	6.0
Operating Hours	60h x 52 weeks = 3,120 h	60h x 52 weeks = 3,120 h	60h x 52 weeks = 3,120 h
Annual kWh	100,152	121,680	93600
Annual Energy Savings kWh		-21,528	6,552
Annual Energy Cost Savings		-SGD 5,382	SGD 1,638

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Financial Analysis and Prediction for Energy Savings Assessment

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Total Cost of Ownership Analysis	Base (T8)	Alternative #1 (T8 ES)	Alternative #2 (T5)
First Cost (SGD)	(7+50)x747 = 42,579	(11+50)x1,000 = 61,000	(5+50)x750 = 41,250
Annual kWh	100,152	121,680	93,600
Annual Electricity Cost (SGD) based on 0.25 SGD/kWh tariff	25,038	30,420	23,400
Service Life	18,000h	18,000h	19,000h
Cost per Lamp (SGD)	SGD 7.00	SGD 11.00	SGD 5.00
Annual Replacement Cost (SGD)	3,120/18000 x 7.0 x 747 = 906	3,120/18000 x 11.0 x 1000 = 1,907	3,120/19000 x 5.0 x 750 = 616
Total Cost of Ownership (SGD), 10 years life cycle	42,579 + (25,038+906)x10 = **302,019**	61,000 + (30,420+1907)x10 = **384,710**	61,000 + (23,400+616)x10 = **282,739**

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Financial Analysis and Prediction for Energy Savings Assessment

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- Life Cycle Cost Analysis

		Year												
Escalation	Base	0	1	2	3	4	5	6	7	8	9	10	FV	PV
0%	First Cost	42,579											42,579	$42,579
3%	Energy Cost		25,038	25,789	26,563	27,360	28,180	29,026	29,897	30,794	31,717	32,669	287,033	$213,579
3%	Replacement Cost		906	933	961	990	1,020	1,050	1,082	1,114	1,148	1,182	10,386	$7,728
													Life Cycle Cost =	$263,887

		Year												
Escalation	Alternative #1	0	1	2	3	4	5	6	7	8	9	10	FV	PV
0%	First Cost	61,000											61,000	$61,000
3%	Energy Cost		30,420	31,333	32,273	33,241	34,238	35,265	36,323	37,413	38,535	39,691	348,731	$259,489
3%	Replacement Cost		1,907	1,964	2,023	2,084	2,146	2,211	2,277	2,345	2,416	2,488	21,862	$16,267
													Life Cycle Cost =	$336,756

		Year												
Escalation	Alternative #2	0	1	2	3	4	5	6	7	8	9	10	FV	PV
0%	First Cost	42,579											42,579	$42,579
3%	Energy Cost		23,400	24,102	24,825	25,570	26,337	27,127	27,941	28,779	29,642	30,532	268,255	$199,607
3%	Replacement Cost		616	634	654	673	693	714	736	758	780	804	7,062	$5,255
													Life Cycle Cost =	$247,440

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Financial Analysis and Prediction for Energy Savings Assessment

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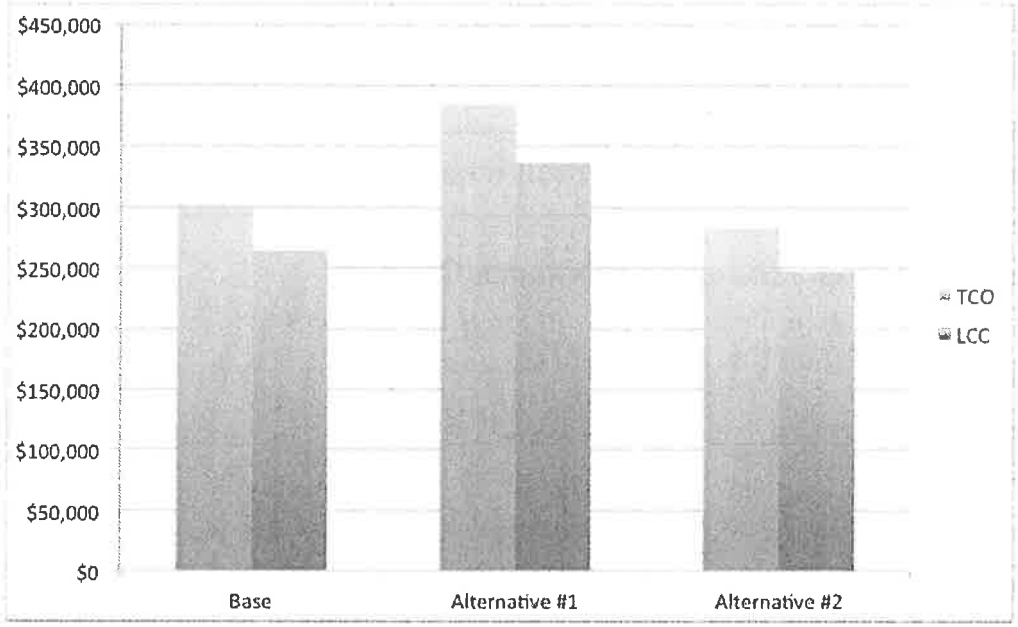
- TCO vs LCC



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Financial Analysis and Prediction for Energy Savings Assessment

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An example will be inserted as class activity

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Outline

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- Budget Planning for Improving Energy Performance
- Financial Analysis and Prediction for Energy Savings Assessment
- Preparing the Checklist for Procurement Procedure
- Case Studies : Energy Performance Contract

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Preparing Checklist for Procurement Procedure

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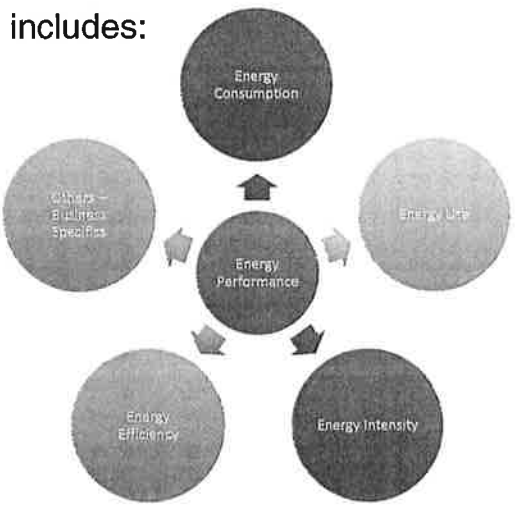
- Evaluation of energy performance of Energy Services, Products and Equipment to be procured that have an impact on significant energy use
- Energy performance includes:



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Outline

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- Budget Planning for Improving Energy Performance
- Financial Analysis and Prediction for Energy Savings Assessment
- Preparing the Checklist for Procurement Procedure
- Case Studies : Energy Performance Contract

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Why Performance Contracting?

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- What is the conventional building retrofit process?



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Why Performance Contracting?

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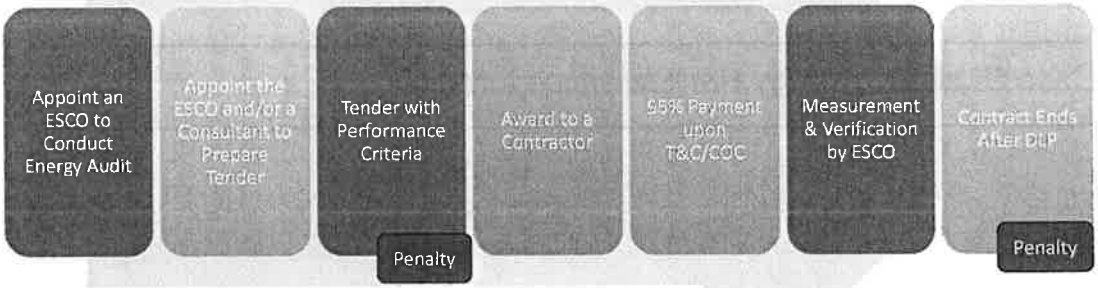
- **A.** Performance Contracting #1



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Why Performance Contracting?

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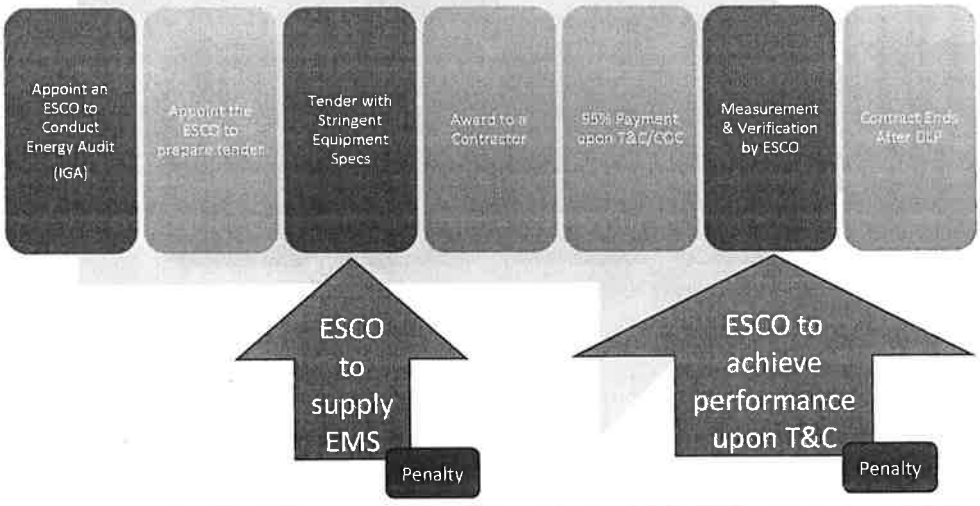
- **B.** Performance Contracting #2



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Why Performance Contracting?

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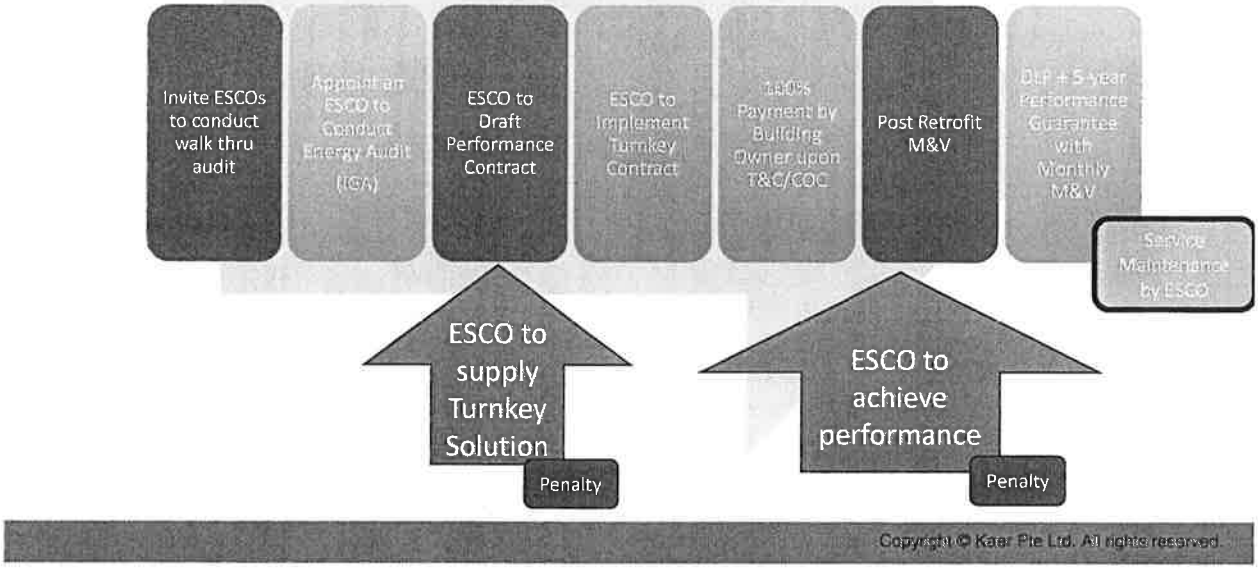
- **C.** Performance Contracting #3 (e.g. GESP)



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Why Performance Contracting?

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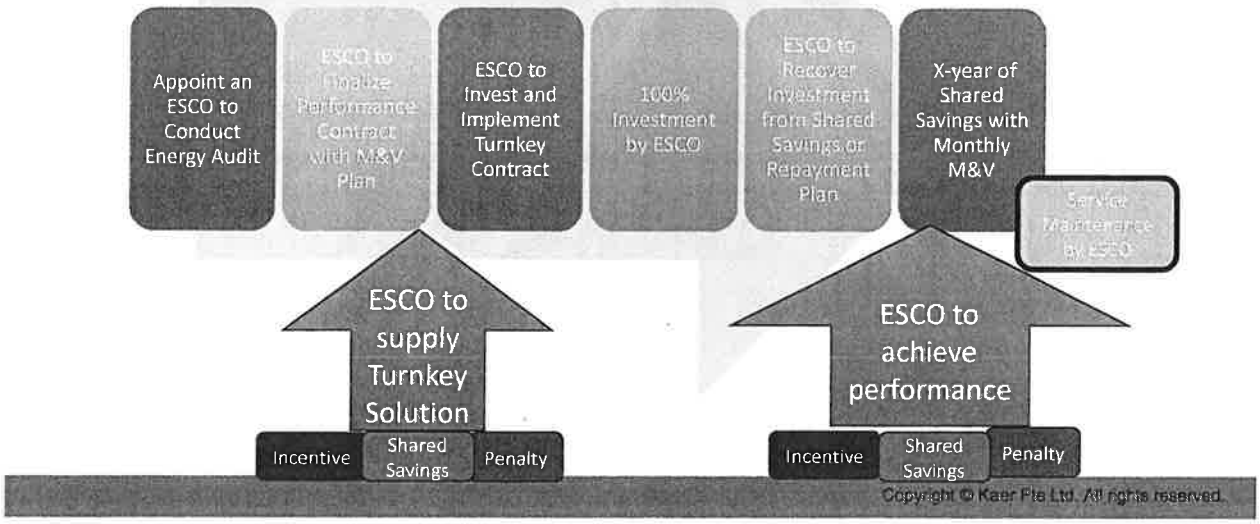
•**D.** Performance Contracting #4 (e.g. Shared Savings with Financing by ESCO, Direct Negotiation)



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Why Performance Contracting?

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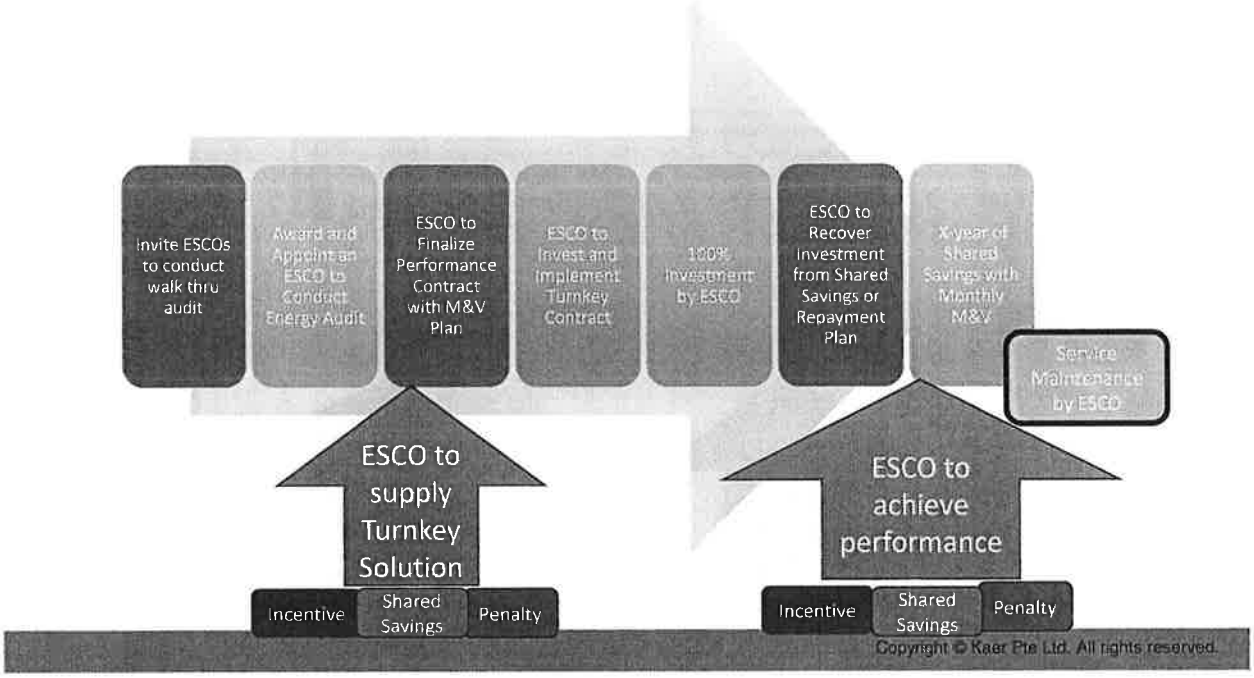
•**E.** Performance Contracting #5 (e.g. Shared Savings with Financing by ESCO, Tender)



Why Performance Contracting?

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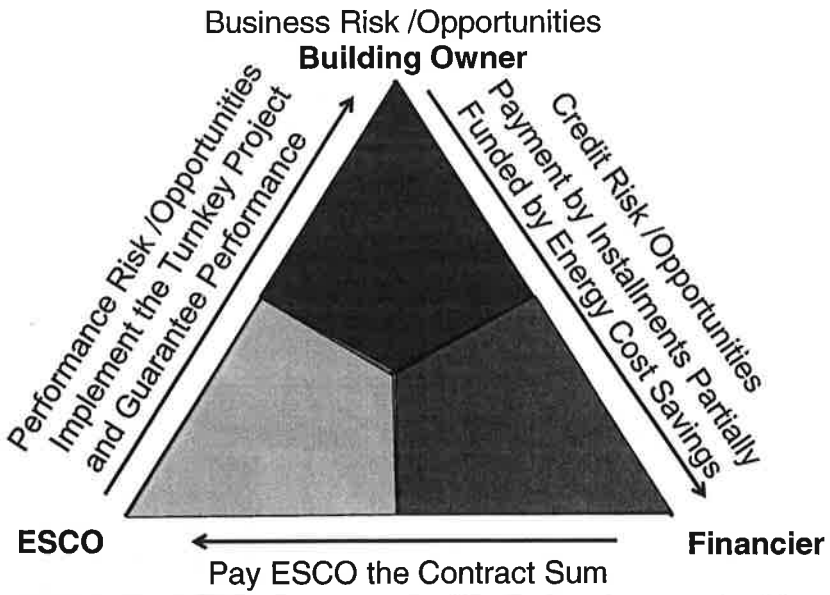
•**E.** Performance Contracting #5 (e.g. Shared Savings with Financing by ESCO)



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Why Performance Contracting?

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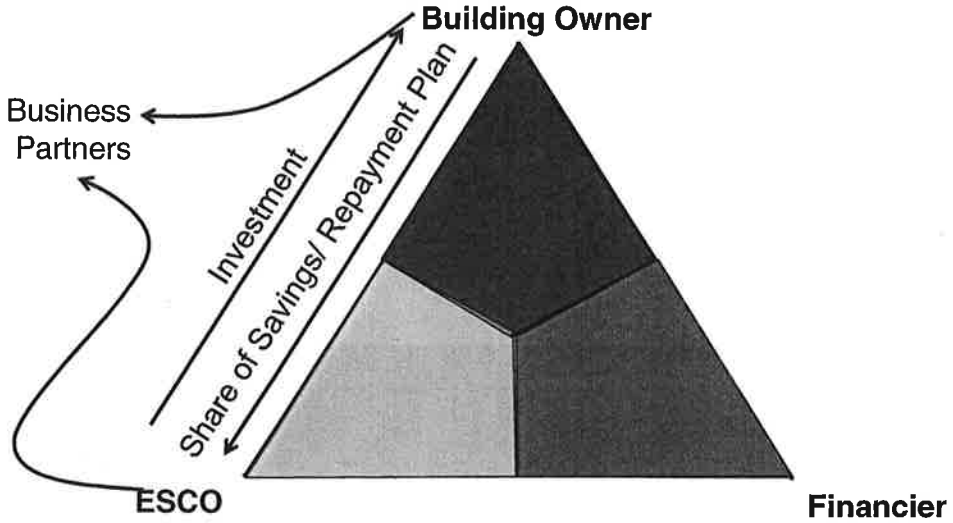
•**E.** Performance Contracting #5 (e.g. Shared Savings with Financing by ESCO)



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Taking Action

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Impact / Savings

Low Cost / High Impact
We need to find solutions that are cost effective (without grants) and make a real impact on reducing our energy consumption.

High Cost / High Impact
Chiller plant replacements are often seen as a very expensive option. This cost barrier is the single biggest hurdle to overcome if we are to make a significant impact in reducing our energy consumption.

Low Cost / Low Impact
Low cost solutions and technologies should be implemented immediately. Every little bit helps.

High Cost / Low Impact

$$$

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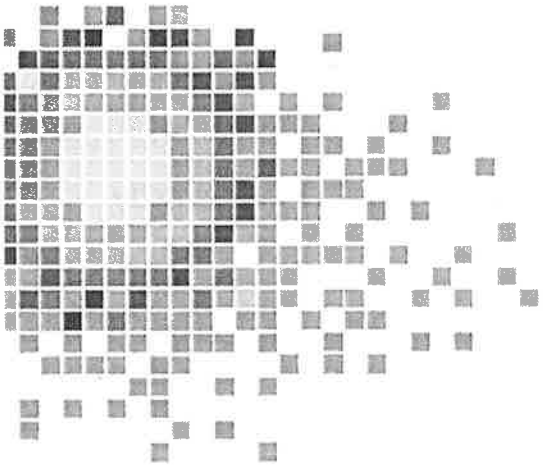

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Thank You

[redacted]

Financial Analysis and Prediction for Energy Savings Assessment

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LUMILUX T8

Service life	18000 h
Lifespan	20000 h
Rated lamp survival factor at 2,000 h	0.99
Rated lamp survival factor at 4,000 h	0.99
Rated lamp survival factor at 6,000 h	0.99
Rated lamp survival factor at 8,000 h	0.99
Rated lamp survival factor at 12,000 h	0.90
Operation mode LLMF/LSF	50 Hz
Rated lamp life time	20000 h
Nominal lamp life time	20000 h

LUMILUX T8 ES

Service life	18000 h
Lifespan	20000 h
Rated lamp survival factor at 2,000 h	0.99
Rated lamp survival factor at 4,000 h	0.99
Rated lamp survival factor at 6,000 h	0.99
Rated lamp survival factor at 8,000 h	0.99
Rated lamp survival factor at 12,000 h	0.90
Operation mode LLMF/LSF	50 Hz
Rated lamp life time	0 h

LUMILUX T5 HE

Service life	19000 h
Lifespan	24000 h
Rated lamp survival factor at 2,000 h	0.99
Rated lamp survival factor at 4,000 h	0.97
Rated lamp survival factor at 6,000 h	0.95
Rated lamp survival factor at 8,000 h	0.92
Rated lamp survival factor at 12,000 h	0.91
Rated lamp survival factor at 16,000 h	0.90
Rated lamp survival factor at 20,000 h	0.85
Operation mode LLMF/LSF	HF
Rated lamp life time	24000 h
Nominal lamp life time	24000 h

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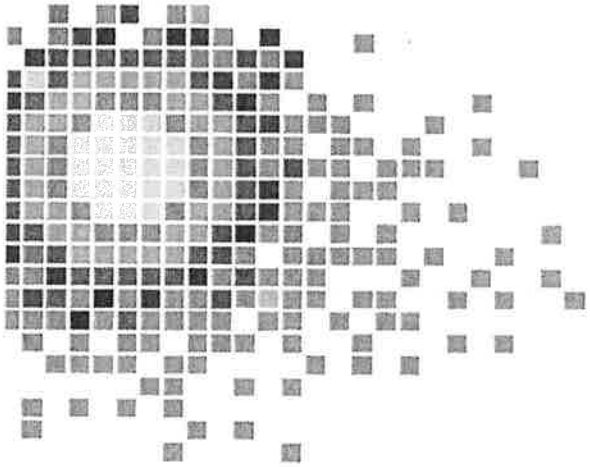

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TOMORROW'S BUILDINGS ENGINEERED TODAY

Introduction & Definition Of Energy Audit – Level 1 & 2

Day1, 4pm – 5pm

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Energy Audit – Definition

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Formal Process Of Examining The Energy Used In A Facility Through **Identification** Of Energy Flows Through The Facility; Deriving The **Rate** of Energy Usage Within The Facility In Relation To Its **Operations**

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Approach – Chilled Water System

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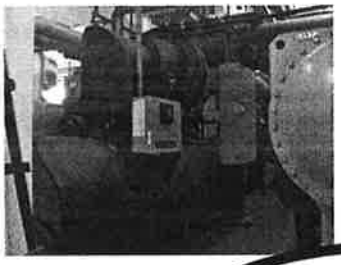
kWh Charge = kWh x S$/kWh

Tariff

OPERATIONS



kW x Hours of Operation

EFFICIENCY

Cooling Loads Tons x kW/RT

USAGE

Building Size/Envelope, Usage, and Weather

Chiller System Efficiency

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Approach – Lighting

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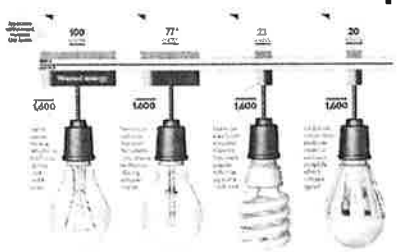
kWh Charge = kWh x S$/kWh

Tariff

OPERATIONS



kW x Hours of Operation

EFFICIENCY

Illuminence x lm/W

USAGE

Brightness Level

Efficacy Of Light Bulb

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Energy Audit – Benchmarking

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INPUT
(Electric, Diesel, LPG, Coal



OUTPUT
(HVAC, MV, Hot Water, Steam, Compressed Air, Lighting, Plug Load, etc

OPERATIONS
Hotel: 24 hours
Office: 10 hours
Retail: 14 hours

BENCHMARKS

$kWh/m^2/year$
kW/RT
W/m^2
Ft^2/Ton
COP
W/CMH

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Energy Audit –Why ? - Objective

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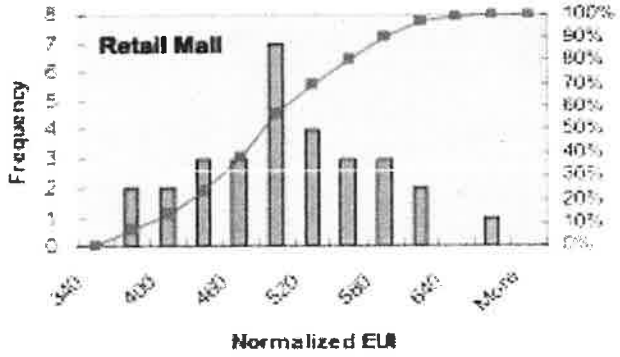
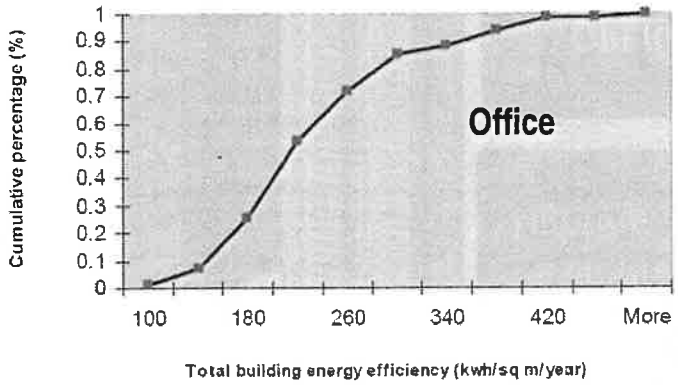
1. To Derive The Facility Energy Usage Index - Intensity, Efficiency & EUI
2. To Benchmark The Facility With Similar Class Of Building
3. To Develop Energy Conservation Measures To Further Improve Its Index

EUI_0 = {TBEC/(GFA-GLA*(FLVCR/100))}

Normalised EUI = EUI_0 - $292.51X_1 - 1179.09X_2 - 1203.06X_3 + 276$

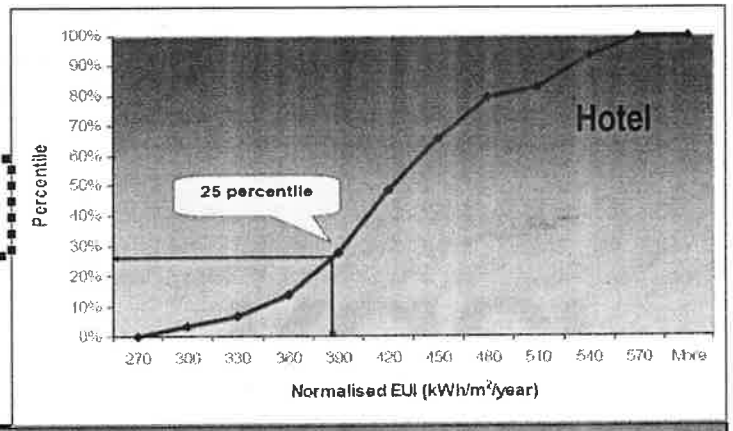




Normalised EEI = (TBEC-DCEC-CPEC)/ (GFA-CPA-DCA)

EUI = TBEC/(GFA-CPA)

Normalised EUI = EUI - 167.97 X + 138.91



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Energy Audit – Not Forgetting Your Original Objective

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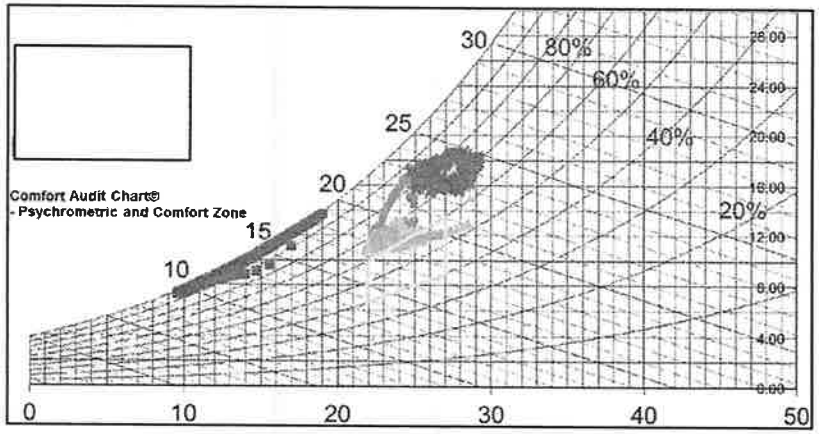
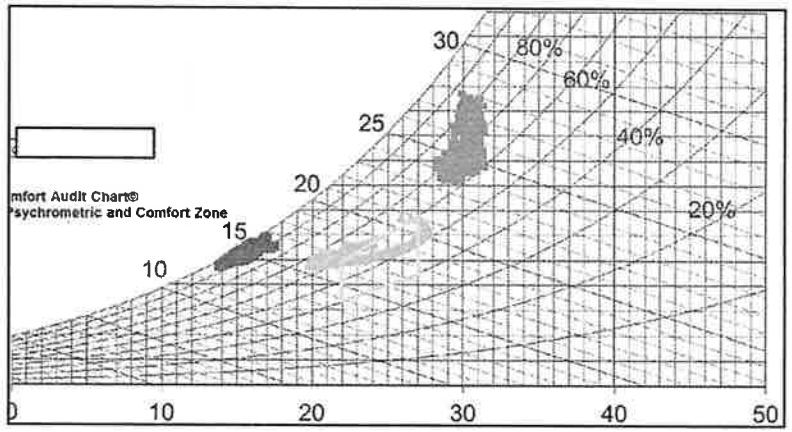
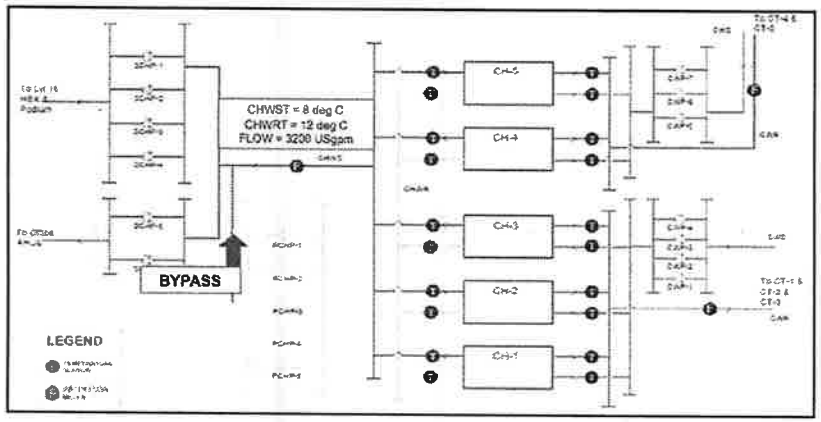
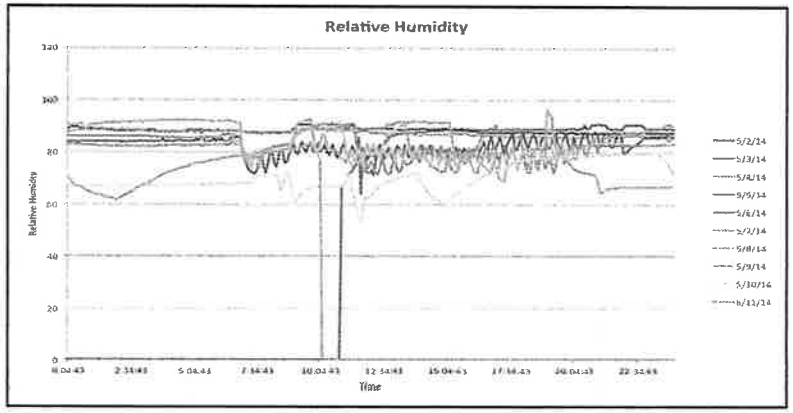
1. To Ascertain The Condition Within The Facility – Hot Spot, Humidity, etc

2. Understand System Operational Shortfall Or Deficiency









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Energy Audit – How & When ? - Methodology

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3 Level Of Energy Audit

a. Level 1 – Walk Through Assessment

b. Level 2 – Detailed Walk Through Assessment

c. Level 3 – Investment Grade Energy Audit

When To Conduct The Different Level Of Energy Audit

a. Depend On The Facility Physical Size And Energy Usage Characteristics

b. On The Needs And Amount of Resources Available

c. Intent Level Of Measures That The Organisation Look For

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Level 1 Energy Audit

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Also known as the Walk Through Audit or Assessment

1. Evaluate the facility energy consumption from the 12-months energy and water charges
2. Carry out brief site survey and understand the design intent of the plant system in the facility
3. Interview the plant operators on operations, challenges and future plan for the facility
4. Identify the major energy consumption system within the facility
5. Develop various level of measures for energy savings and cost analysis
6. The details and depth of the audit depends on the availability of information and auditor experience

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Level 1 Energy Audit – Site Survey

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Prior Information Before The Site Survey

1. List of equipment and system available on the facility
2. 12-months utilities bill, include electric, diesel, LPG etc and water charges
3. Brief description of facility such as GFA, NLA, data centre and F&B outlet

Site Survey Focus

a. Identify major energy consuming system and process

b. Identify areas on energy wastages and inefficiency

c. Identify gaps between plant operations and plant design intent

d. Identify areas where design condition are not met or over achieved

e. Identify areas for further site study and analysis

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Level 1 Energy Audit – System Available

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Office Building

1. Chilled Water Plant System
2. Airside – AHU & FCU
3. Lighting System
4. Mechanical Ventilation
5. Vertical Transportation

Retail Mall

1. Item 1 to 5 above
2. Kitchen Exhaust Fan
3. Refrigeration System

Hotel

1. Item 1 to 5 as office building
2. Hot Water System
3. Steam System
4. Refrigeration System

Industry

1. Item 1 to 5 as office building
2. Item 2 to 4 as hotel
3. Compressed air system
4. Vacuum system
5. Scrubber system
6. Manufacturing System

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Level 1 Energy Audit – Data Analysis

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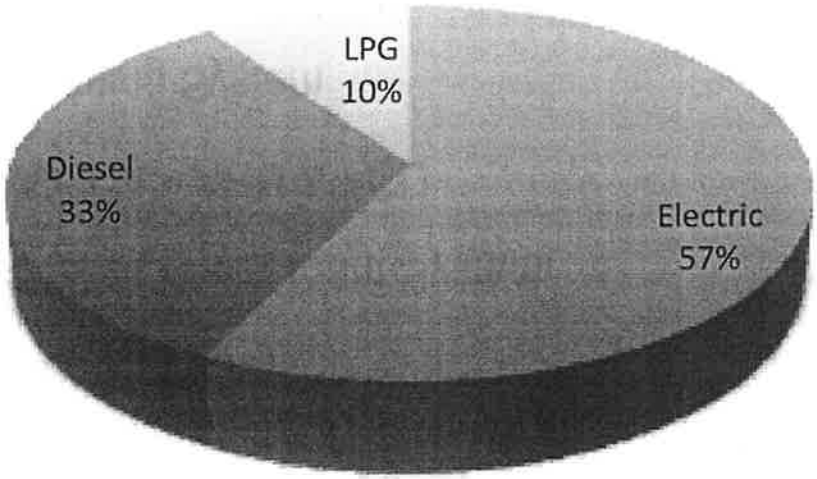
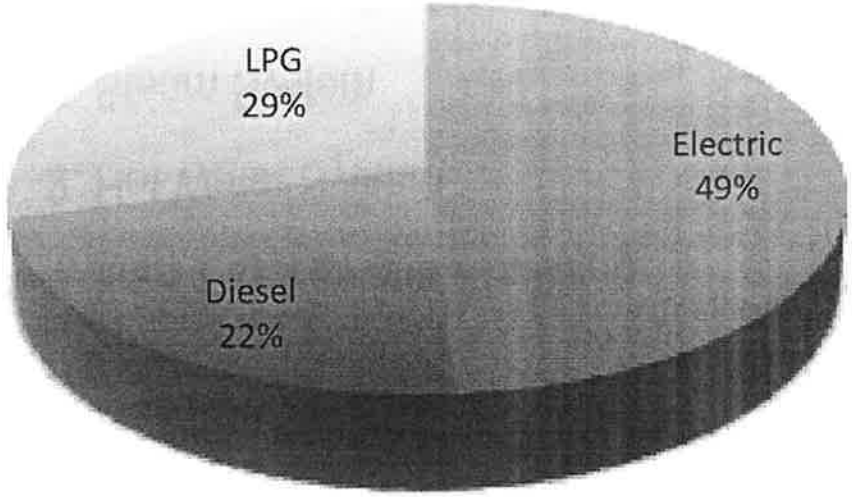
Overview Of Annual Energy Consumption

Description	liters/kg	kcal/kg or liters	kWh	Cost
Electric			5,883,476	$ 2,008,287.74
Diesel	334,743	10.03	3,357,468	$ 910,499.80
LPG	89,280	10.87	970,475	$ 1,178,586.00
			10,211,419	$ 4,097,373.54





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Level 1 Energy Audit - Benchmarking

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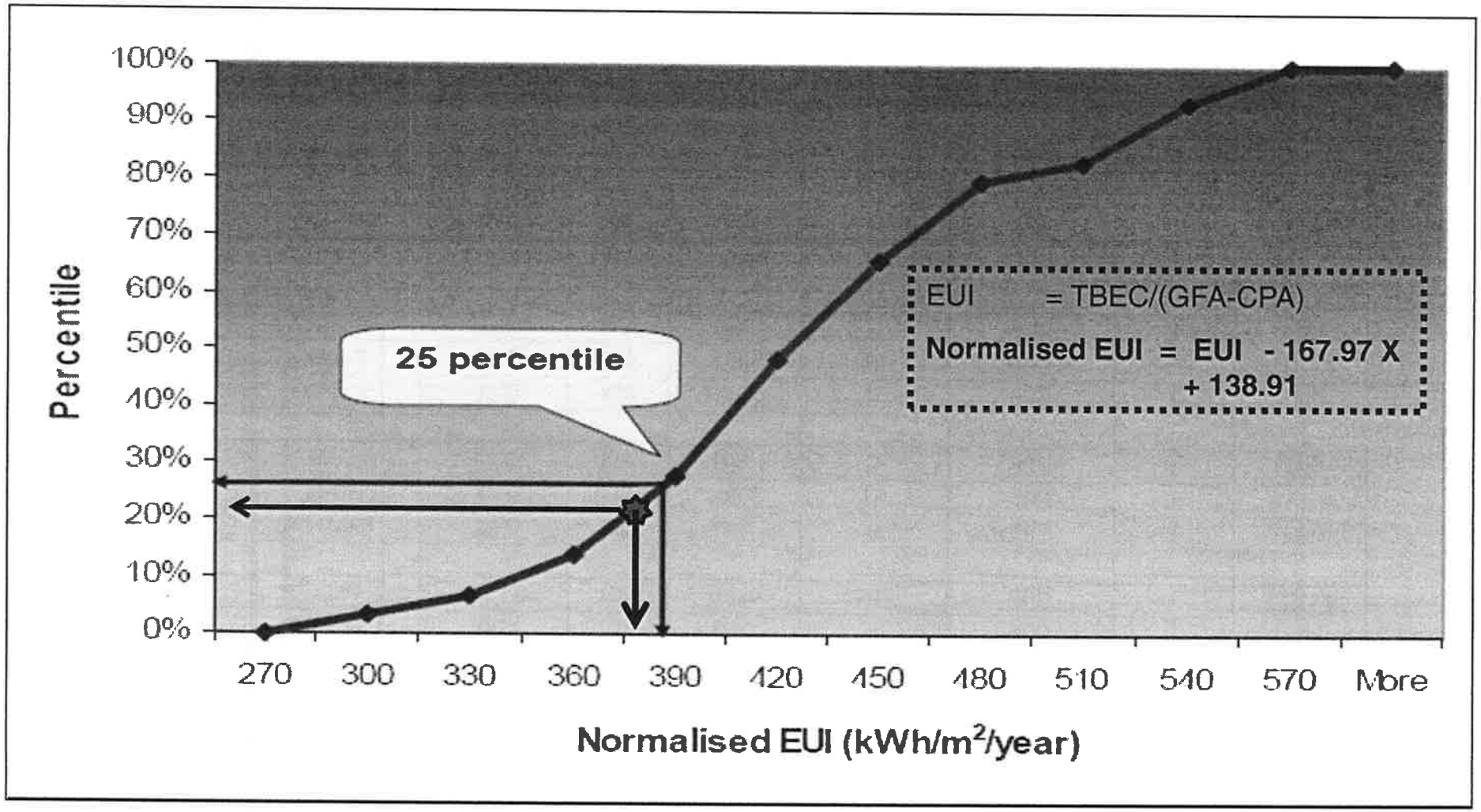

- *Hotel Normalized EUI = 376 kWh/m²/yr, 22% cohort*

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Level 1 Energy Audit – CHW Plant Efficiency

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No.	Item	Rated Capacity	Unit	% Load	Input Amp	Input Voltage	PF	Input kW
1	Chiller 1-1	400.0	ton	0%	0	400	1	0.00
2	Chiller 1-2	400.0	ton	64%	182	400	1	126.09
3	CHWP1	37.0	kW	0%	0	400	1	0.00
4	CHWP2	37.0	kW	58%	17	400	1	11.78
5	CHWP3	37.0	kW	0%	0	400	1	0.00
6	CWP 1	37.0	kW	0%	0	400	1	0.00
7	CWP 2	37.0	kW	72%	24	400	1	16.63
8	CWP 3	37.0	kW	0%	0	400	1	0.00
9	CT 1	11.0	kW	96%	10	400	1	6.93
10	CT 2	11.0	kW	0%	0	400	1	0.00
								kW/Ton

No Heat balance
CHWpump VSD at 28.6Hz, but flow at 100%??
Cwpump VSD at 36Hz, again Flow at 100%
VSD not regulated

Total kW	161
Total Tonnage	176
System kW/Ton	**0.920**
Component kW/Ton	0.201
Chilled Water Pump kW/Ton	0.067
Condenser Water pump kW/Ton	0.095
Cooling Tower kW/Ton	0.039
Chiller kW/Ton	0.718

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Level 1 Energy Audit – CHW Heat Balance

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No Heat balance CHWpump VSD at 28.6Hz, but flow at 100%?? Cwpump VSD at 36Hz, again Flow at 100% VSD not regulated	Total kW	161
	Total Tonnage	176
	System kW/Ton	**0.920**
	Component kW/Ton	0.201
	Chilled Water Pump kW/Ton	0.067
	Condenser Water pump kW/Ton	0.095
	Cooling Tower kW/Ton	0.039
	Chiller kW/Ton	0.718

Item	CHWS T DegF	CHWR T DegF	CHW Flow Usgpm	Rton	CWS T DegF	CWR T degF	CW Flow Usgpm	CW Tonnage	Electrical Ton	Heat Balance
Chiller 1-1	0	0	0	0	0	0	0	0	0.0	0
Chiller 1-2	43.8	51.9	520	175.5	80.8	86.7	840	206.5	35.9	-2%

Heat Balance, X = $\dfrac{\text{[Condenser Water Tonnage in kW] - (Chilled Water Tonnage in kW + Chiller Power kW)}}{\text{[Condenser Water Tonnage in kW]}} \times 100\%$

Accept if the value is -5% < X > +5%

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Chilled Water System Forecast

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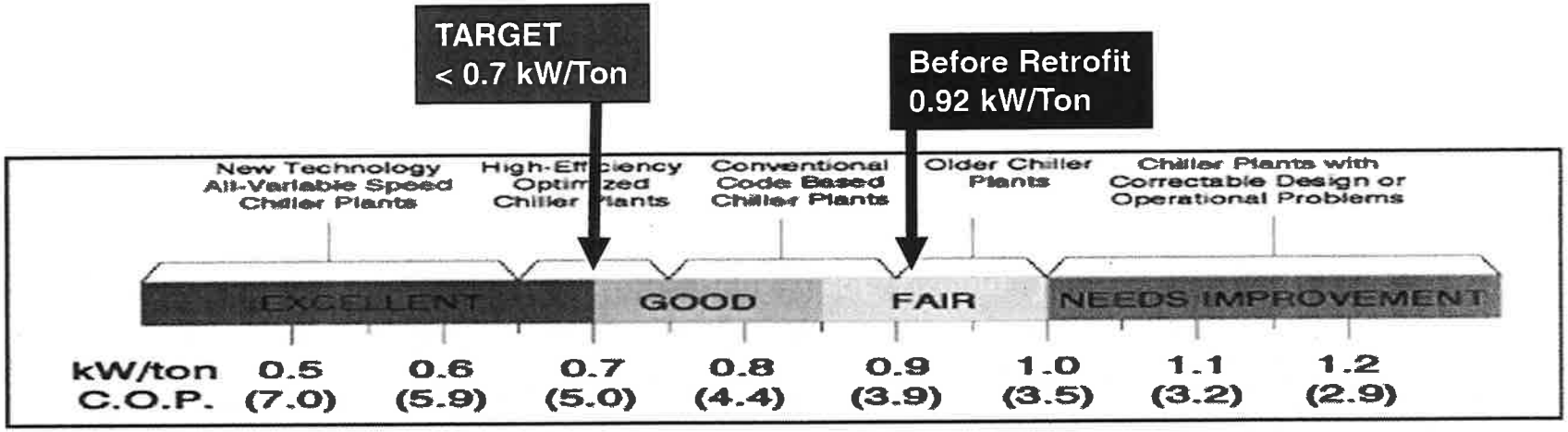

Before Retrofitting Chilled Water Plant Efficiency : 0.92 kW/Ton

Target Chilled Water Plant Efficiency : < 0.7 kW/Ton

Energy Savings Potentials Of Up To 578,160 kWh per annum
Or $144,540 per annum

Optimisation Of Plant With M&V System
Investment : S$250,000 Payback 1.7 years

Assumption: 24-hr Average C-Ton=300RT, Tariff: S$0.25/kWh

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Chilled Water System Forecast

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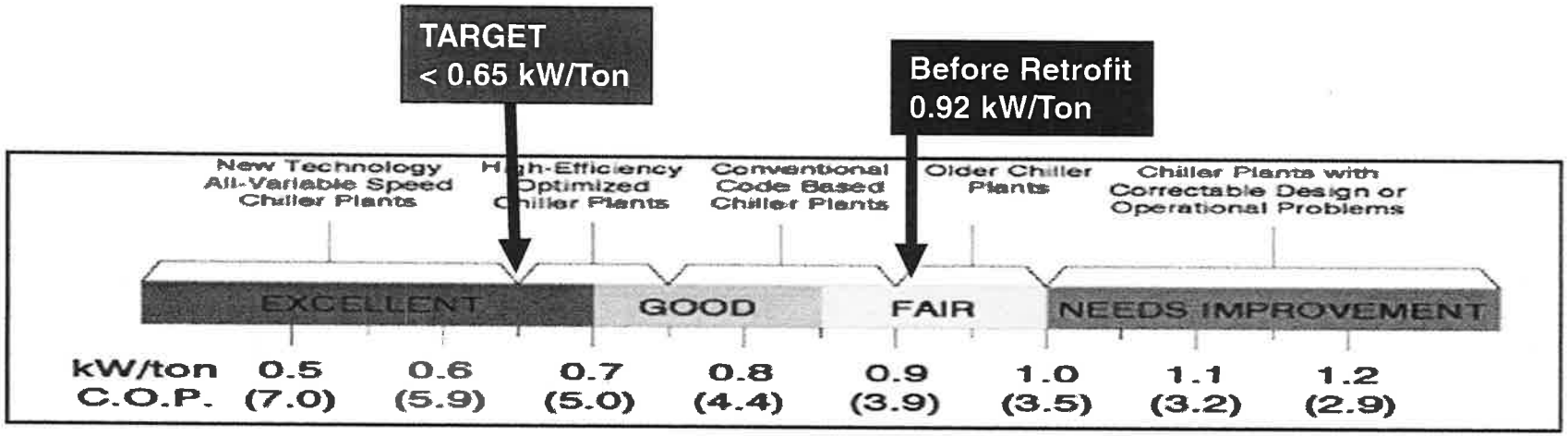

Output Type	Full Load	Part Load	Part Load	Part Load	Part Load	Part Load	Part Load	Part Load	Part Load	Part Load
Percent Load	100.00	90.00	80.00	70.00	60.00	50.00	40.00	30.00	20.00	11.00
Chiller Capacity	400 Tons	360 Tons	320 Tons	280 Tons	240 Tons	200 Tons	160 Tons	120 Tons	80 Tons	44 Tons
Chiller Input kW	219 kW	196 kW	175 kW	156 kW	133 kW	114 kW	96 kW	79 kW	63 kW	49 kW
Chiller Input Power	0.546 kW/Ton	0.544 kW/Ton	0.547 kW/Ton	0.556 kW/Ton	0.556 kW/Ton	0.568 kW/Ton	0.599 kW/Ton	0.656 kW/Ton	0.784 kW/Ton	1.122 kW/Ton
Chiller COP	6.44	6.47	6.43	6.33	6.33	6.19	5.87	5.36	4.48	3.13

	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
Tonnage per Chiller	400	360	320	280	240	200	160	120	80	40
Total Operating Tonnage	400	360	320	280	240	200	160	120	80	40
Chiller Efficiency	0.548	0.544	0.547	0.557	0.554	0.570	0.600	0.658	0.788	1.225
CHWP Efficiency	0.093	0.075	0.059	0.045	0.033	0.040	0.050	0.067	0.100	0.200
CWP Efficiency	0.093	0.075	0.059	0.045	0.033	0.040	0.050	0.067	0.100	0.200
CT Effiency	0.041	0.033	0.026	0.020	0.015	0.018	0.022	0.030	0.045	0.089
Total Efficiency	0.774	0.728	0.692	0.668	0.636	0.668	0.722	0.821	1.032	1.714
CHW FlowRate/RT	2.40	2.40	2.40	2.40	2.40	2.88	3.60	4.80	7.20	14.40
CW FlowRate/RT	3.00	3.00	3.00	3.00	3.00	3.60	4.50	6.00	9.00	18.00

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Lighting – Challenge And Opportunities

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a. Estimate The Lighting Brightness Is Reasonable For The Task At Hand
b. For Hotel And Retail, The Ambience May Be Imperative To Create The Mood And Enhance The Display
c. Focus On Common Area Lighting And Offices

- Fluorescent tube with high frequency ballast has potential savings of approximately 20 W
- Based on 1,000 tubes, the expected energy savings is
- = [20W x 12 hrs x 5 days x 1,000 tubes x 52 weeks]/1000 = 62,400 kWh
- @ S$0.25/kWh; the energy cost savings is S$15,600 per year

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AHU Fan – Challenge And Opportunities

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a. Estimate The Lighting Brightness Is Reasonable For The Task At Hand
b. For Hotel And Retail, The Ambience May Be Imperative To Create The Mood And Enhance The Display
c. Focus On Common Area Lighting And Offices

- Fluorescent tube with high frequency ballast has potential savings of approximately 20 kW
- Based on 1,000 tubes, the expected energy savings is
- = [20W x 12 hrs x 5 days x 1,000 tubes x 52 weeks]/1000 = 62,400 kWh
- @ S$0.25/kWh; the energy cost savings is S$15,600 per year

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Airside – Fan Power And Tonnage

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a. Derive the installed AHU fan distribution efficiency in W/CMH
b. Derive the AHU efficiency in kW/Ton

- Standard Constant Air Volume AHU distribution efficiency at 0.47 W/CMH
- Standard Variable Air Volume AHU distribution efficiency at 0.74 W/CMH
- Most AHU now operate at efficiency of 0.2 to 0.4 kW/Ton
- Targeted AHU efficiency to aim for is 0.15 kW/Ton
- Estimated AHU distribution efficiency at 0.25 W/CMH

What Are The Challenges And Opportunities ?

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Mechanical Ventilation

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a. Design Air Change: 20 – Peak Load Condition
b. Provision For Part Load Operations

- Assume current fan power: 13.5 kW x 2 units
- Volume Of Space : 20m x 10m x 4m = 800 m3
- Estimated CMH required : 16, 000 CMH
- Estimated fan power is 8 kW
- With Fan Speed Controls based on temperature and CO sensor, more savings opportunities could be scope out

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Level 1 – Report Requirement

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1. Executive Summary
2. Brief Description Of Building And Used
3. Utility Bill Analysis
4. Building Benchmarking
5. Chilled Water Plant Efficiency Rating And Benchmarking
6. Airside Observation And Analysis
7. Hot Water Plant Efficiency Rating And Benchmarking
8. Lighting Observation And Analysis
9. Energy Conservation Measures – No Cost
10. Energy Conservation Measures – Short Term
11. Energy Conservation Measures – Mid Term
12. Energy Conservation Measures – Long Term

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Energy Audit – Level 2

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Detail Site Survey And Facility Energy Analysis

1. Detailed understanding of the system designed, installed and operations
2. Spot measurement of system operations within the facility
3. Detailed input from the operators on the system designed, installed and operations

Site Survey Objectives

a. Derive the energy consumption percentage of each system in the facility

b. Identify action or areas that affect the system operations and maintenance

c. Develop energy conservations measures that address current system deficit and potential energy savings with cost and savings analysis

d. Develop an intensive energy conservation measures that requires further data collection and analysis with estimates on cost and savings analysis

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Energy Audit – Level 2 – Where Do You Start ?

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1. Energy Consumption And Cost Analysis
2. Analysis Of Design Data Of System Available In The Facility
3. Site Survey And Spot Measurement Of The Available System In The Facility
4. Survey And Spot Measure The Space Condition / Controls System
5. Survey And Spot Measure The Split Units / Chilled Water Plant / VRV System
6. Survey And Spot Measure The The Lighting System In The Facility
7. Survey And Spot Measure The Hot Water / Boiler Condition
8. Survey And Spot Measure The Mechanical Ventilation System
9. Survey And Understand The Control Logic Of The Building Automation System

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Energy Audit – High Impact Component

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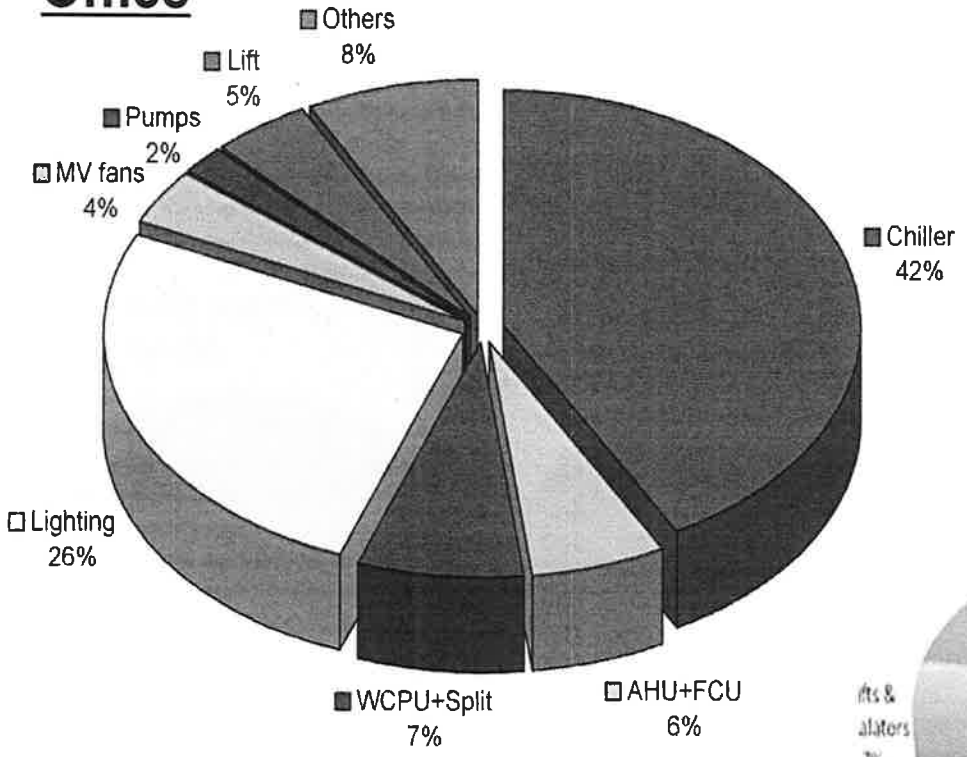
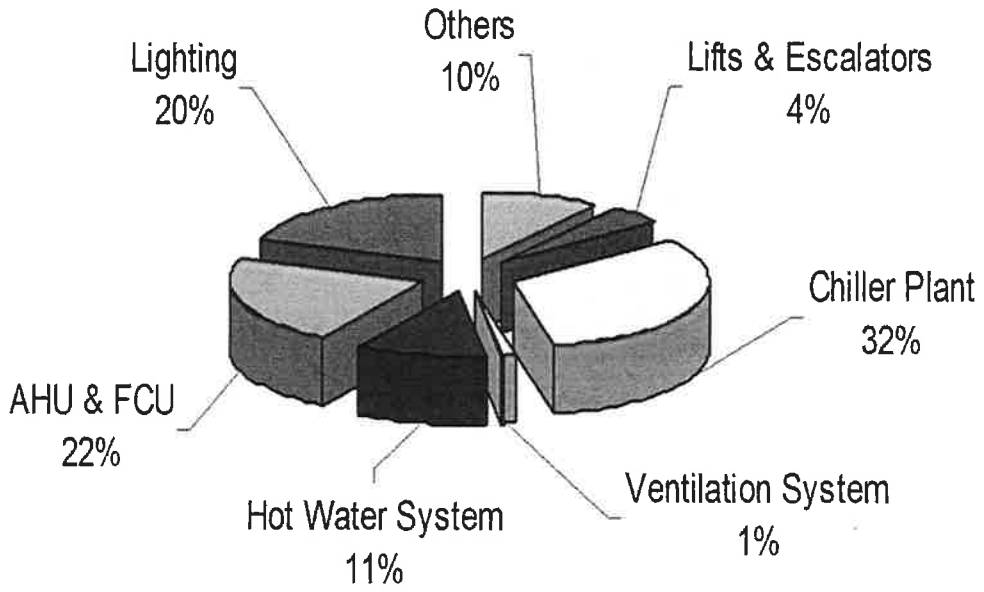
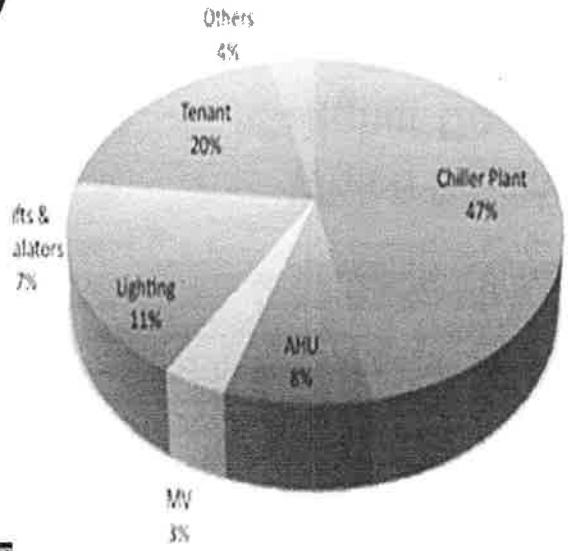
Office



Hotel



Retail



Which Component Has The Higher Impact?

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Energy Audit – Comparative Analysis

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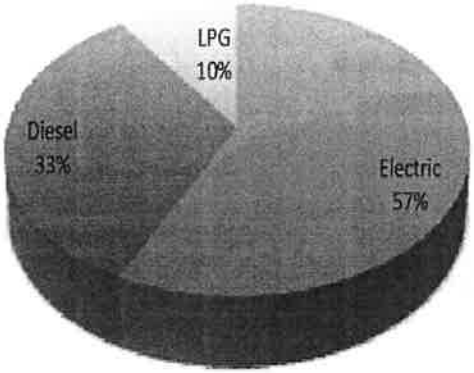
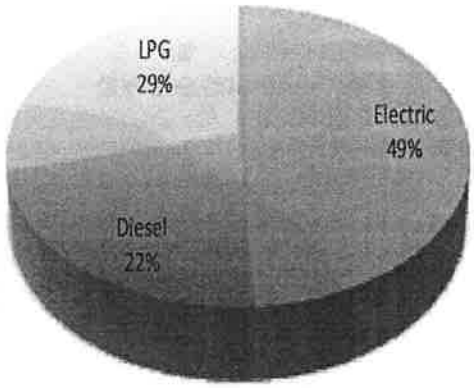


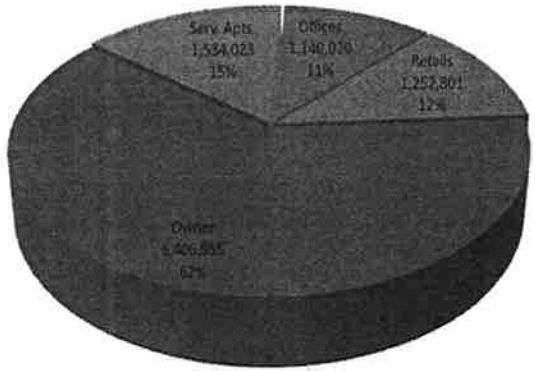
Energy Used, kWh



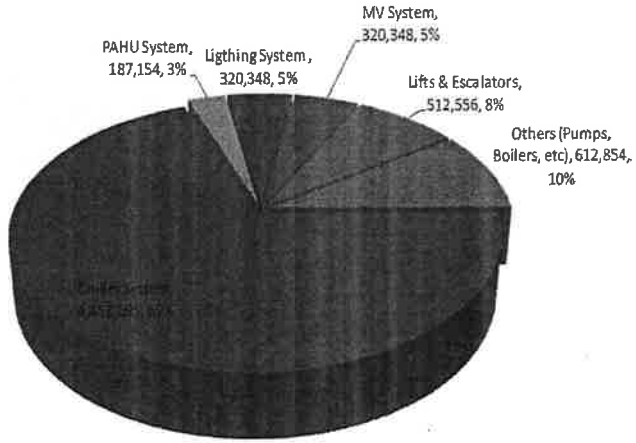
Cost Of Energy Used, S$

Which Source Of Energy Has The Higher Cost Impact?

What Is Actually Your Actual Components Usage?



Annual Total Energy Used Of Building



Annual Landlord Energy Usage

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Energy Audit – HVAC Approach

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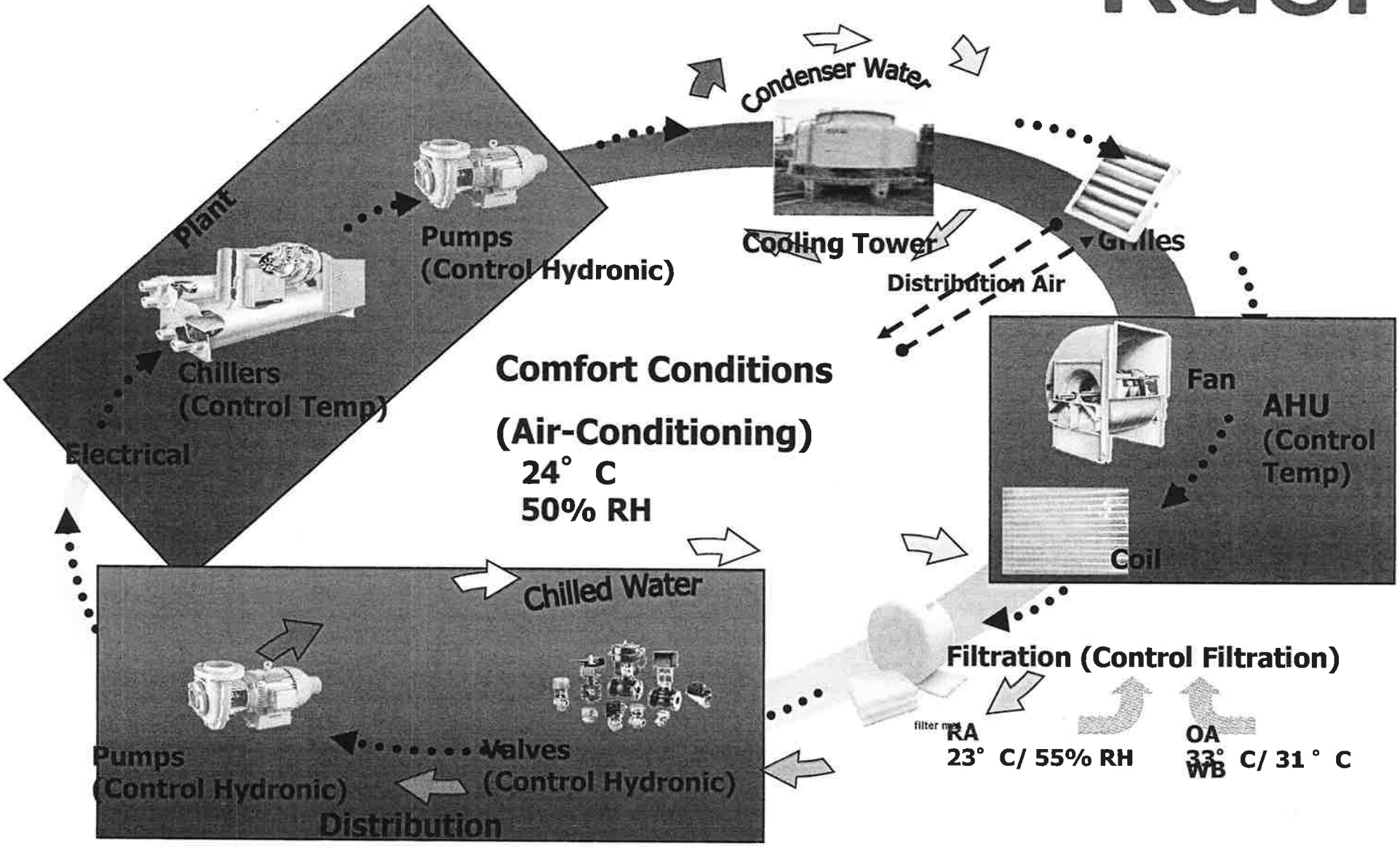

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Energy Audit – Airside Approach

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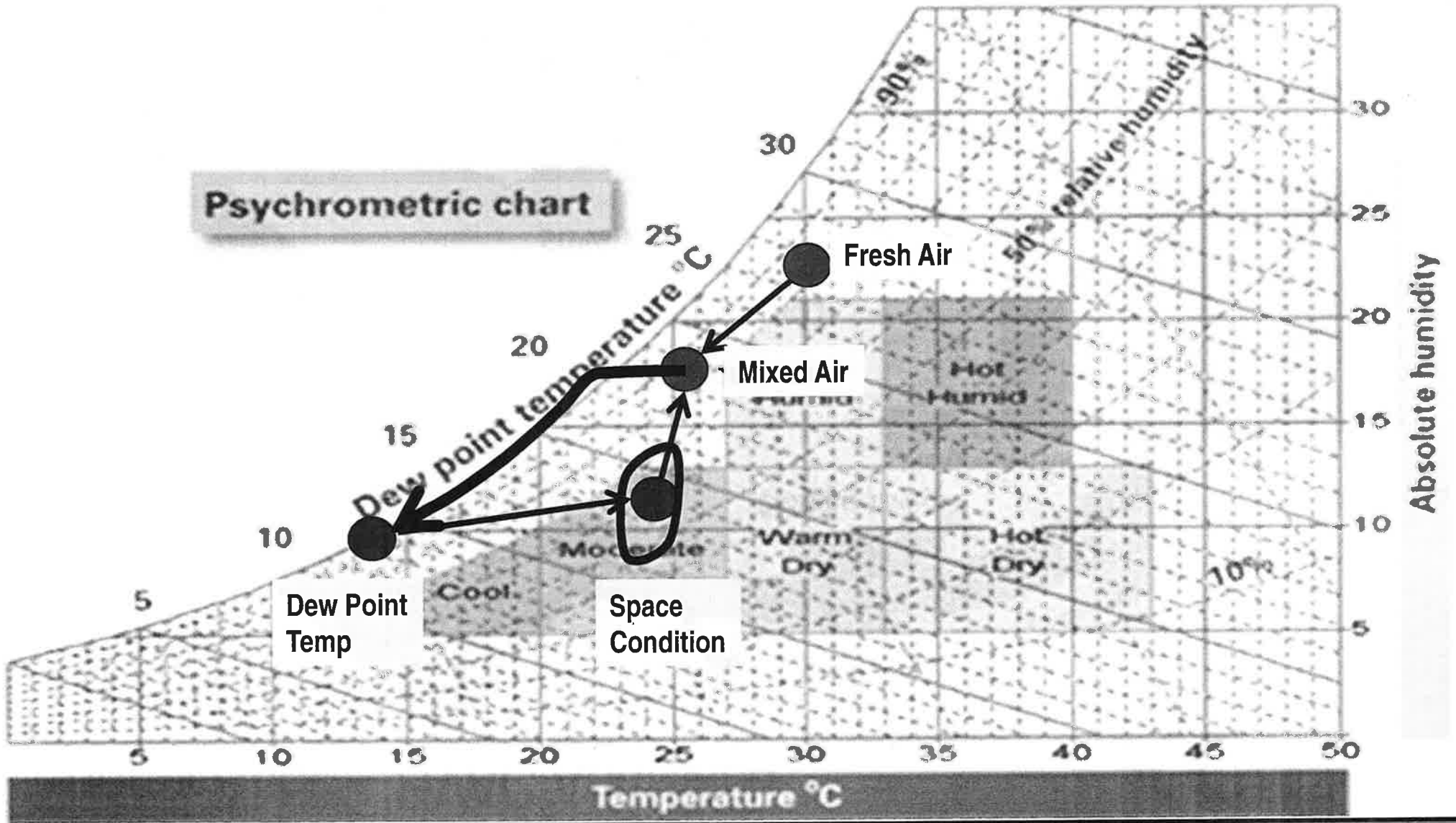

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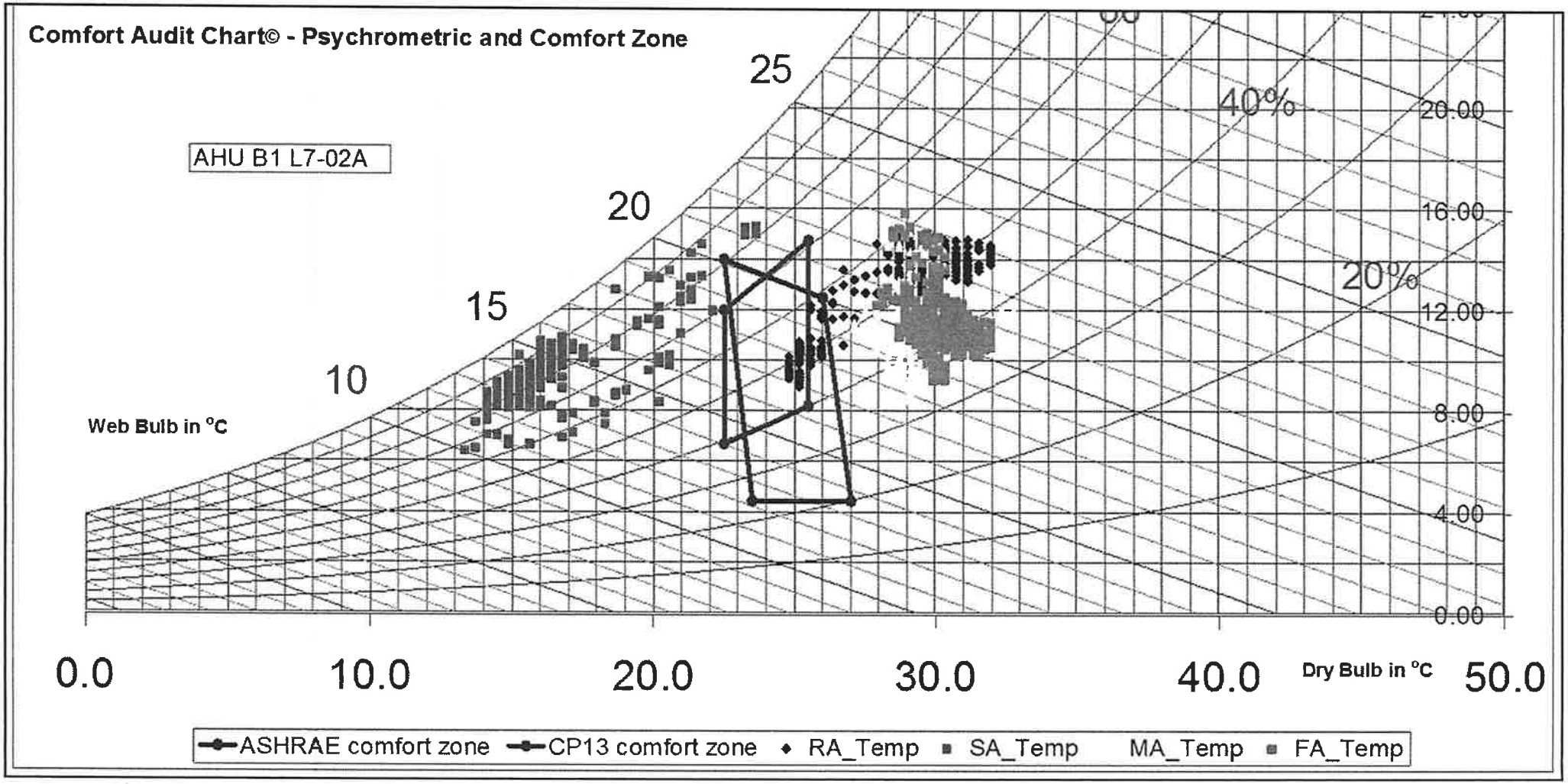
Airside Data Analysis – How Do You Read It ?



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Airside Data Analysis – How Do You Read It ?

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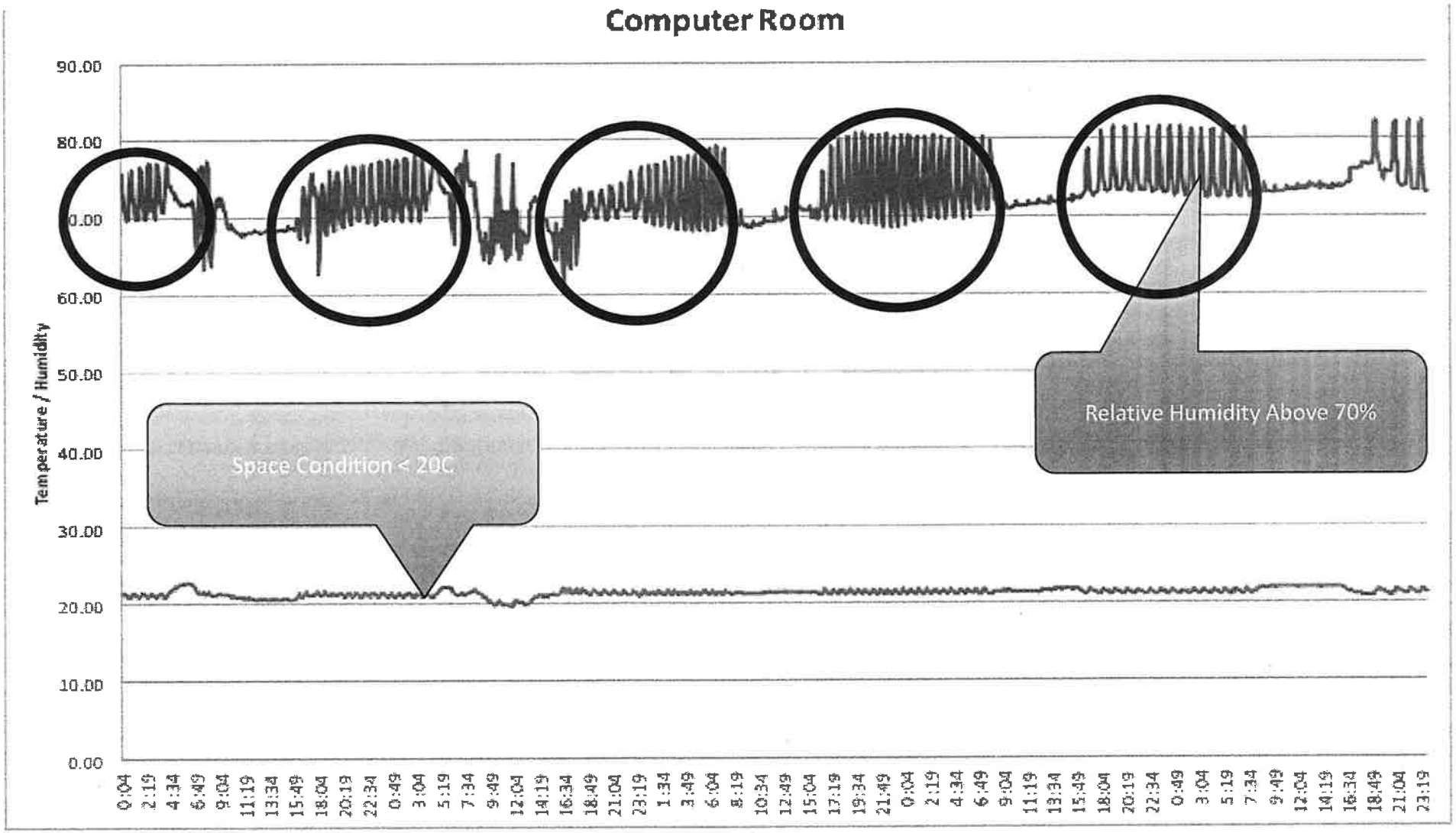

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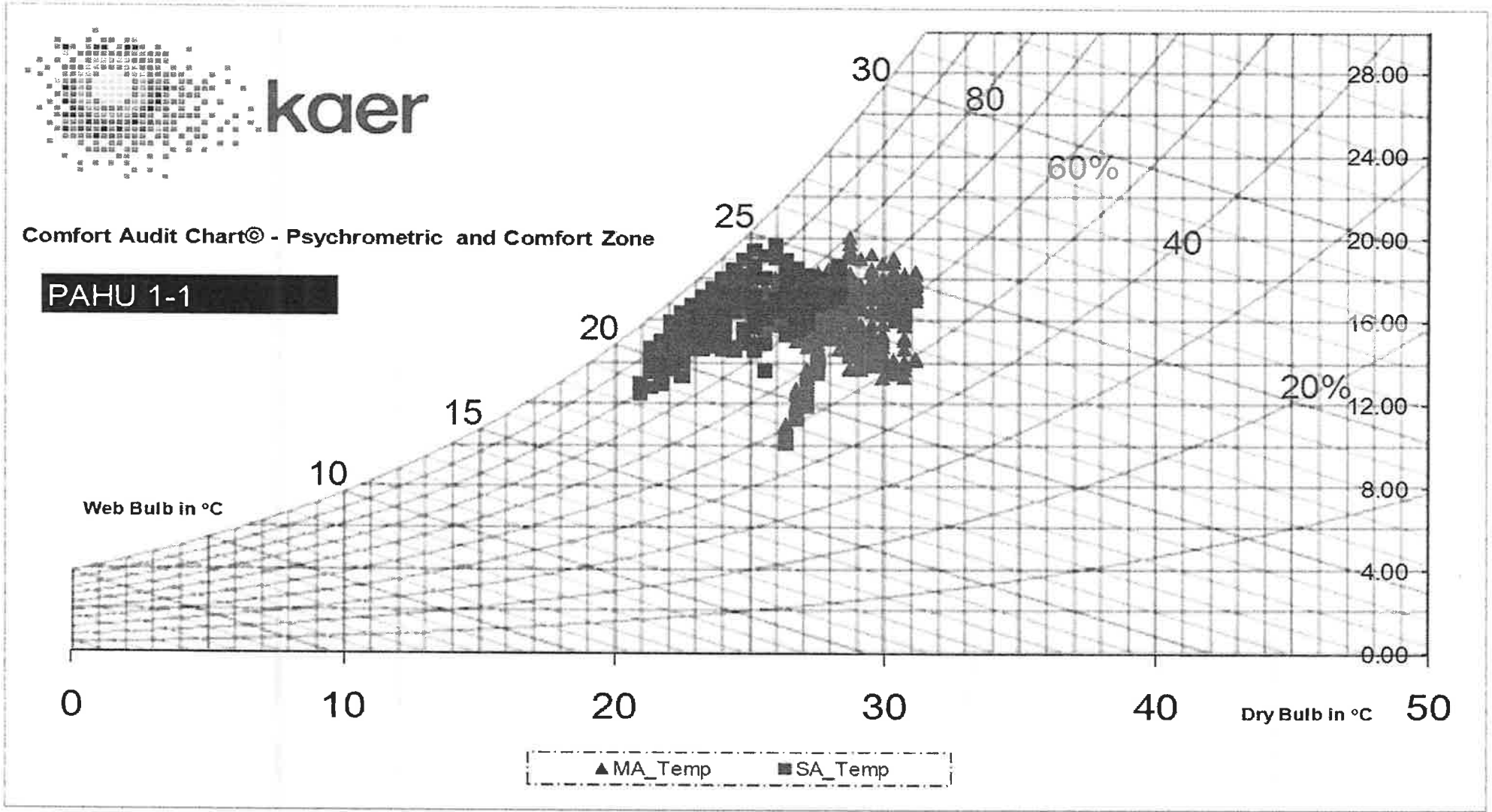
Airside Data Analysis – How Do You Read It ? kaer



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Basic Indoor Quality –CO2

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Level	Location	Average			Remarks
		Temp (oC)	RH (%)	CO2 (ppm)	
1st	Main Lobby	24.6	66.5	488	Air-conditioned
	Gym	23.6	65.4	512	Air-conditioned
2nd	Lift Lobby	26.2	73.6	523	Natural Ventilation
3rd	Lift Lobby	27.3	75.8	502	Natural Ventilation
9th	Unit 9-1 (Living Room)	21.8	73.1	501	Air-conditioned
	Unit 9-1 (Dining Area)	22.3	67.9	516	Air-conditioned
10th	Lift Lobby	27.3	74.6	510	Natural Ventilation
11th	Lift Lobby	27.1	71.6	502	Natural Ventilation
19th	Unit 19-1 (Bed Room)	23.6	73.4	531	Air-conditioned
	Unit 19-1 (Living Room-1)	23.0	79.6	498	Air-conditioned
	Unit 19-1 (Living Room-2)	23.6	79.6	[illegible]	Air-conditioned
25th	Lift Lobby	27.2	71.6	495	Natural Ventilation
	Unit 25-3 (Living Room-2)	23.9	62.9	487	Air-conditioned
	Unit 25-3 (Living Room-3)	23.1	67.6	490	[illegible] conditioned
	Unit 25-3 (Study Room)	24.0	58.7	516	Air-conditioned

Table 26.Summary of Indoor Air Quality

- Most of the CO2 level average ppm ranges from 427ppm to 512ppm
- Meet Singapore code of practice the CO2 level average may vary from 100 to 1000ppm.

Humidity Should Be Addressed

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Importance Of CHW & CW Piping Layout

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Circuit Gilles Villeneuve, Canada

June 11-13, 2010 | 8th of 19 races

Allianz

70 laps x 4.361 km = 305.270 km



Commentary On The Track

Bernd Mayländer
Official Formula 1™ Safety Car driver

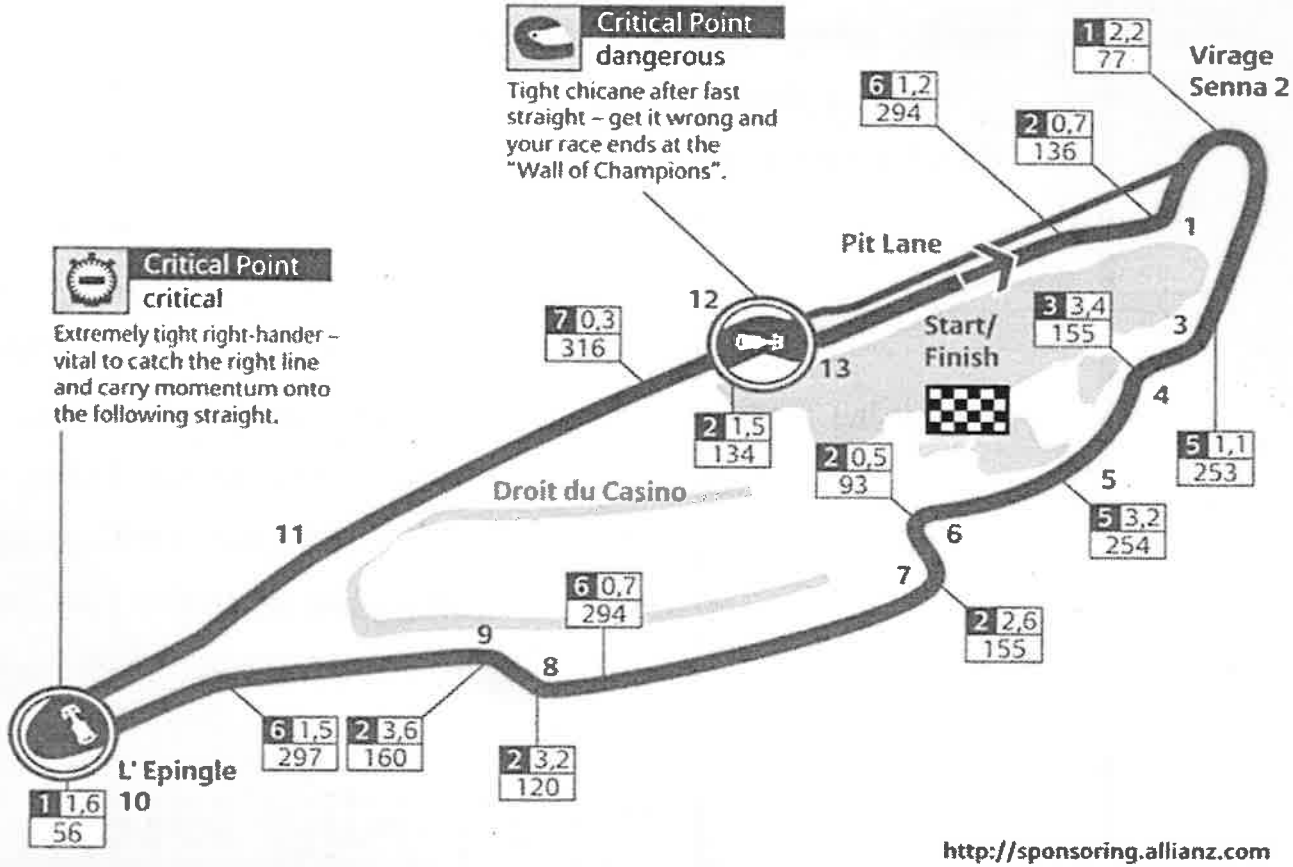
The race course is situated on an island in the city of Montreal. The circuit is quite fast, but the race track itself is not as challenging as other tracks. It can be quite a strain on the drivers due to high temperatures and the high full throttle quota. Also, there are not enough run-off zones, and the wall outside the exit to the final chicane called "wall of champions" is particularly challenging – if you get in wrong, it may result in an early retirement from the race.

2 1,6 / 80 — Gear/Lateral G-force / Speed (kmph)

Run-off areas, gravel/asphalt

Critical Points

Status: January 06, 2010



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Type Of Chilled Water Pipe Layout

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1. Fixed Speed Dedicated Primary Chilled Water Piping
2. Fixed Speed Parallel Primary Chilled Water Piping
3. Fixed Speed Dedicated Prii-Fixed Speed Secondary Chilled Water Piping
4. Fixed Speed Parallel Pri-Fixed Speed Secondary Chilled Water Piping
5. Fixed Speed Dedicated Pri-Variable Fow Secondary Chilled Water Piping
6. Fixed Speed Parallel Primary- Variable Flow Chilled Water Piping
7. Variable Speed Dedicated Primary Chilled Water Piping
8. Variable Speed Parallel Primary Chilled Water Piping
9. Variable Speed Dedicated Prii-Fixed Speed Secondary Chilled Water Piping
10. Variable Speed Parallel Pri-Fixed Speed Secondary Chilled Water Piping
11. Variable Speed Dedicated Pri-Variable Fow Secondary Chilled Water Piping
12. Variable Speed Parallel Primary- Variable Flow Chilled Water Piping

Other Inputs

1. Is there a Tertiary Pumps
2. Is it a 2-pipe system or a 3-pipe system
3. Is it a First-In First-Out Or First-In Last-Out Pipe Layout

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CHW Piping Layout

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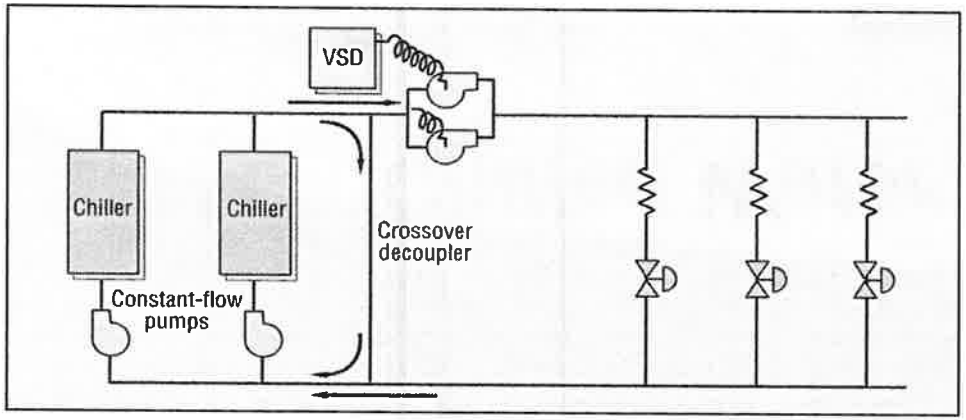
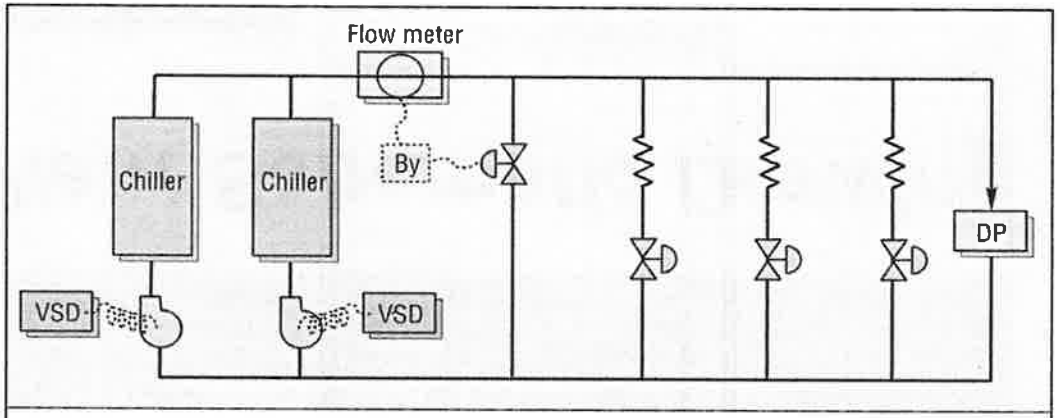
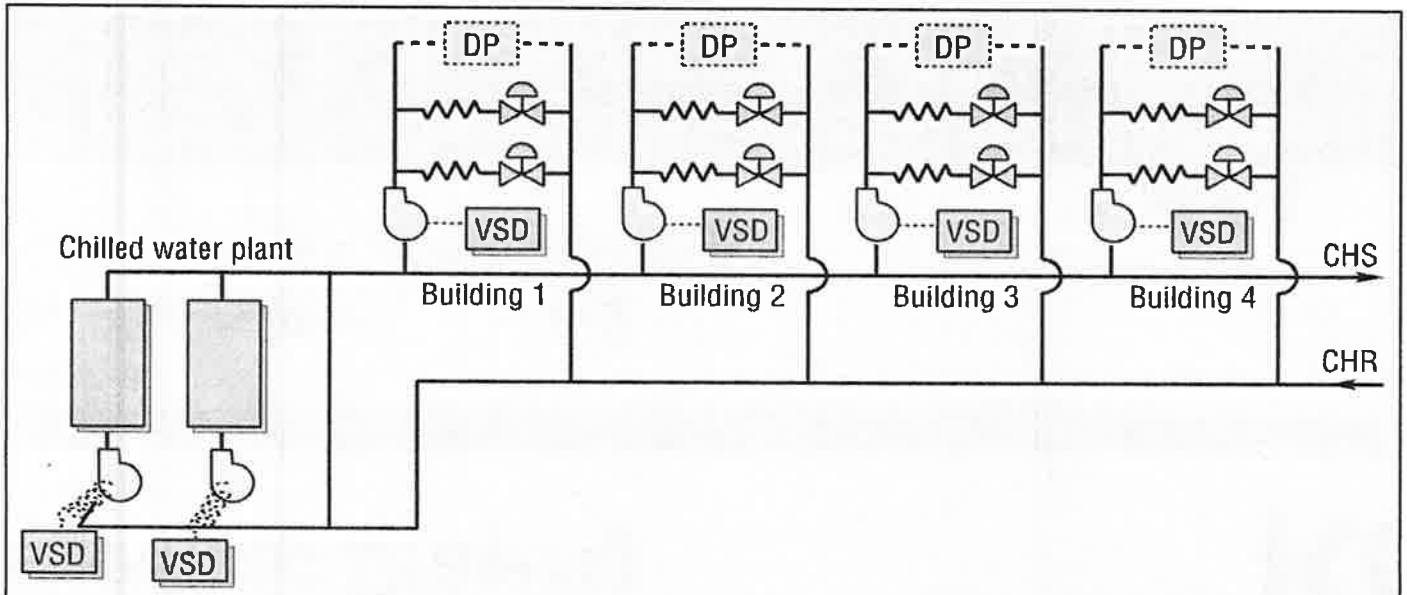


Primary-Secondary Flow CHW Plant Design



Typical variable-flow CHW plant design.



Distributed campus CHW pumping.

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CHW Schematic Drawing

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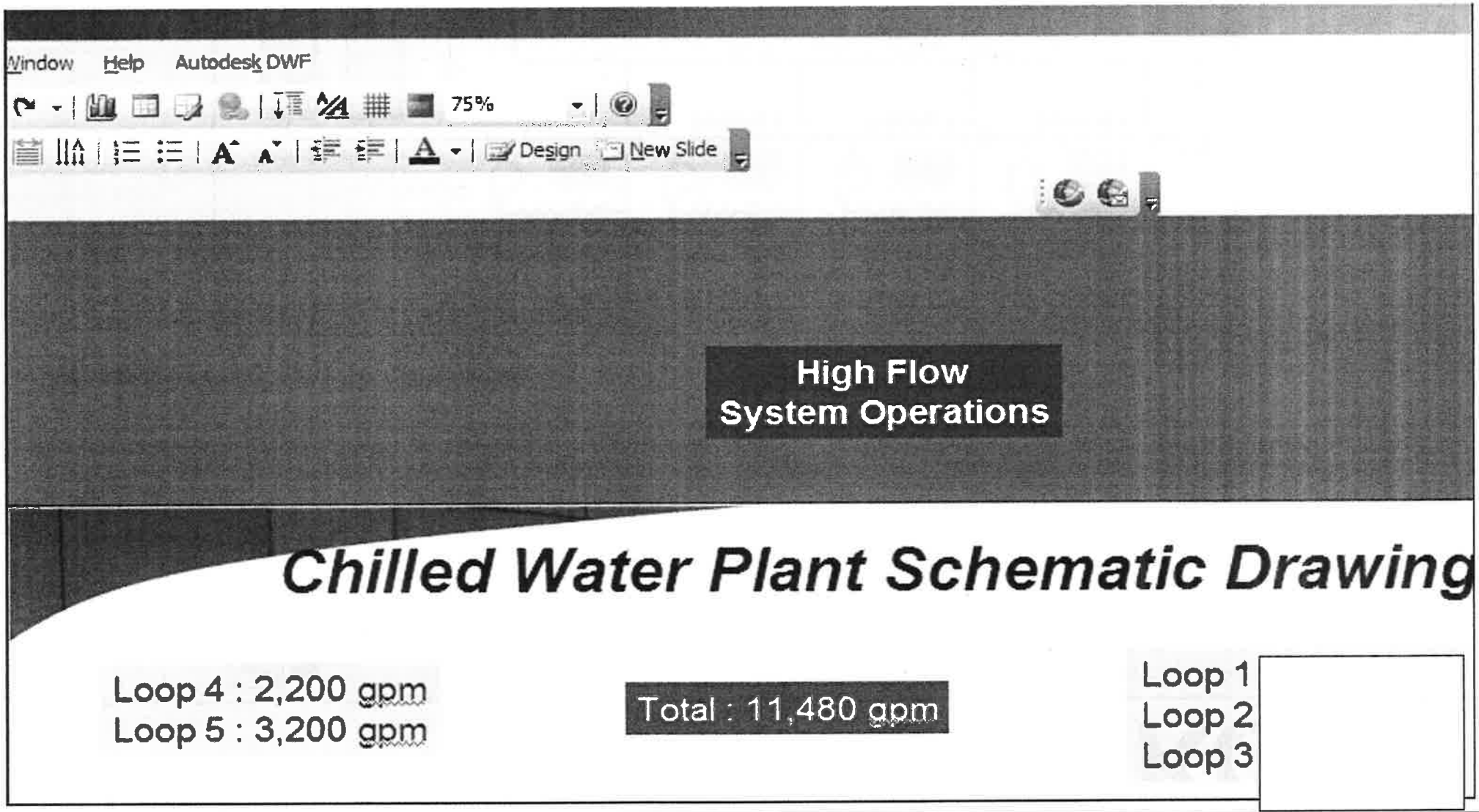

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CHW Piping Layout – Storage Tank

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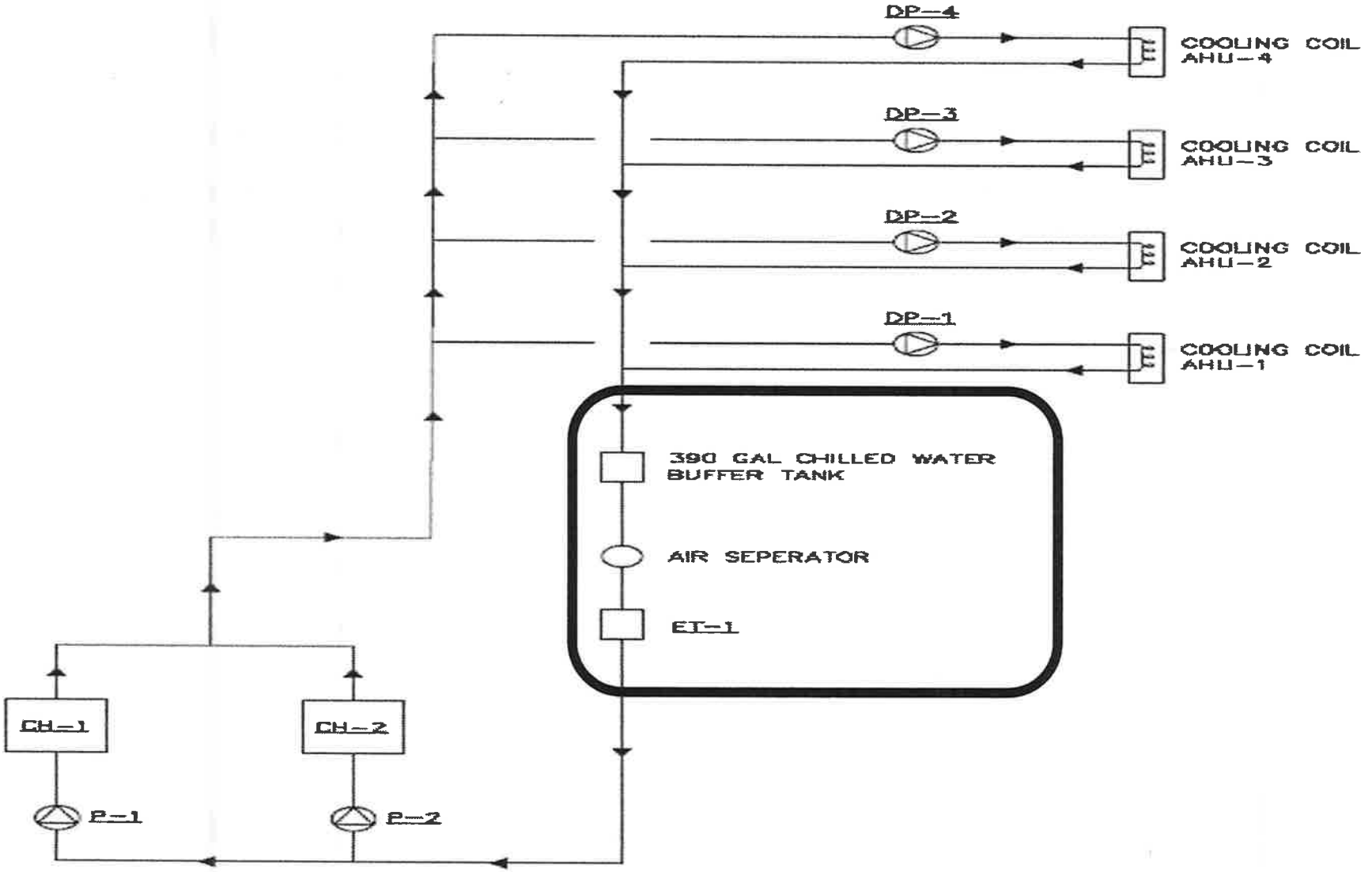

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CHW Schematic Drawing

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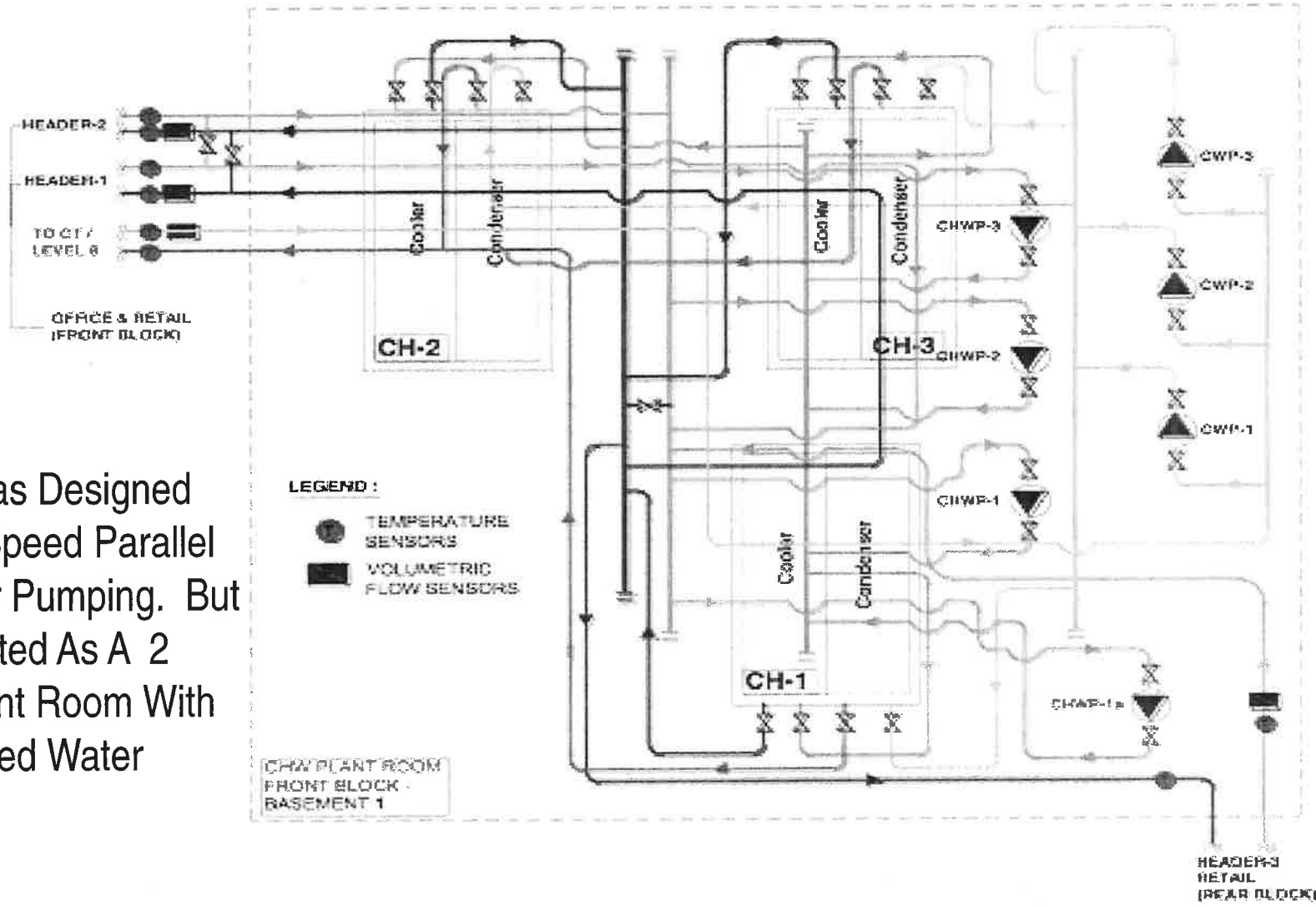

This Plant Was Designed As Variable Speed Parallel Chilled Water Pumping. But It Was Operated As A 2 Separate Plant Room With Variable Chilled Water Pumping

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Can You See The 2 Circuit ?

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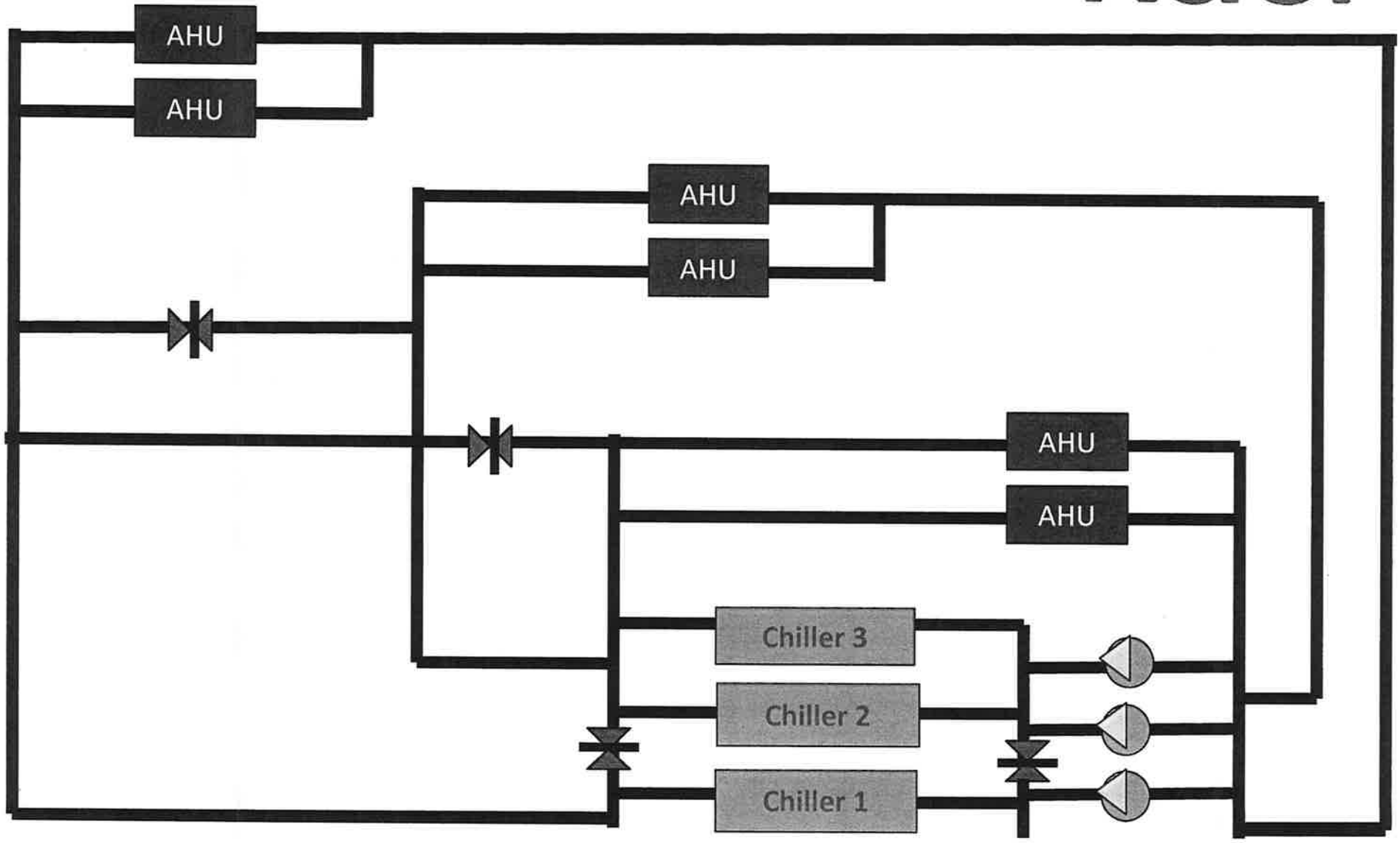

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What Do We Look In CHW Pipe Layout

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1. Proper Mixing Of Chilled Water Return
2. Equal Distribution Of Chilled Water Thru Each Chiller W/o Balancing Valve
3. Proper Mixing Of Chilled Water Supply Before Distribution
4. Sufficient Supply Of Chilled Water Through Each Branch
5. Supply Only What You Require

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Type Of Condenser Water Pipe Layout

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1. Fixed Speed Dedicated Primary Condenser Water Piping
2. Fixed Speed Parallel Primary Condenser Water Piping
3. Fixed Speed Dedicated Priimary-Fixed Speed Secondary Condenser Water Piping
4. Fixed Speed Parallel Priimary-Fixed Speed Secondary Condenser Water Piping
5. Variable Speed Dedicated Primary Condenser Water Piping
6. Variable Speed Parallel Primary Condenser Water Piping
7. Variable Speed Dedicated Priimary-Fixed Speed Secondary Condenser Water Piping

Other Inputs

1. Is it a 2-pipe system or a 3-pipe system ?
2. Is it a First-In First-Out Or First-In Last-Out Pipe Layout ?
3. Is it a 'Push' or a 'Pull" configuration ?

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Type Of Condenser Water Pipe Layout

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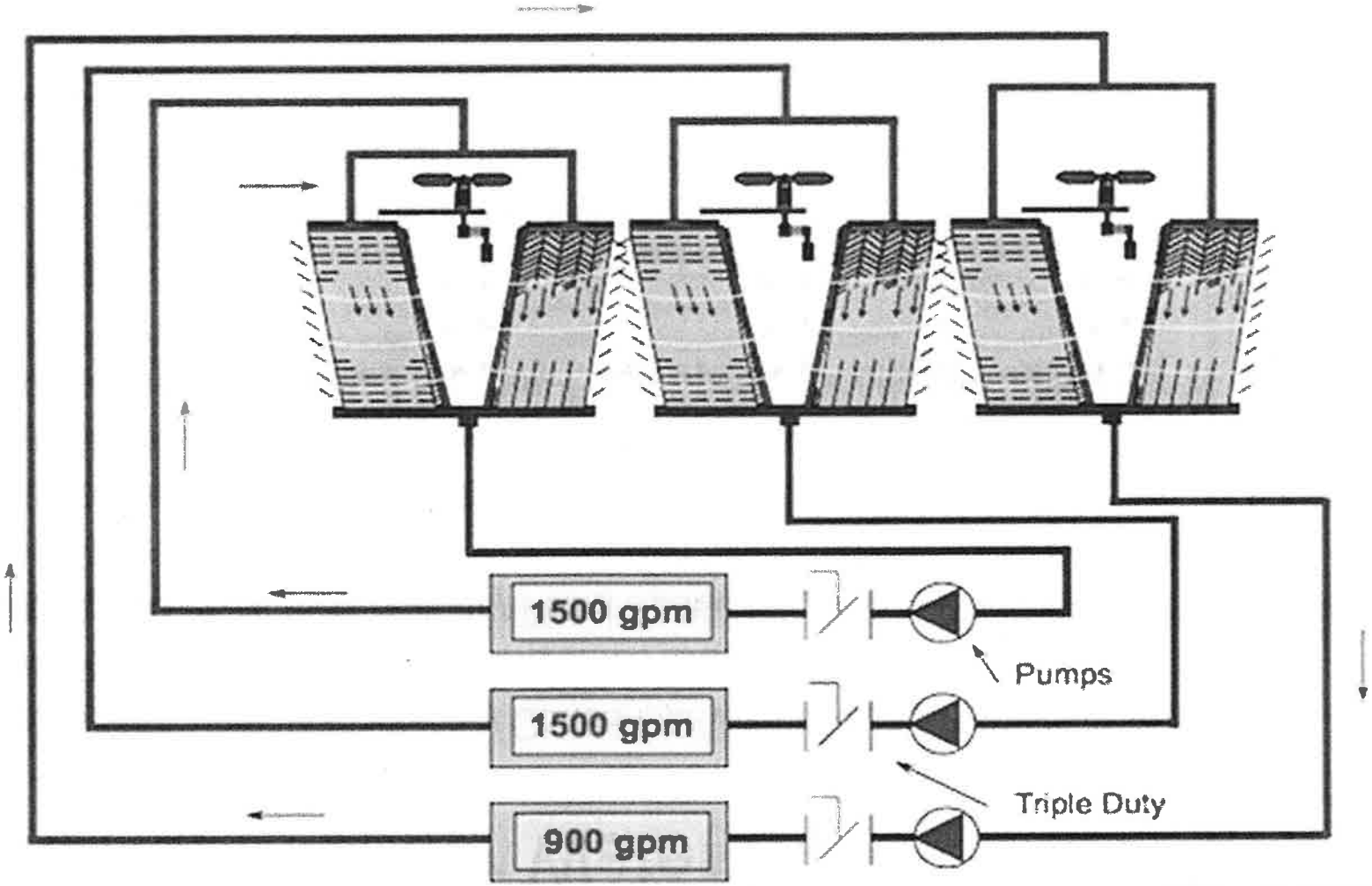
Independent Circuits



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Type Of Condenser Water Pipe Layout

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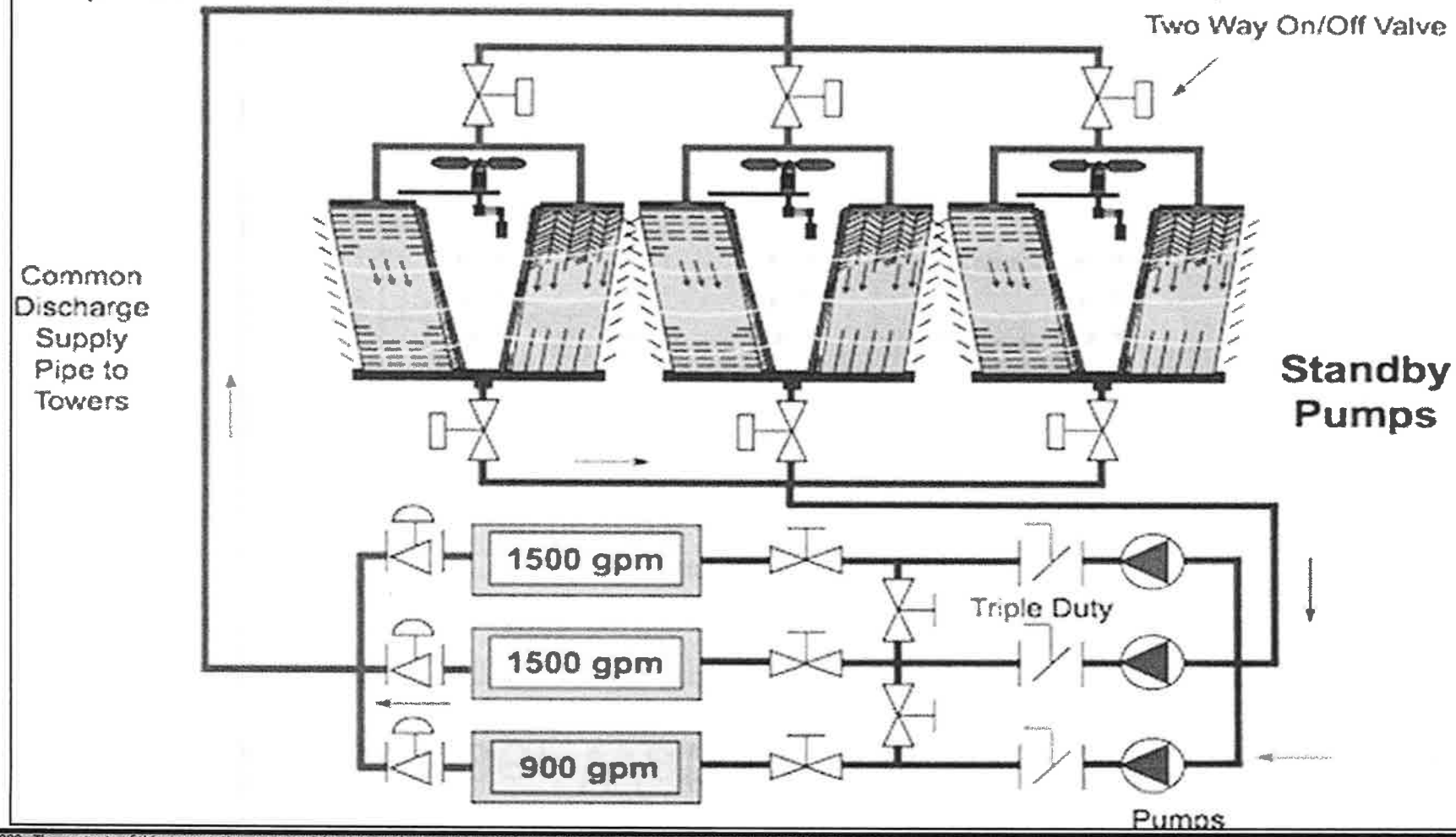
If you have a lot of pipe friction loss, You may need flow limiters to protect condensers.



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Type Of Condenser Water Pipe Layout

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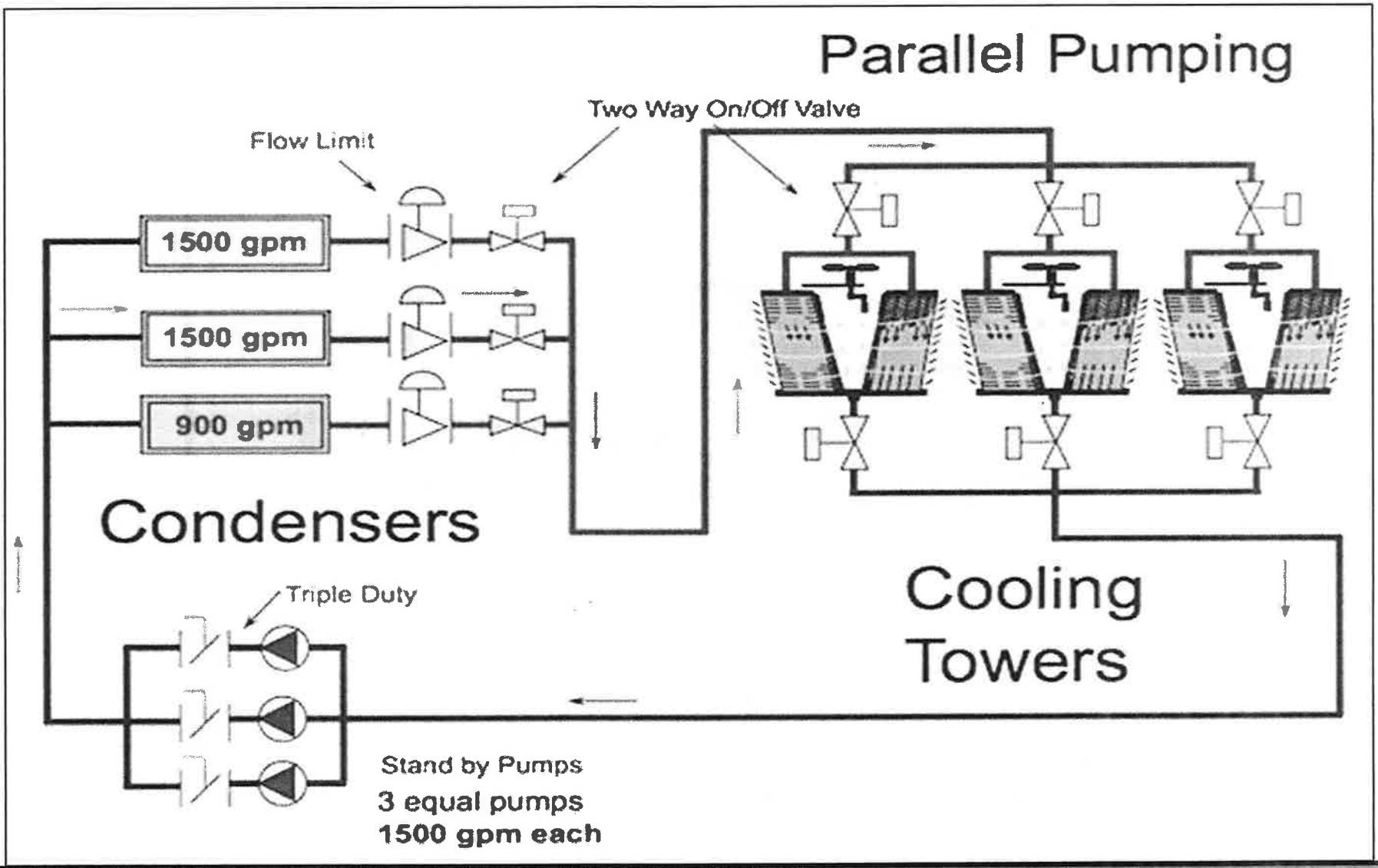

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Type Of Condenser Water Pipe Layout

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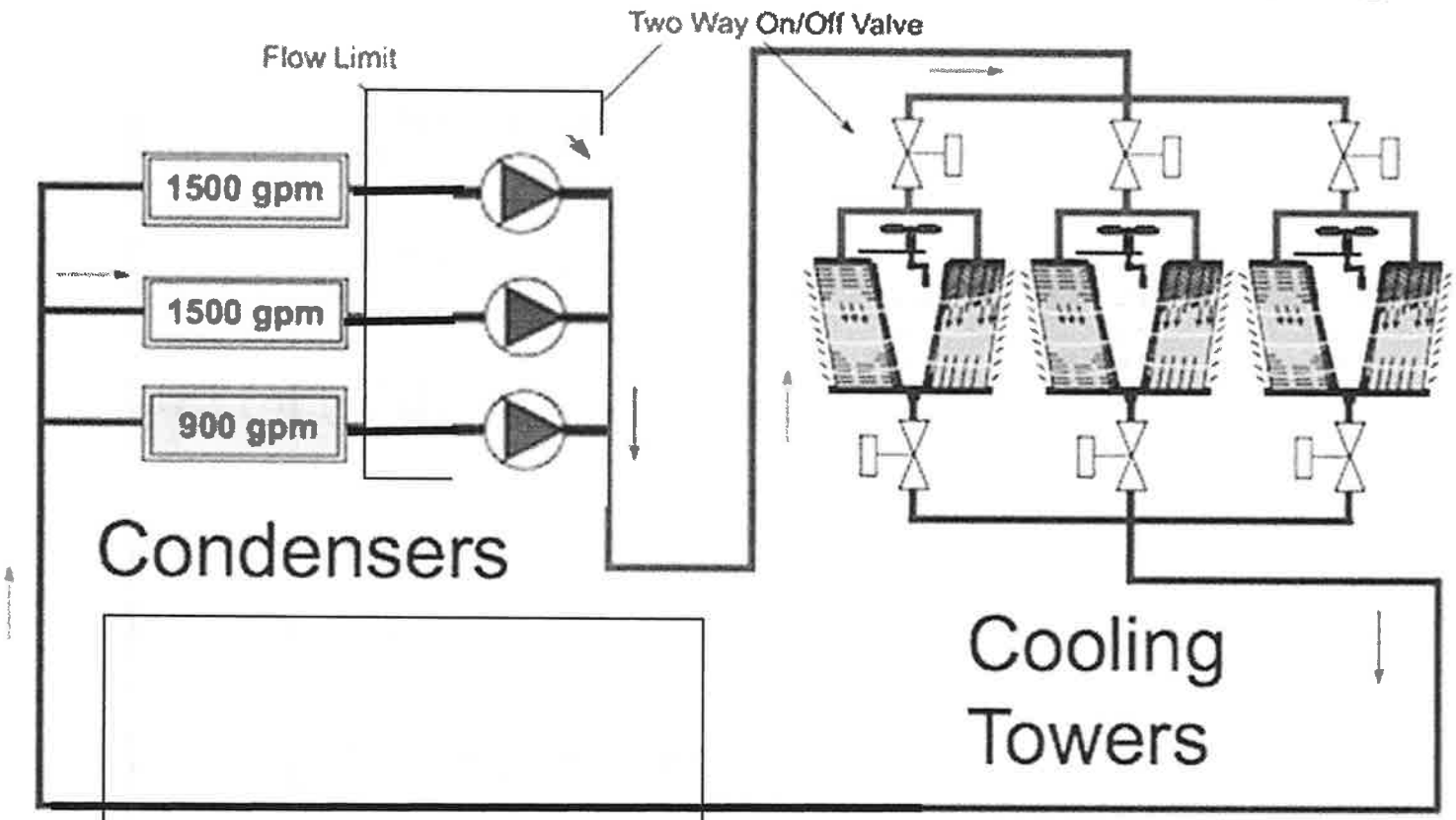
Parallel Pumping



A Pull Through Condenser Water System – Can It Work ?

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What Do We Look In CW Pipe Layout

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1. Proper Mixing Of Condenser Water Return
2. Equal Distribution Of Condenser Water Thru Each Chiller W/o Balancing Valve
3. Proper Mixing Of Condenser Water Supply Before Distribution
4. Sufficient Supply Of Condenser Water Through Each Chiller
5. Supply Only What You Require ?

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Hot Water System Findings

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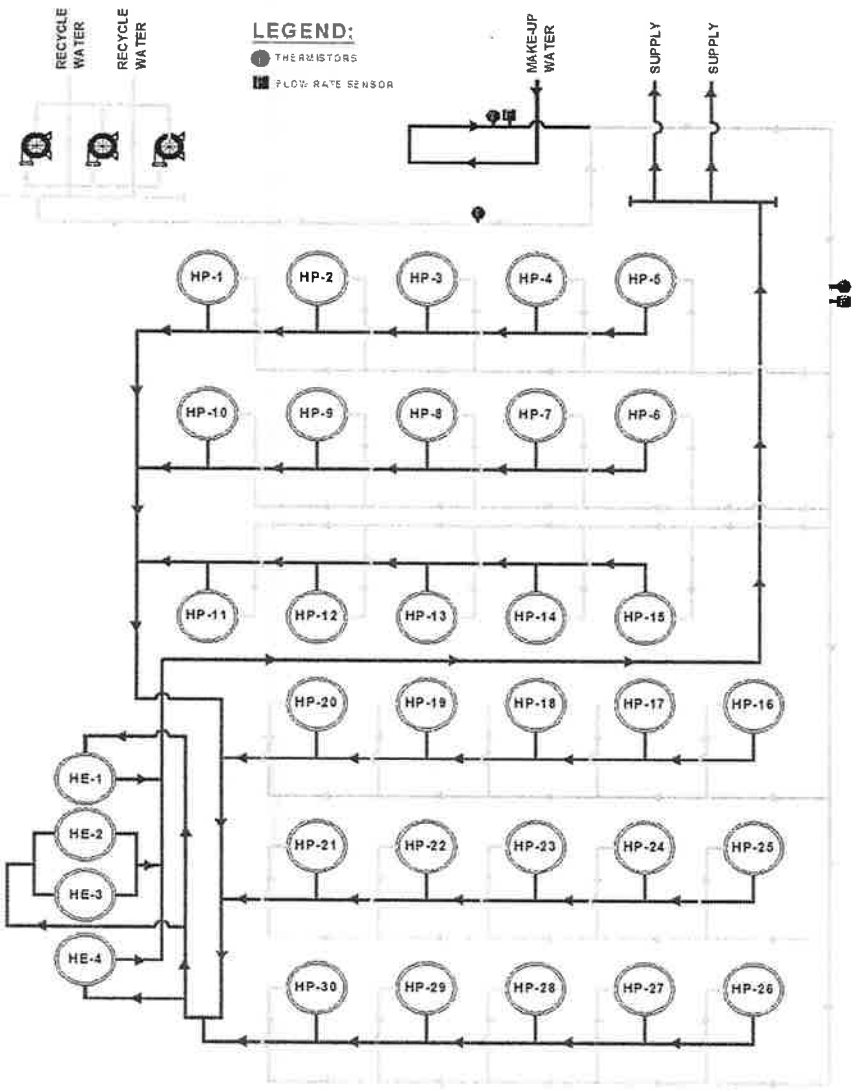

30 x 8.7kW$_H$ heat pumps

4 x 4.8kW$_H$ heaters

Rated COP = 3.3kW$_H$/kW

Other Type Of Hot Water System

1. Steam Boiler – Hot Water System – Gas, Diesel, Electric
2. Water To Water Heat Pump Hot Water System
3. Air To Water Heat Pump Hot Water System
4. Heat Recovery Hot Water System
5. Electric Heater Hot Water System

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Hot Water System – Spot Measurement

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Description	Design Data	Operating Conditions		Remarks
		Peak Period	Off-Peak Period	
Percent Loading	100%	26%	13%	Operating at Part load condition
Heat Load (kW_H)	280	72	37	
Hot Water Supply Temp (°C)	50~60	55.09	57.28	set point at 52°C
Mixed Water Temp (°C)	-	32.95	34.07	-
Hot Water Return Temp (°C)	-	39.21	38.02	Insulation for the pipes can be poor
Make-up Water Temp (°C)	30	30.39	30.92	normal temperature
Water Flow Rate (gpm)	35	14	7	make-up + recycling
Recyling Pump (kW)	-	0.2	0.2	
Heat Pump (kW)	66	31.8	24.5	Operating at Part load condition
Electric Heaters (kW)	19	4.8	2.9	
COP (Kw_H/kW)	3.3	2.0	1.4	inefficient

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MV System – Spot Reading

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No	FAN REF NO.	LOCATION (AREA SERVED)	MOTOR RATING (KW)	OPERATION STATUS
	Basement Carpark			
1	CEAF-B1-01	Basement Carpark	28.8	1 operate and 1 standby - speed of operation based on CO sensors
2	CEAF-B1-03	Basement Carpark	28.8	
3	CFAF-B1-01	Basement Carpark	28.8	
4	CFAF-B1-03	Basement Carpark	28.8	

No	FAN REF NO.	LOCATION (AREA SERVED)	MOTOR RATING (kW)	OPERATION STATUS
	TEF-02-01	Toilet	0.11	Operation of fans based on Motion Sensors
1	TEF-03-01	Toilet	0.17	
2	TEF-05-01	Toilet	0.11	
3	EAF-05-01	Pantry	3	
4	EAF-05-02	Dressing Room 1	1.5	
5	EAF-05-03	Dressing Room 2	1.5	
6	TEF-15-01	Toilet Extract	15	
7	TEF-15-03	Observation POD Toilet Extract	2.2	
8	TEF-15-05	Toilet Extract (FI Block)	3	
9	TEF-15-07	NAC Toilet Extract	2.2	

No	FAN REF NO.	AREA SERVED	MOTOR RATING (KW)	OPERATION STATUS
	Staircase Ventilation Fan			
14	SVF-15-01	Stair 1 (Upper Sly) Ventilation Fan	2.70	Not in operation. Only operation on activation for Fire Alarm system
15	SVF-15-02	Stair 2 (Upper Sly) Ventilation Fan	2.70	
16	SVF-15-03	Stair 3 (Upper Sly) Ventilation Fan	2.70	
17	SVF-15-04	Stair 4 (Upper Sly) Ventilation Fan	2.70	
18	SVF-15-05	Stair 5 (Upper Sly) Ventilation Fan	2.70	
19	SVF-15-07	Stair 7 (Upper Sly) Ventilation Fan	0.58	
20	SVF-15-08	Stair 8 (Upper Sly) Ventilation Fan	0.58	

Observe The Design Versus Operations

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Lighting System – Spot Measurement

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Area	Exisiting Illumination Level (Lux)	Recommended Illumination Level (Lux)
Main Lobby	100-400	100-250
Reception	100-800	100-250
M1 & M2 Lobby	90-200	100-200
Level 3 Ballroom Lobby	50-150	100-200
Lift	30	75-150
Mill Restaurant	50-400	200-500
Guest Room		
Bathroom	99	75-150
Main Area	120-230	75-150
Lift Lobby		
Office Lift Lobby	300-500	100-200
Level 1 Lift Lobby	30-130	100-200
Level 3 Lift Lobby	50-150	100-200
Level 2A Health Club Lift Lobby	30-130	100-200
Corridor		
Level 10 Corridor	20-70	50-100
Level 17 Corridor	20-70	50-100

For Task Lighting – Comply To Standard Requirement Then Address The Efficiency
For Ambience Lighting - Address The Efficiency

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Energy Conservation Measures

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1. Immediate Measures – Enhancement
2. Mid Term Measures – Optimisation + M&V
3. Long Term Measures – Investment Grade



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Level 2 – Report Requirement

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1. Executive Summary
2. Energy Profile – Consumption, Cost & Carbon
3. Energy Conservation Measures – Short Term, Mid Term & Long Term
4. Building Benchmarking – Summary of System, Opportunities and Shortfall
5. Chilled Water System
    - Summary of system
    - O&M Issues and opportunities
6. Airside and Controls
    - Summary of system
    - O&M Issues and opportunities
7. Hot Water Plant System
    - Summary of system
    - O&M Issues and opportunities
8. Lighting Observation And Analysis
    - Summary of system
    - O&M Issues and opportunities
9. Energy Conservation Measures
    - Details of measures for short, mid tem and long term measures

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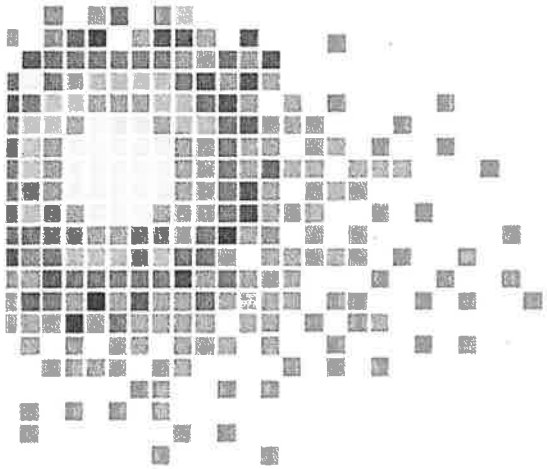

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Basic Formulas for Energy Audit Level I

Chiller Plant
(Quick Approximation)

Chiller Plant – Cooling Loads

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$$\text{Cooling Loads (Ton)} = \frac{\text{Chilled Water Flow (USGPM)} \times \text{Chilled Water } \Delta T\ (^{\circ}F)}{24}$$

Chilled Water ΔT (°F) = Chilled Water In Temp (°F) – Chilled Water Out Temp (°F)

Unit Conversion from SI to English

Chilled Water ΔT (°F) = {Chilled Water In Temp (°C) – Chilled Water Out Temp (°C)} x 1.8

Chilled Water Flow (USGPM) = Chilled Water Flow (l/s) x 15.85

Cooling Loads (Ton) = Cooling Loads (kWr) ÷ 3.517

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Chiller Plant – Heat Rejection

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$$\text{Heat Rejection (Ton)} = \frac{\text{Condenser Water Flow (USGPM)} \times \text{Condenser Water } \Delta T\ (^{\circ}F)}{24}$$

Cond Water ΔT (°F) = Cond Water Out Temp (°F) – Cond Water In Temp (°F)

Unit Conversion from SI to English

Cond Water ΔT (°F) = {Cond Water Out Temp (°C) – Cond Water In Temp (°C)} x 1.8

Chilled Water Flow (USGPM) = Cond Water Flow (l/s) x 15.85

Heat Rejection (Ton) = Heat Rejection (kWr) ÷ 3.517

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Chiller Plant – Power kW

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Power Input (kW) = 1.732 x V x I x Power Factor

Chillers

Power Input (kW) = 1.732 x 415 x RLA% x Rated Load Amp x 0.85

Power Input (RT) = Power Input kW ÷ 3.517

Pumps or Fans

Power Input (kW) = 1.732 x 415 x Operating Load Amp x 0.9

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Chiller Plant – Heat Balance

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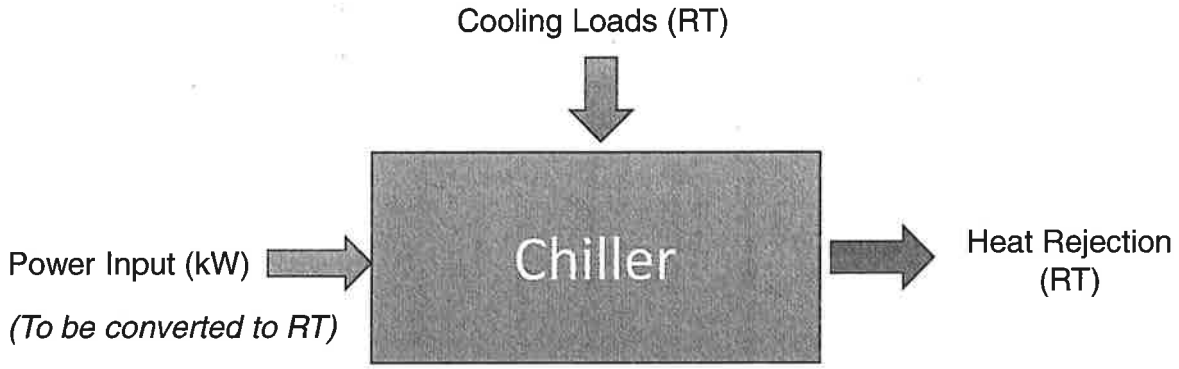

$$\text{Heat Balance \%} = \frac{\text{Cooling Loads (RT)} + \text{Power Input (RT)} - \text{Heat Rejection (RT)}}{\text{Heat Rejection (RT)}} \times 100\%$$

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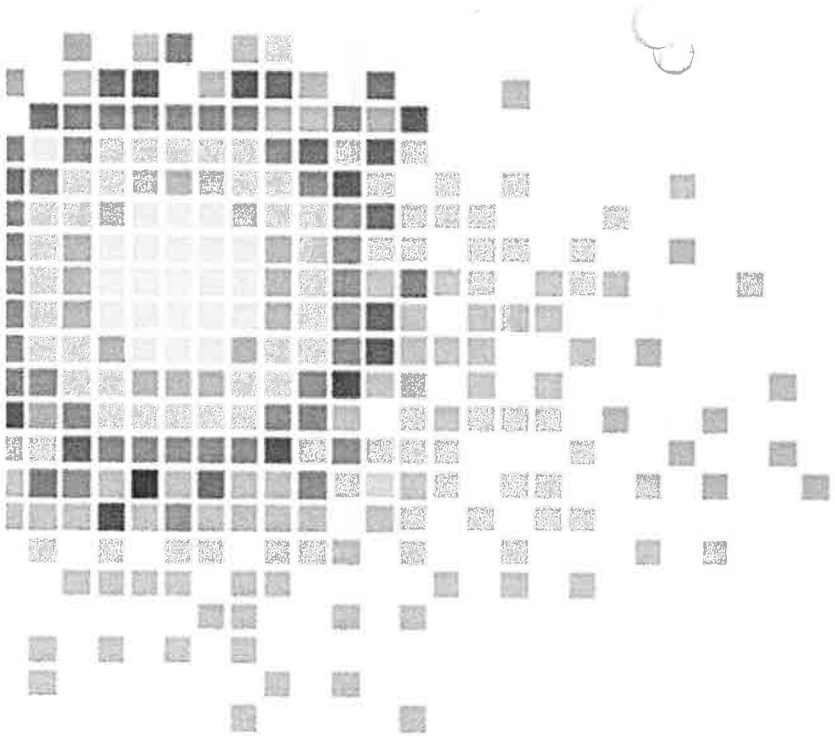

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TOMORROW'S
BUILDINGS
ENGINEERED
TODAY

Energy Audit – Level 3

Day 2, 9am – 10am

Utilities Consumption FY2009

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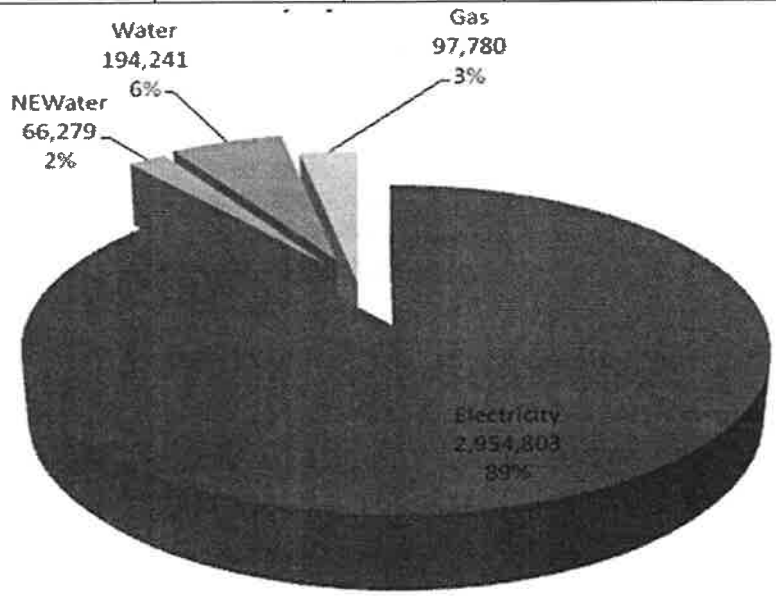
Month	Electricity				NEWater		Water		Gas	
	Peak kWh	Offpeak kWh	Total Usage kWh	Total Cost S$	Usage Cu M	Cost S$	Usage Cu M	Cost S$	Usage kWh	Cost S$
Dec-08	998,205	219,118	1,217,323	248,438	3,541	5,523	7,738	16,187	50,000	10,545
Jan-09	990,576	213,764	1,204,340	246,412	5,662	8,833	6,789	14,545	50,000	10,545
Feb-09	905,503	196,508	1,102,011	226,180	4,365	6,810	7,023	14,950	50,000	7,413
Mar-09	1,011,487	210,431	1,221,918	248,888	3,148	4,911	8,363	17,268	50,000	7,297
Apr-09	977,560	200,954	1,178,513	241,826	3,514	5,482	7,579	15,912	50,000	7,298
May-09	1,029,242	219,602	1,248,844	254,767	3,468	5,410	7,836	16,356	50,000	7,297
Jun-09	985,878	206,488	1,192,366	244,652	3,669	5,723	8,097	16,807	50,000	7,297
Jul-09	999,014	211,260	1,210,273	246,430	3,231	5,040	8,649	17,762	50,000	7,297
Aug-09	1,004,470	227,688	1,232,158	249,881	3,450	5,382	7,967	16,582	50,000	7,907
Sep-09	979,295	218,339	1,197,634	243,946	2,563	3,998	7,371	15,552	50,000	7,907
Oct-09	1,029,631	222,025	1,251,656	255,520	3,055	4,766	7,617	15,977	50,000	7,907
Nov-09	1,001,220	220,028	1,221,249	247,864	2,821	4,401	7,829	16,343	50,000	9,067
Total	***11,912,080***	***2,566,205***	***14,478,285***	***$ 2,954,803***	***42,486***	***$ 66,279***	***92,856***	***$194,241***	***600,000***	***$ 97,780***



Electrical Consumption FY2009

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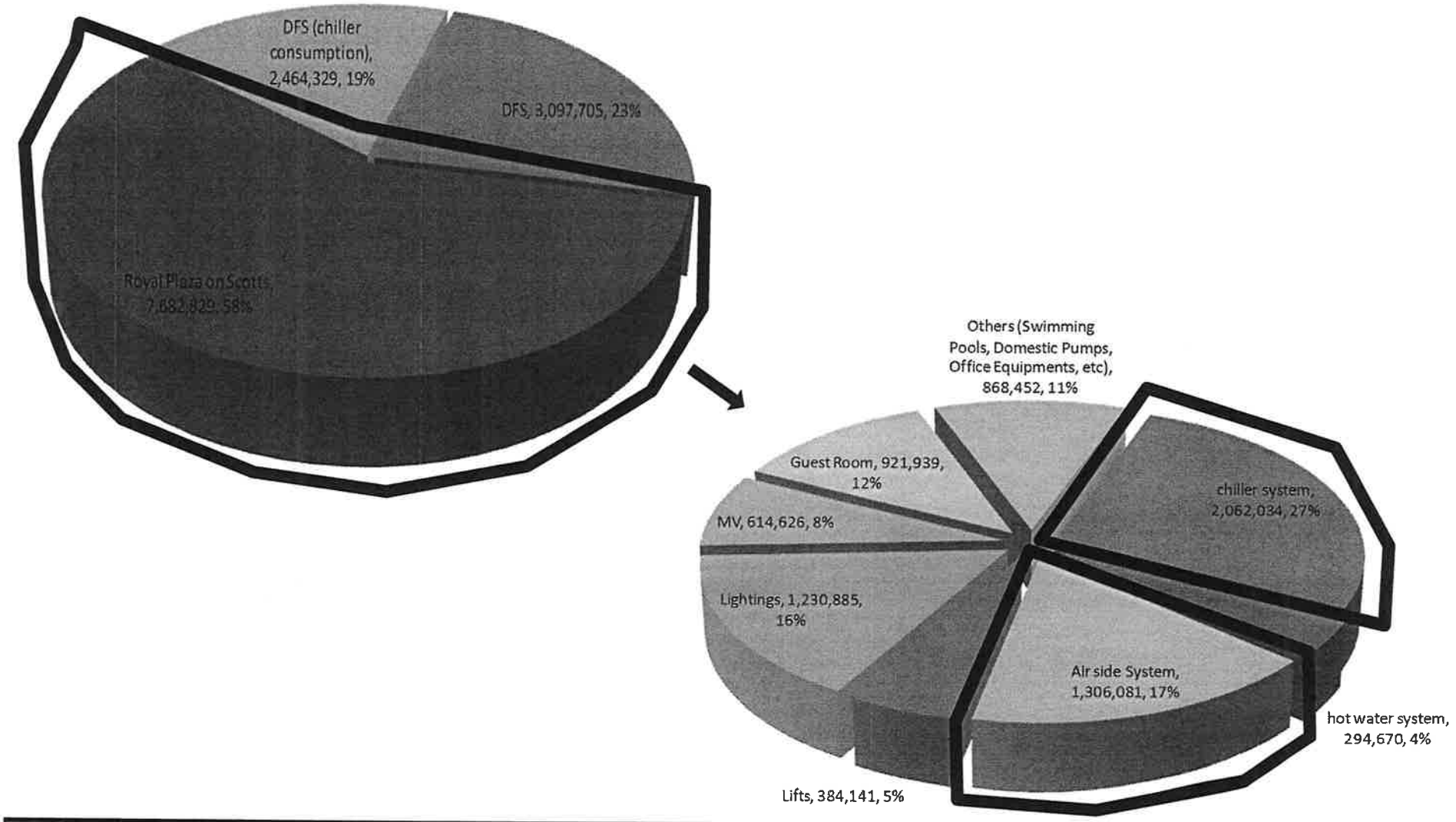
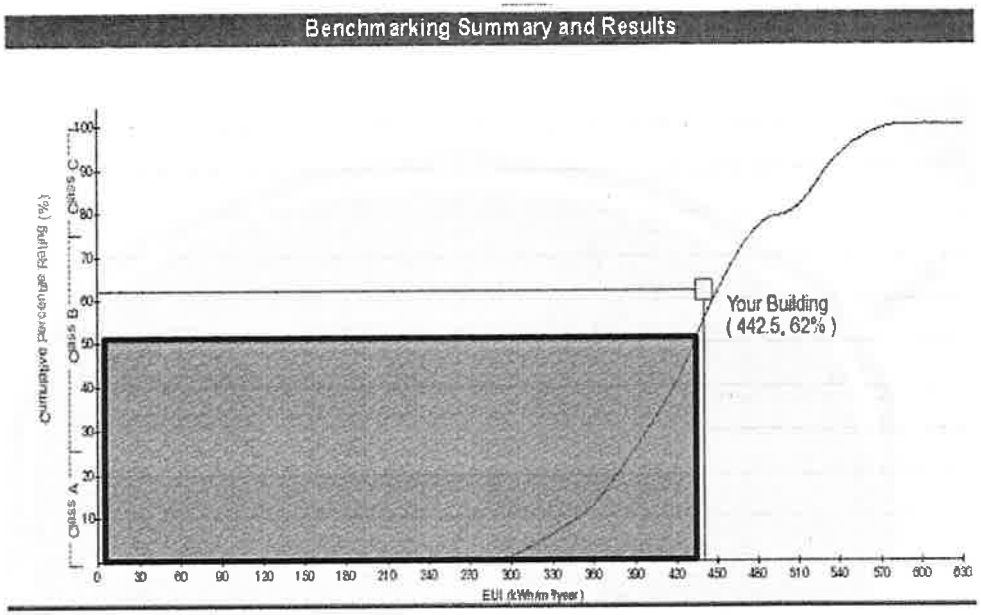
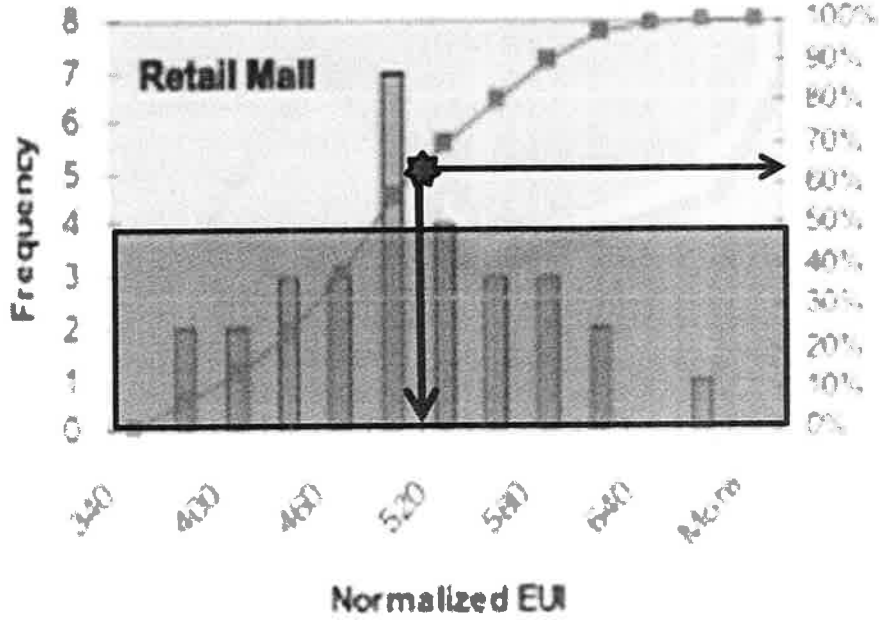


EUI* Energy Benchmarking

* Energy Utilisation Index





- ***Hotel Normalized EUI = 443 kWh/m²/yr, 63% cohort***
- ***Normalized Average EUI for Hotel = 431 kWh/m²/yr, 50% cohort***
- ***Retail Mall EUI (DFS) = 539 k kWh/m²/yr, 64% cohort***
- ***Normalised Average EUI for Retail Mall = 520 kWh/m²/yr, 50% cohort***

Air Side System Findings

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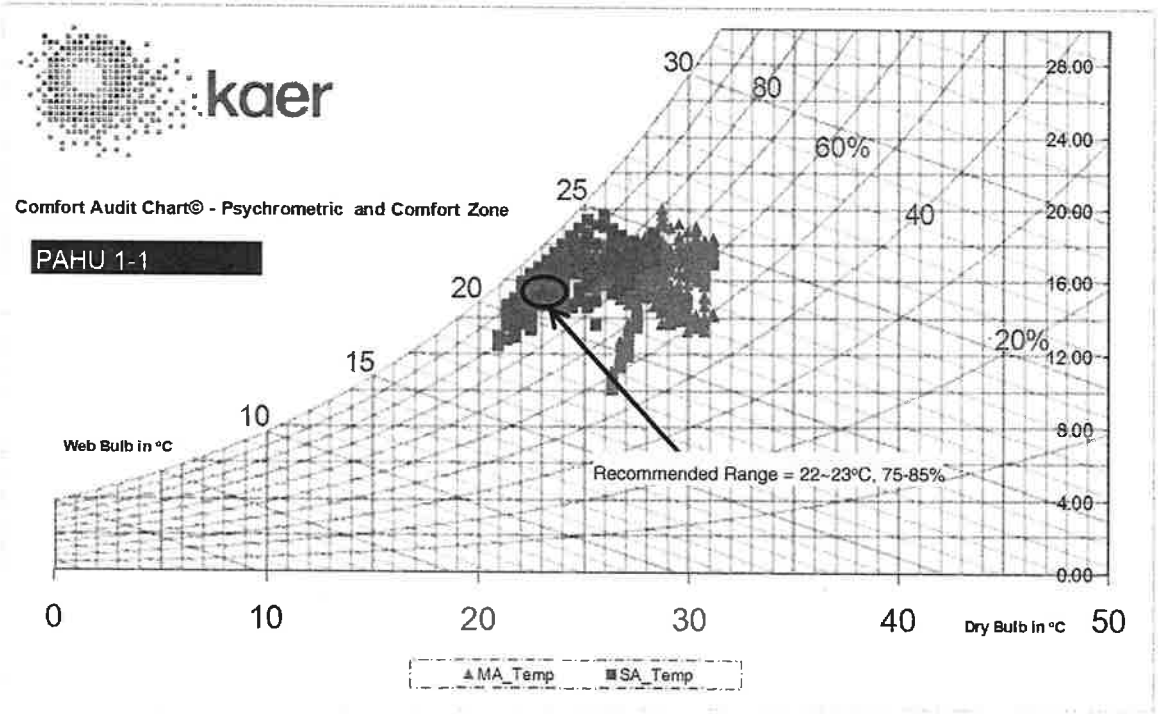
PAHU 1-1 Findings



Opportunities To Improve Humidity Level In The Hotel Rooms

- ***This unit serves most of the AHUs for fresh air and pre-cooling***
- ***Average supply temp and RH = 23.75°C and 86%***
- ***This unit has 0.98kW/m³/s, recommended range by SS53 is 1.7kW/m³/s***

Air Side System Findings

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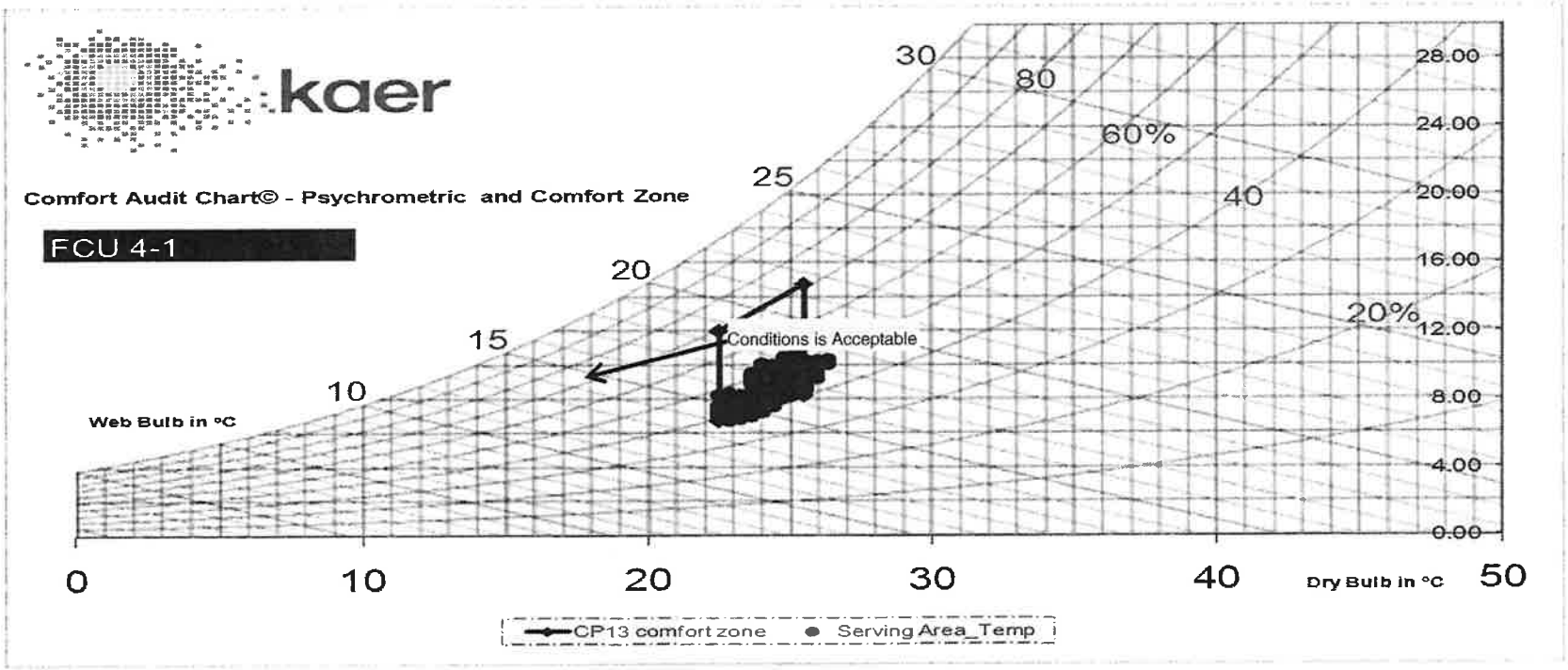
FCU 4-1 Findings



- ***This unit serves the 4th sty office***
- ***Serving area conditions is 24.5°C and 47%, still acceptable***
- ***This unit has 0.53kW/m³/s***

Basic Indoor Quality Findings

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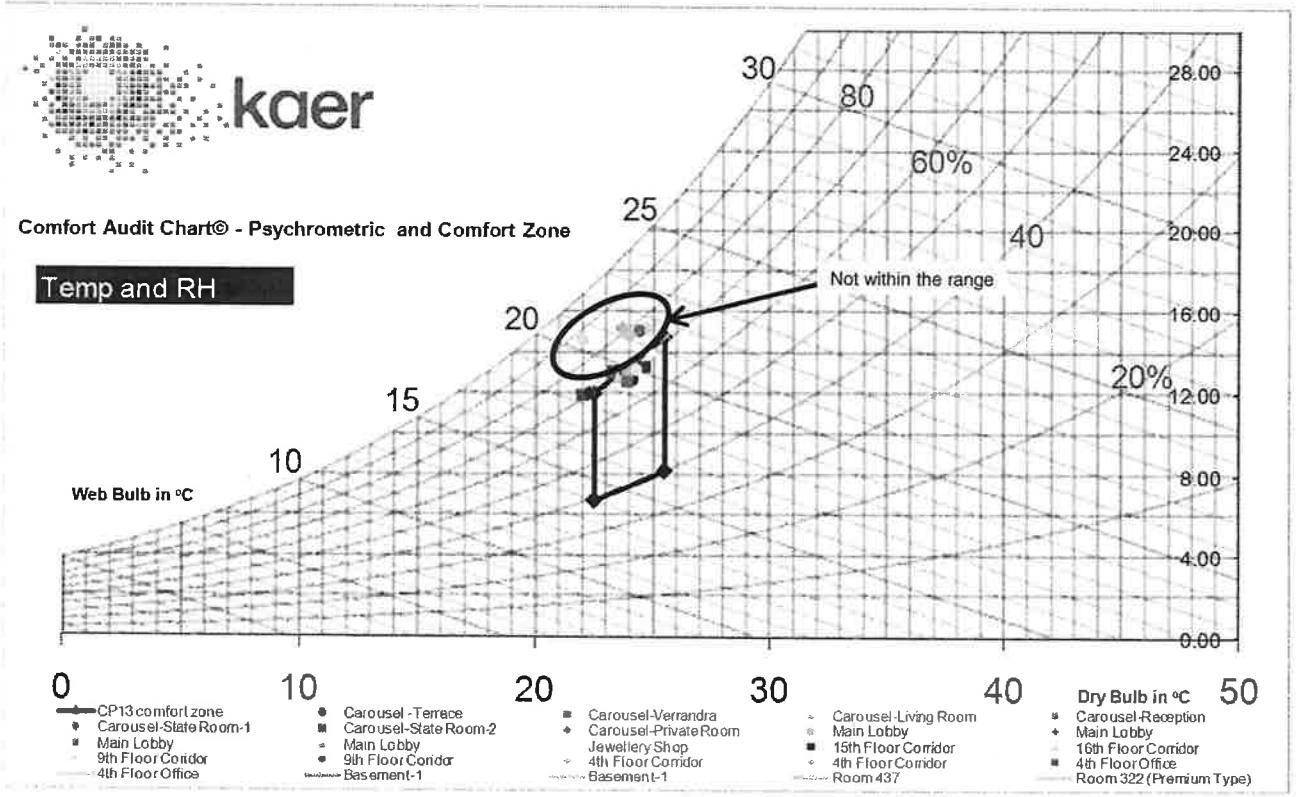

Opportunities To Improve Humidity Level In The Hotel Rooms

- ***Most Temp and RH are not within CP13 recommended conditions***

Basic Indoor Quality Findings

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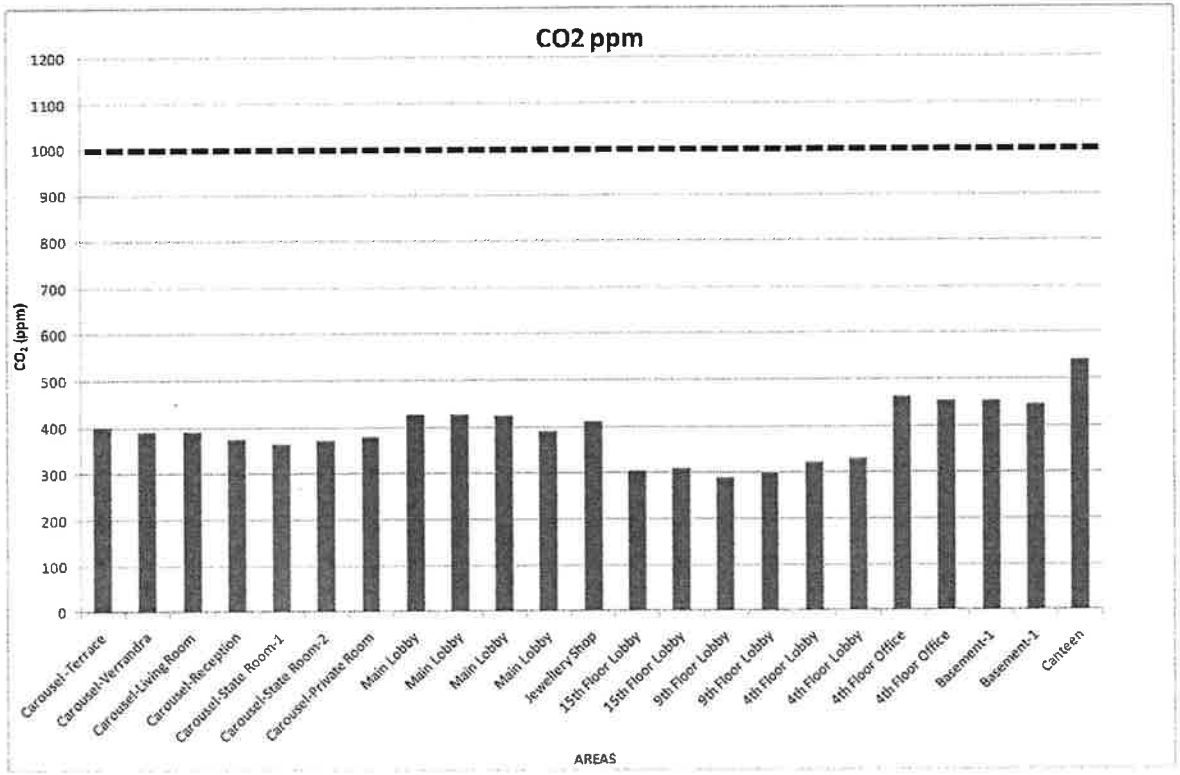

Opportunities To Improve Energy Consumption Through CO2 controlled PAHU Units

- ***CO2 in ppm average = 390ppm***
- ***SS54 recommended limit is ≤1000ppm***

Chiller Plant System Layout

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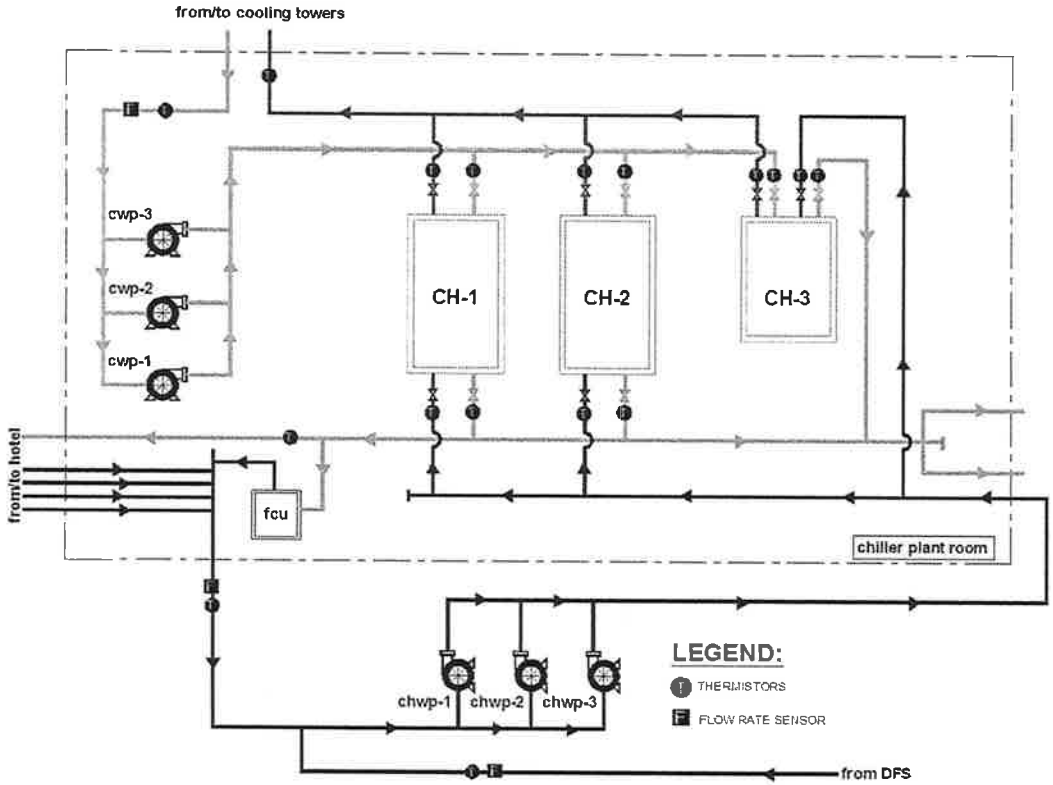

Chilled Water Plant System Schematic Diagram

2 x 550 Ton chillers

1 x 350 Ton chillers

Hotel | Mall

Rated Efficiency = 0.75kW/Ton

Current Average Efficiency = 0.83kW/Ton

Chiller Plant System Findings

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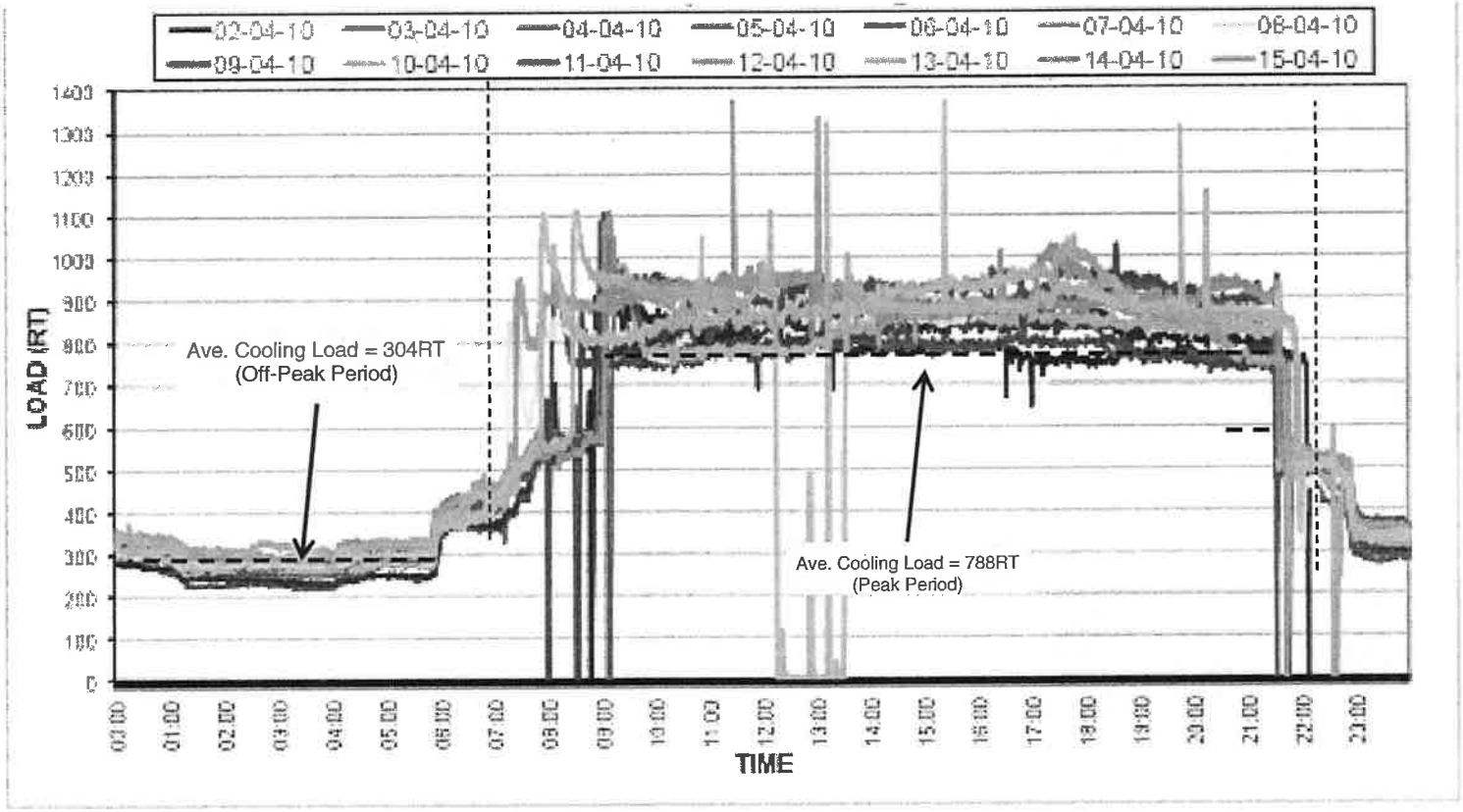
Cooling load Profile



- ***2 Big Chillers = 1100RT (Total Rated Capacity)***
- ***Off Peak Period = 304RT, Peak Period = 788RT***

Chiller Plant System Findings

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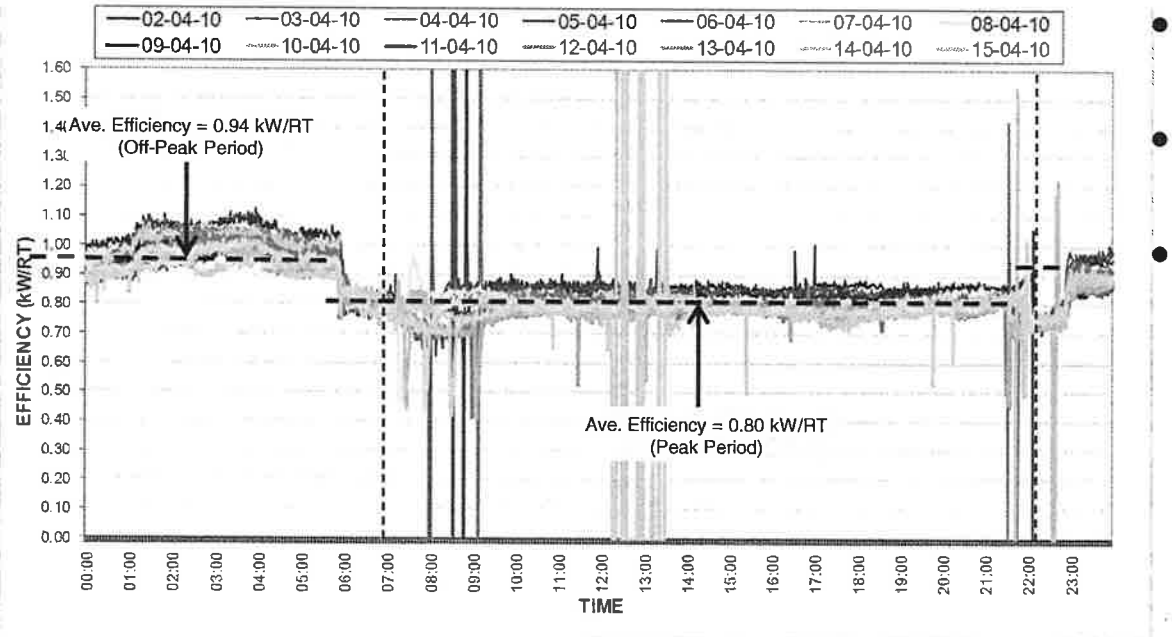
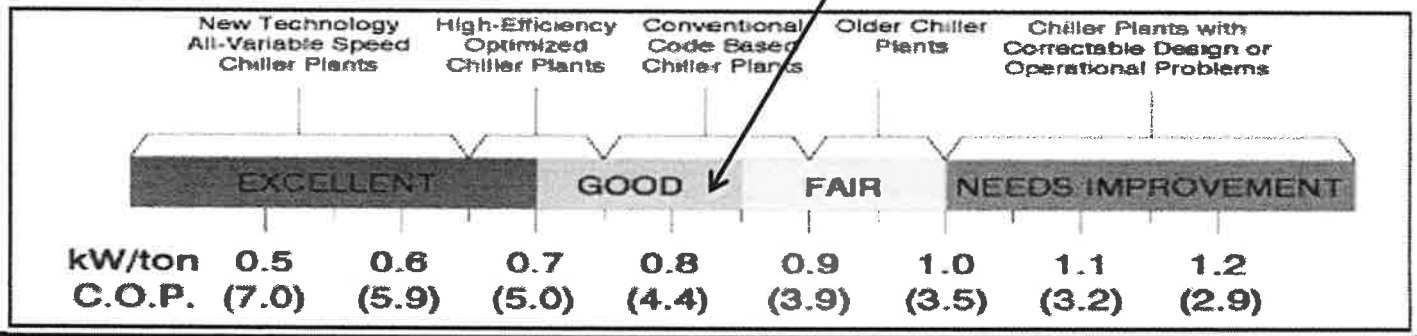
System Efficiency



- ***Off Peak Period = 0.94kW/RT***
- ***Peak Period = 0.80kW/RT***
- ***Operating Average= 0.83kW/RT***



Chiller Plant System Findings

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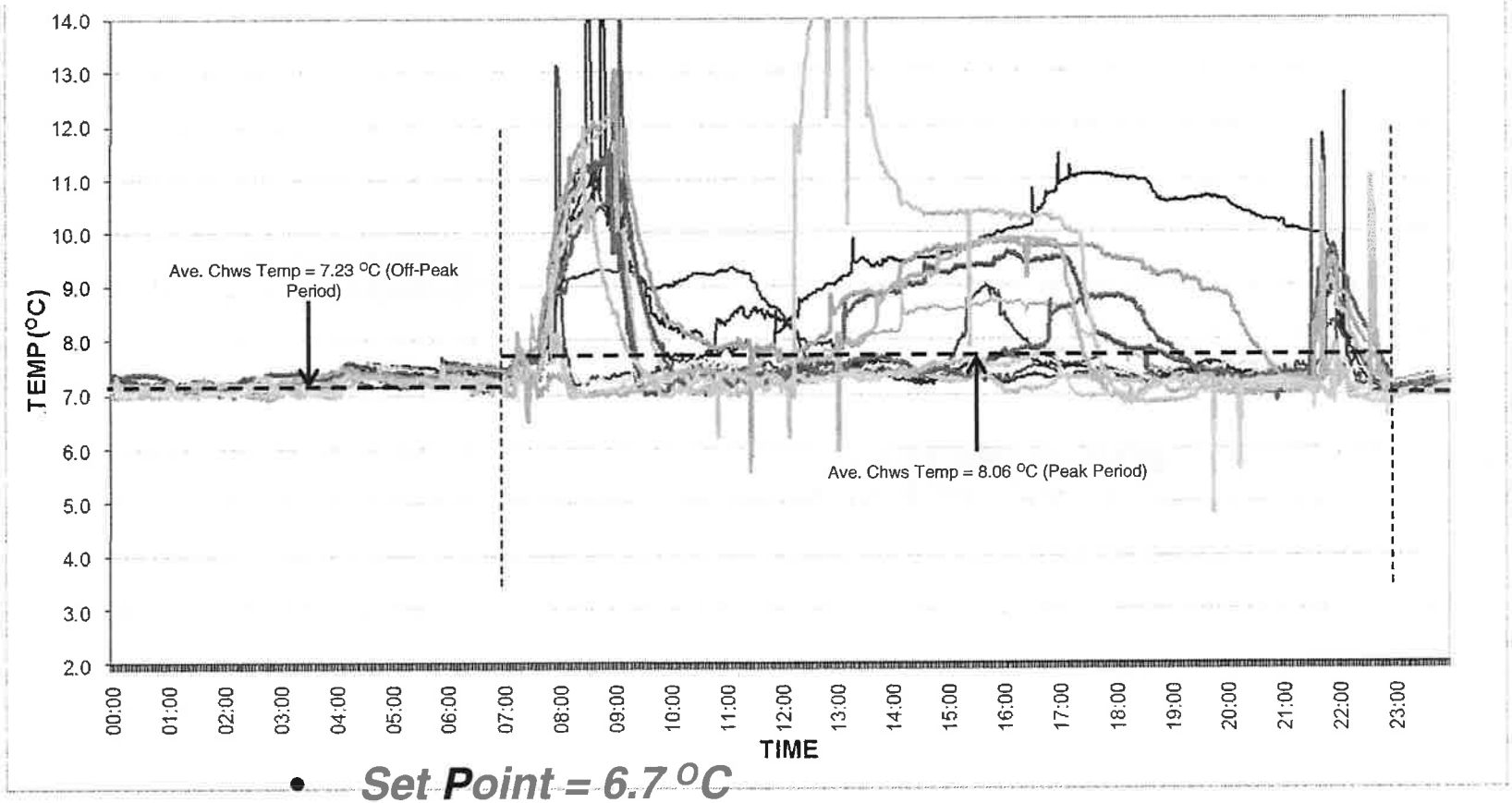
Header : Chilled Water Supply Conditions



- ***Set Point = 6.7 °C***
- ***Off peak Period ave. ChwsTemp = 7.23 °C***
- ***Peak Period ave. Chws Temp = 8.06 °C***

Chiller Plant System Findings

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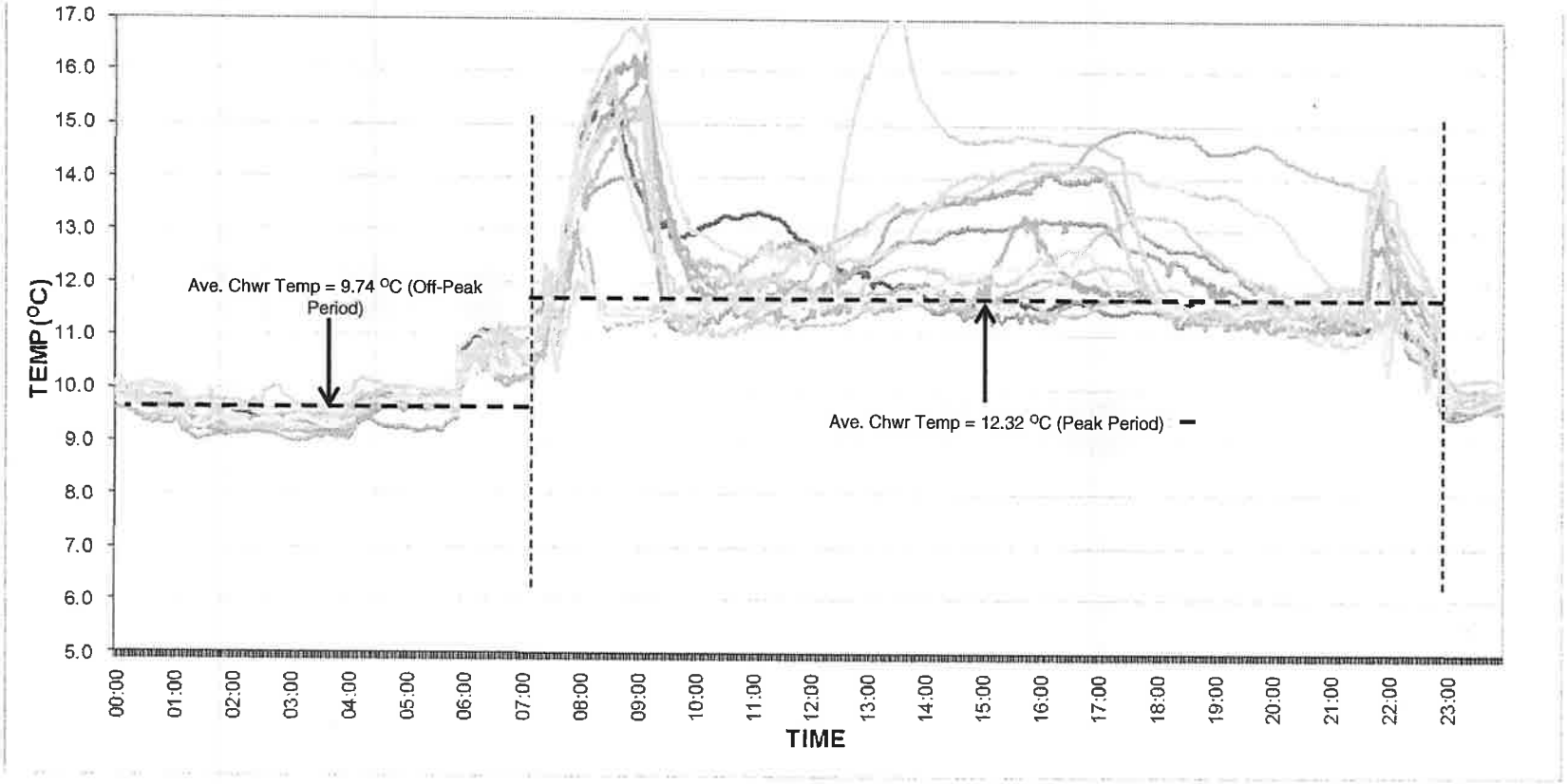
Header : Chilled Water Return Conditions



- ***Off peak Period ave. ChwrTemp = 9.74 °C***
- ***Peak Period ave. Chwr Temp = 12.32 °C***

Chilled Water System Histogram

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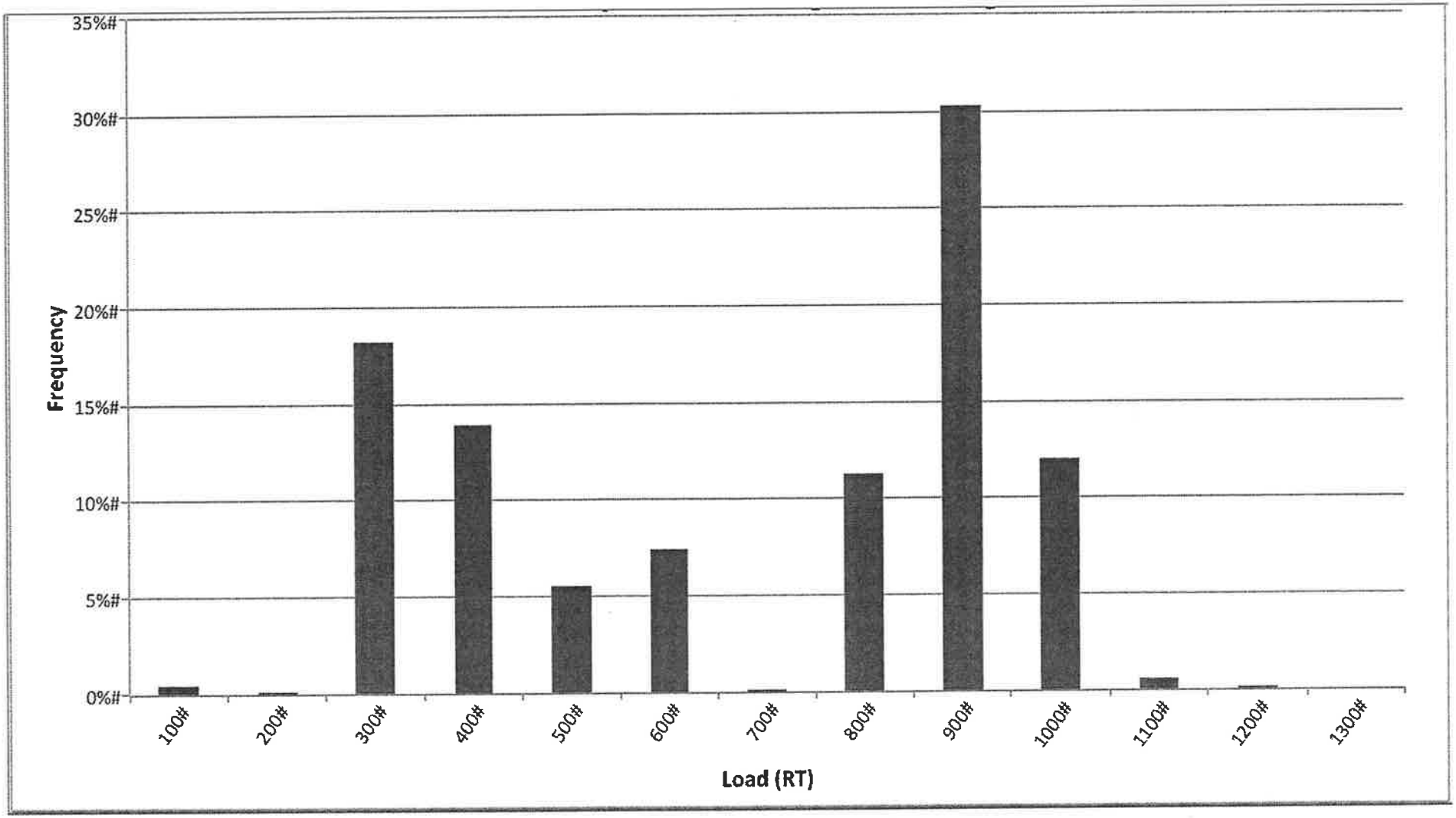

Chiller Plant System Findings

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Chiller System Findings Summary

Operating Parameters	Operating Data		
	Total Average	Peak Period (7am-11pm)	Off-Peak Period (11pm-7am)
Cooling Load (RT)	627	788	304
Power Consumption (kW)	518	634	286
System Efficiency (kW/RT)	0.83	0.80	0.94
CHW Supply Temp (^{O}C)	7.78	8.06	7.23
CHW Return Temp (^{O}C)	11.46	12.32	9.74
CHW Flowrate (USgpm)	2270	2461	1619
Condenser Cooling Load	760	946	388
CW Supply Temp (^{O}C)	28.21	28.87	26.88
CW Return Temp (^{O}C)	33.01	34.18	30.67
CW Flowrate (USgpm)	2109	2374	1365

Description	Rated Efficiency (kW/RT)	Operating Efficiency (kW/RT)	SS 530/ SS 531/ CP13 Standard	Remarks
Chillers	0.56	0.65	0.58	SS 530
Chilled Water Pumps	0.10	0.07	0.12	CP 13
Condenser Water Pumps	0.05	0.07	0.09	CP 13
Cooling Towers	0.04	0.04	0.06	SS 530
Total System	***0.75***	***0.83***	***0.85***	SS 530 & CP13

Chiller Plant System Findings

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Summary of Chiller 1 Findings

Operating Parameter	Design Data	Average Operating Condition		Remarks
		Peak Period	Off-Peak Period	
Chiller Cooling Load (RT)	550	429	309	Operating at part-load condition
Compressor kW	307	272	209	
Chiller Efficiency (kW/RT)	0.56	0.63	0.68	
CHW Supply Temp (°C)	6.7	7.72	7.21	set point is 6.7°C
CHW Return Temp (°C)	12.2	12.11	9.82	
CHW ΔT (°C)	5.5	4.39	2.61	ΔT is low
CHW Flowrate (USgpm)	1332	1302	1574	over pumping
CHW Flowrate/RT (gpm/RT)	2.4	3.0	5.1	
CW Supply Temp (°C)	29.4	29.11	27.41	Good CWS Temperature
CW Return Temp (°C)	35	33.92	30.94	
CW ΔT (°C)	5.6	4.81	3.53	ΔT is low
CW Flowrate (USgpm)	1555	1,297	1,338	over pumping during off peak
CW flowrate/RT (gpm/RT)	2.8	3.0	4.3	
Evap. Approach Temp (°C)	N.A.	0.9	-	Acceptable
Cond. Approach Temp (°C)	N.A.	1.9	-	Slighty High

Chiller Plant System Findings

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Summary of Chiller 2 Findings

Operating Parameter	Design Data	Average Operating Condition		Remarks
		Peak Period	Off-Peak Period	
Chiller Cooling Load (RT)	550	434	293	Operating at part-load condition
Compressor kW	307	282	200	
Chiller Efficiency (kW/RT)	0.56	0.65	0.68	
CHW Supply Temp (°C)	6.7	7.77	7.13	set point is 6.7°C
CHW Return Temp (°C)	12.2	12.45	9.84	
CHW ΔT (°C)	5.5	4.69	2.71	ΔT is low
CHW Flowrate (USgpm)	1332	1235	1440	over pumping
CHW Flowrate/RT (gpm/RT)	2.4	2.8	4.9	
CW Supply Temp (°C)	29.4	29.37	26.97	Good CWS Temperature
CW Return Temp (°C)	35	34.22	29.91	
CW ΔT (°C)	5.6	4.85	2.95	ΔT is low
CW Flowrate (USgpm)	1555	1,320	1,449	over pumping during off peak
CW flowrate/RT (gpm/RT)	2.8	3.0	4.9	
Evap. Approach Temp (°C)	N.A.	0.3	-	Acceptable
Cond. Approach Temp (°C)	N.A.	1.9	-	Slighty High

Hot Water System Findings

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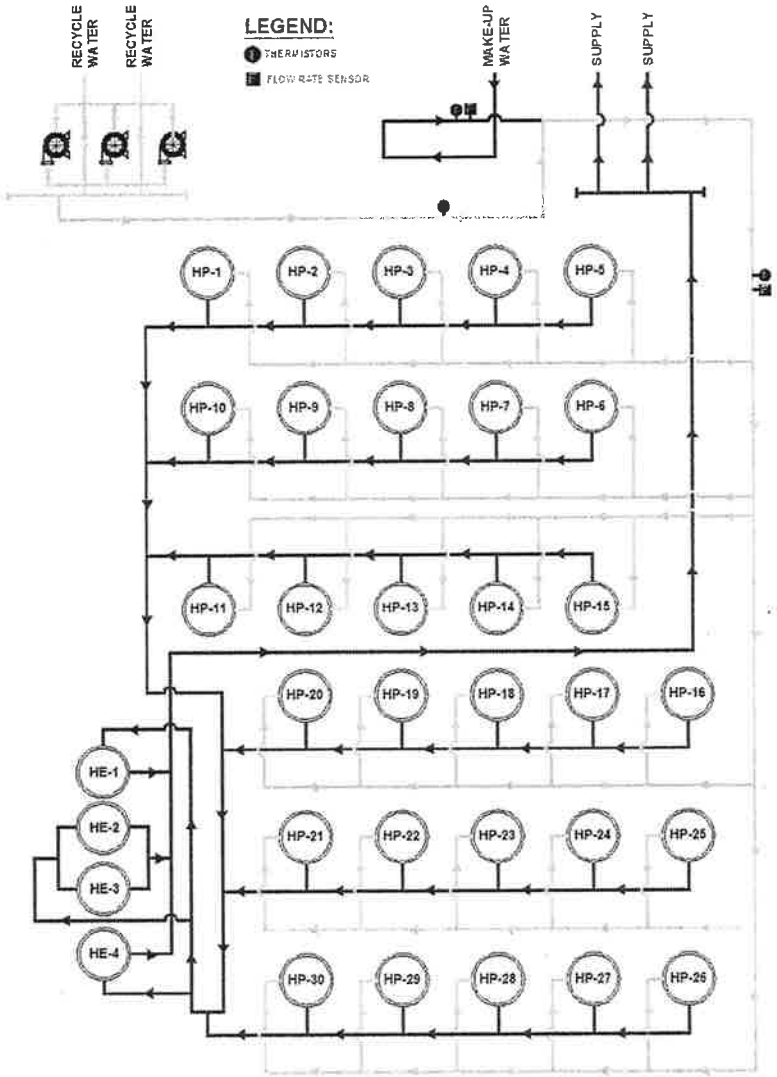

30 x 8.7kW$_H$ heat pumps

4 x 4.8kW$_H$ heaters

511 Rooms

Kitchens

Rated COP = 3.3kW$_H$/kW

Current Average COP = 1.71kW$_H$/kW

Hot Water System Findings

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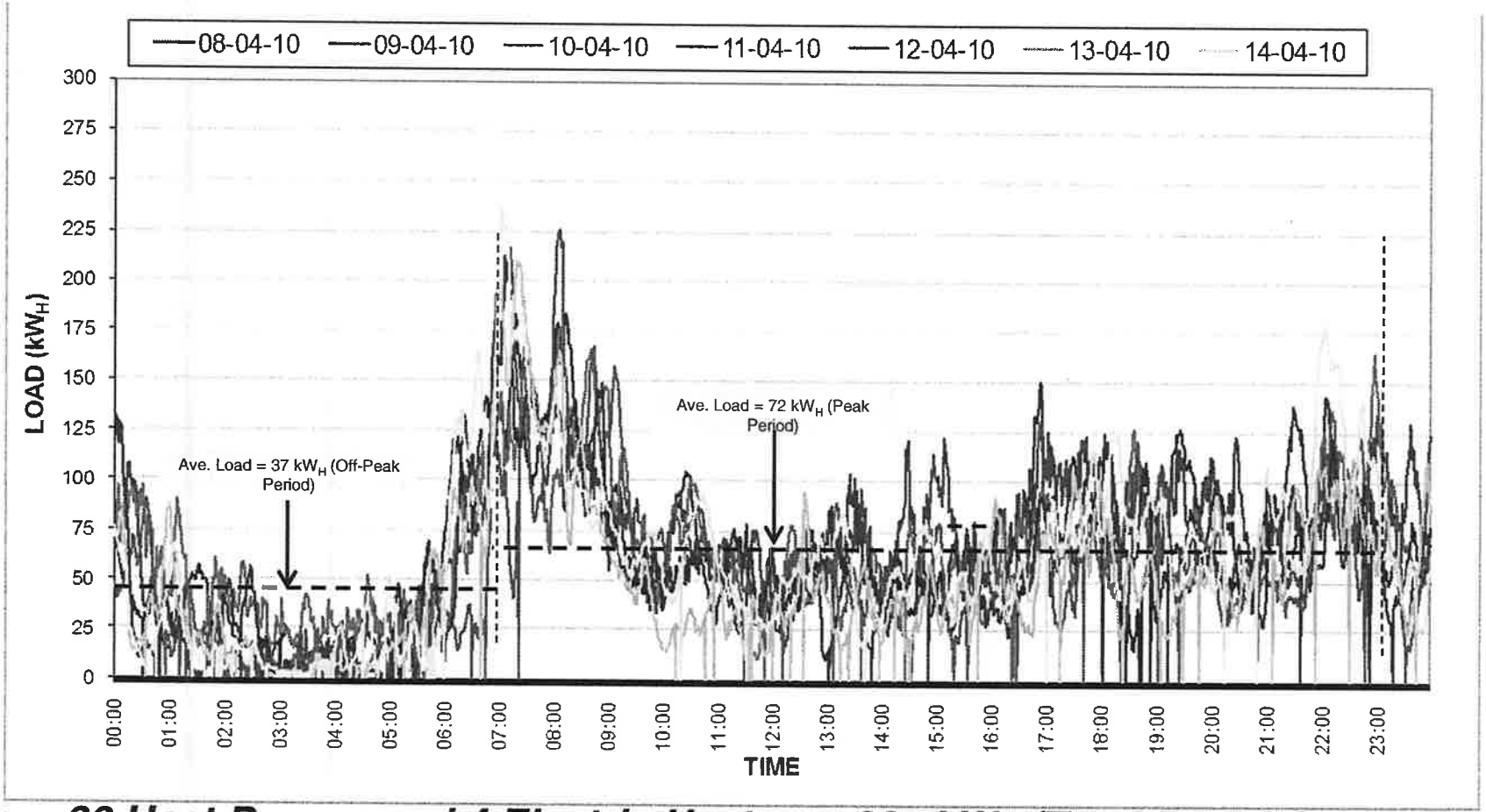
Heat load Profile



- ***30 Heat Pumps and 4 Electric Heaters= 280 kW$_H$ (Total Rated Capacity)***
- ***Off Peak Period ave. load = 37 kW$_H$***
- ***Peak Period ave. Load = 72 kW$_H$***

Hot Water System Findings

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Summary of Hot Water System Findings

Description	Design Data	Operating Conditions		Remarks
		Peak Period	Off-Peak Period	
Percent Loading	100%	26%	13%	Operating at Part load condition
Heat Load (kW_H)	280	72	37	
Hot Water Supply Temp (°C)	50~60	55.09	57.28	set point at 52°C
Mixed Water Temp (°C)	-	32.95	34.07	-
Hot Water Return Temp (°C)	-	39.21	38.02	Insulation for the pipes can be poor
Make-up Water Temp (°C)	30	30.39	30.92	normal temperature
Water Flow Rate (gpm)	35	14	7	make-up + recycling
Recyling Pump (kW)	-	0.2	0.2	
Heat Pump (kW)	66	31.8	24.5	Operating at Part load condition
Electric Heaters (kW)	19	4.8	2.9	
COP (Kw_H/kW)	3.3	2.0	1.4	inefficient

MV System Findings

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Equipment No	Area Served	Measured Flow (CMH)	Measured Motor (kW)	Fan Efficiency (W/CMH)	Actual kVA	Actual kVAr	Actual PF
Kitchen Exhaust & Fresh Air							
EAF 1-1	Common Areas	32,022	12.7	0.40	18.2	169.95	0.70
EAF 2-1	Common Areas	53,460	12.9	0.24	17.9	154.00	0.72
KEF 1-1	Main Kitchen	1,125	0.97	0.86	1.74	2.09	0.56
Toilet Exhaust Fan							
EAF 1-2	Toilet	33,984	10.9	0.32	16	255.90	0.68
EAF 2-2	Toilet	21,480	12.3	0.57	17.4	302.43	0.71

Lighting System Findings

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S/N	Location	Lux Measurement						Light Fitting	Area or activity	(CP38:1999)	Recommended
		Pt-1	Pt-2	Pt-3	Pt-4	Pt-5	Average			Range	Design Value
1	Carousel -Terrace	535	360	723	378	400	479	0 Halogens	Dining Room	200-500	300
2	Carousel-Verrandra	120	73	171	125	94	117	0 Halogens	Dining Room	200-500	300
3	Carousel-Living Room	122	92	110	130	85	108	5 Halogens	Dining Room	200-500	300
4	Carousel-Reception	378	375	145	140	350	278	5 Halogens	Dining Room	200-500	300
5	Carousel-State Room-1	150	111	100	-	-	120	Halogens	Dining Room	200-500	300
6	Carousel-State Room-2	130	92	145	-	-	122	Halogens	Dining Room	200-500	300
7	Carousel-Private Room	200	145	110	-	-	152	5 Halogens	Dining Room	200-500	300
8	Main Lobby	1100	175	136	250	170	366	5 Fluor, 52	Entrance Halls	200-500	300
9	Main Lobby	622	225	167	600	210	365	Halogens,20 PLC 13W,	Entrance Halls	200-500	300
10	Main Lobby	63	93	88	48	65	71	2 Dome light 300W, 3	Entrance Halls	200-500	300
11	Main Lobby	76	100	120	115	120	106	Pin light 60W	Entrance Halls	200-500	300
12	Jewellery Shop	2400	2400	1500	2923	1520	2149	5 Halogens, 20	Show room	300-750	500
13	15th Floor Corridor	140	54	95	260	96	129	5 Fluor 10W, 10 Fluor	Corridor	100-200	150
14	16th Floor Corridor	56	66	35	54	74	57	8W	Corridor	100-200	150
15	9th Floor Coridor	200	56	61	111	120	110	5 Fluor 10W, 10 Fluor	Corridor	100-200	150
16	9th Floor Coridor	51	43	35	96	105	66	8W	Corridor	100-200	150
17	4th Floor Corridor	130	53	40	120	180	105	5 Fluor 10W, 10 Fluor	Corridor	100-200	150
18	4th Floor Corridor	52	63	42	51	102	62	8W	Corridor	100-200	150
19	4th Floor Office	160	265	350	200	564	308	0 Flour 2x36W	Office	300-750	500
20	4th Floor Office	600	555	227	-	-	461	Flour 2x36W, 6 PLC	Office	300-750	500
21	Basement-1	104	391	395	156	450	299	0 Fluor 58W, 61 Flour 2x36W	Circulation areas	100-200	150
22	Basement-1	134	140	146	445	452	263	22 Flour 36W, 21 Flour 2x36W	Circulation areas	100-200	150
23	Room 437	35	25	50	-	-	37	2 Halogens, 6 PLC	Hotel Bedroom	75-150	100
24	Room 322 (Premium Type)	40	28	32	-	-	33	2 Halogens, 7 PLC 0W	Hotel Bedroom	75-150	100
25	Room 828 (Deluxe Premium Type)	36	58	29	24	-	37	2 Halogens, 7 PLC 0W	Hotel Bedroom	75-150	100
26	Room 1520 (Deluxe Suite Type)	32	47	23	37	-	35	2 Halogens, 9 PLC 0W	Hotel Bedroom	75-150	100
27	Canteen	168	250	120	250	230	204	8 Fluor 58W, 38 PLC 10W, 4 Halogens	Canteen	200-500	300

M&V Requirement

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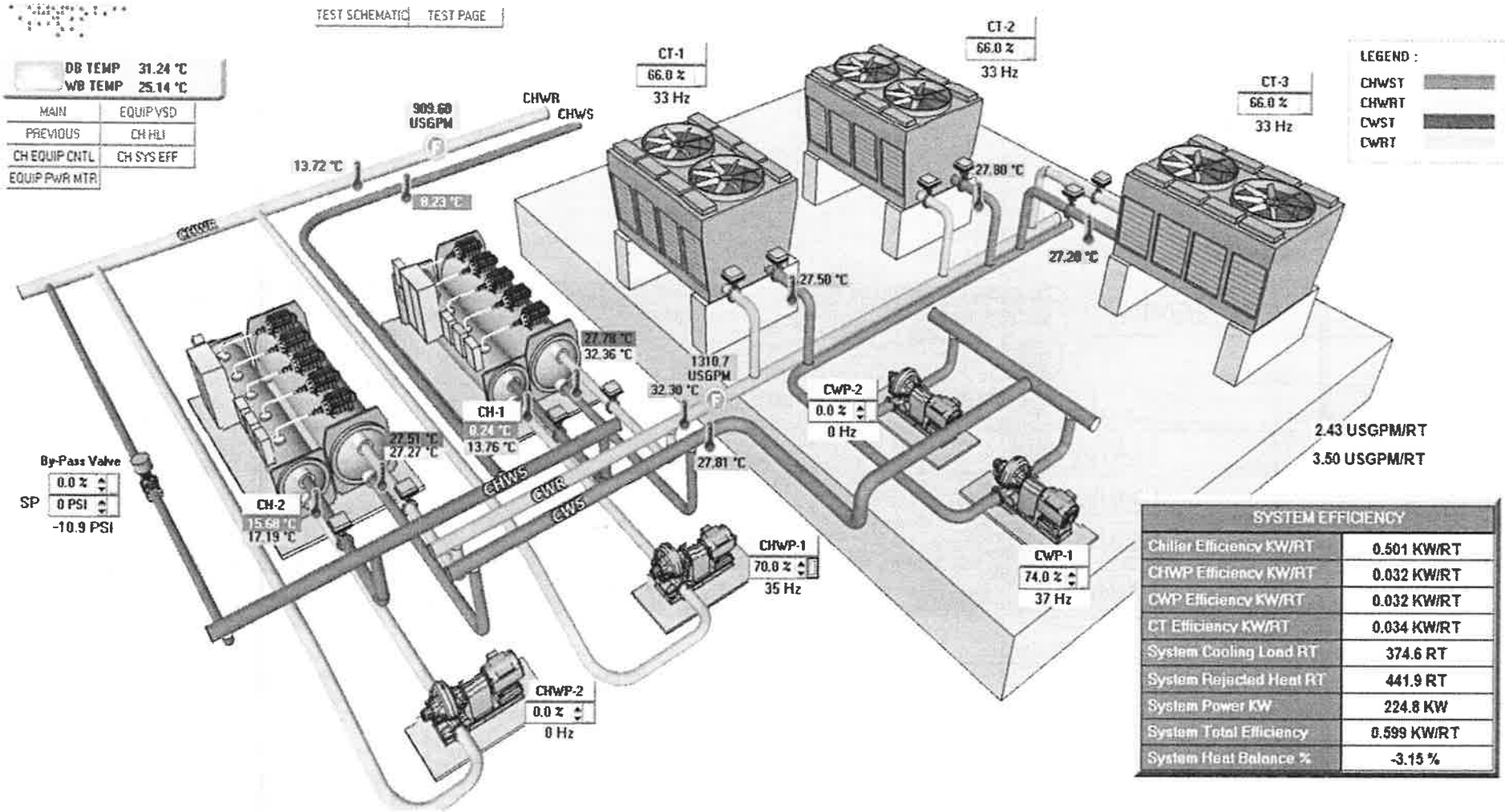

Countermeasure 1

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Optimization & Ehancement of Chiller Plant System

System Efficiency Before Implementation (Peak Period)	kW/RT	0.80
System Efficiency Before Implementation (Off Peak Period)	kW/RT	0.94
System Efficiency After Implementation (Peak Period)	kW/RT	0.76
System Efficiency After Implementation (Off Peak Period)	kW/RT	0.79
Estimated Average System Cooling Load	RT	546
Operation Hour of Chiller System	Hour	8,760
Weighted Electricity Rate	SGD/kWh	0.2

Countermeasure 2

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Replacement of chiller 3 to a 0.56 kW/RT Chiller

System Efficiency Before Implementation (Peak Period)	kW/RT	-
System Efficiency Before Implementation (Off Peak Period)	kW/RT	0 94
System Efficiency After Implementation (Peak Period)	kW/RT	-
System Efficiency After Implementation (Off Peak Period)	kW/RT	0 72
Estimated Average System Cooling Load	RT	304
Operation Hour of Chiller System	Hour	2 920
Weighted Electricity Rate (Off Peak Periods)	SGD/kWh	0 2

Countermeasure 3

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Design To Achieve Chilled Water Plant Of 0.6 kW/Ton

System Efficiency Before Implementation (Peak Period)	kW/RT
System Efficiency Before Implementation (Off Peak Period)	kW/RT
System Efficiency After Implementation (Peak Period)	kW/RT
System Efficiency After Implementation (Off Peak Period)	kW/RT
Estimated Average System Cooling Load	RT
Operation Hour of Chiller System	Hour
Weighted Electricity Rate (Off Peak Periods)	SGD/kWh

Countermeasure 4

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New Hot Water System

System COP Before Implementation (Peak Period)	kW_H/kW	2.0
System COP Before Implementation (Off Peak Period)	kW_H/kW	1.4
System cOP After Implementation (Peak Period)	kW_H/kW	4.0
System COP After Implementation (Off Peak Period)	kW_H/kW	4.0
Estimated Average System Heating Load	kW_H	54

Level 3 – Report Requirement

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1. Executive Summary
2. Energy Profile – Consumption, Cost & Carbon
3. Energy Conservation Measures – Short Term, Mid Term & Long Term
4. Building Benchmarking – Summary of System, Opportunities and Shortfall
5. Chilled Water System
    - Details Data Collection And Analysis
    - Intensive Capital Investment ECM & Analysis
6. Airside and Controls
    - Details Data Collection And Analysis
    - Intensive Capital Investment ECM & Analysis
7. Hot Water Plant System
    - Details Data Collection And Analysis
    - Intensive Capital Investment ECM & Analysis
8. Lighting Observation And Analysis
    - Details Data Collection And Analysis
    - Intensive Capital Investment ECM & Analysis
9. Energy Conservation Measures
    - Details of Investment Grade ECM & Savings

Summary of Energy Audit Levels I, II & III

Energy Level I Assessment – Preliminary or Walk-through	Energy Level II Assessment – Standard	Energy Level III Assessment – Comprehensive or Detailed
A level I assessment, sometimes referred to as a level I assessment, or preliminary assessment, evaluates the overall energy consumption of the facility and is expected to provide a rough estimate of energy savings, investment costs and payback of the preliminary recommendations.	A level II assessment identifies the actual amount of energy used by a facility the source of the energy and what the energy is used for. It also identifies areas where savings may be achieved, recommends measures to be taken, and provides a statement of expected costs and potential savings. **It also involves short term metering and logging.**	Level III assessment is similar to a level II assessment except it also involves **long-term detailed metering and data logging**. A level III assessment provides a detailed analysis of energy usage, the savings that can be made, and the cost of achieving those savings. It may cover the whole facility or may concentrate on an individual item and/or system, such as a single industrial process or one of the services.
This assessment is usually designed to determine if the level of energy use of a facility has been reasonable or excessive. It provides initial energy baselines of the facility so that the effect of energy measures may be evaluated. **It may or may not involve a site visit.** The information given to or gathered by the ESCO needs to be sufficient to enable the overall efficiency of the facility to be ascertained.	The expected scope of work for Level II assessment is as follows:	The expected scope of work for Level III assessment is as follows:
The scope of work for Level I appraisal is as follows:	Follow-up from Level I assessment and report where available;	Follow-up from Level II assessment and report where available;
Gather facility-wide energy use on a monthly and/or annual basis;	Facility investigation;	Define facility/process audited;
Derive performance indicators;	Detailed facility and systems energy input and energy use;	Facility/process investigation and **detailed measurements;**
Propose broad conclusions and recommendations, with estimated energy savings and payback; and	Reconciliation of energy accounts with loads;	**Detailed metering** down to half-hourly time interval where required;
Submit written report.	Variation on energy use on a month-to-month basis;	Derive target energy use and **develop baseline model** where relevant;
	Energy performance indicators;	Detailed recommendations including costs, savings and accuracy of estimates;
	Recommended improvement work with indicative cost and saving;	Detailed investment plan;
	Implementation priority and plan;	Suggest refinement to energy policy and energy program; and
	Alignment of recommendations with client's energy program; and	Written report and presentation.
	Written report and presentation.	

Reference:
Scope of services as recommended by NEA:
http://app.e2singapore.gov.sg/Incentives/Energy_Efficiency_Improvement_Assistance_Scheme.aspx

Additional References:

1.1

BCA Building Energy Benchmarking 2014
http://www.bca.gov.sg/GreenMark/others/BCA_BEBR_Abridged_FA.pdf

BCA Building Energy Benchmarking 2015
http://www.bca.gov.sg/GreenMark/others/BCA_BEBR_Abridged_FA_2015.pdf

Singapore's carbon emission factor
http://www.ema.gov.sg/statistic.aspx?sta_sid=20140729MPY03nTHx2a1

Tree Offsetting for Carbon Emission
http://www.carbonify.com/carbon-calculator.htm
http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

Number of trees in Singapore
https://www.nparks.gov.sg/activities/family-time-with-nature/recommended-activities/know-10-trees

1.2
Procedure for Measuring and Reporting Building Performance
http://energy.gov/eere/buildings/performance-metrics-tiers

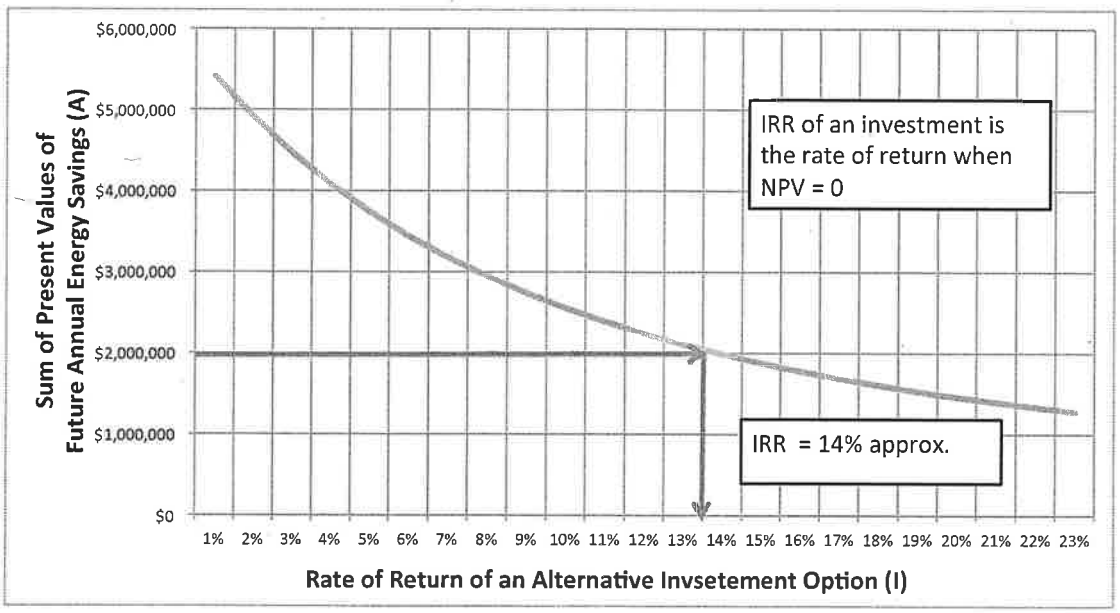
1.3
Energy Star – Guideline for Energy Management
http://www.energystar.gov/sites/default/files/buildings/tools/Guidelines%20for%20Energy%20Management%206_2013.pdf

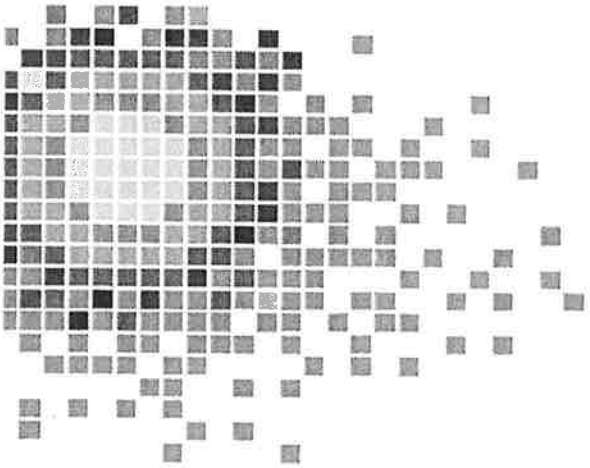
Simple Payback ROI vs IRR

Investment (S$)	Annual Energy Savings (S$)	Simple Payback (years)	ROI	IRR
1,000,000	80,000	12.50	8%	2%
1,000,000	90,000	11.11	9%	4%
1,000,000	100,000	10.00	10%	6%
1,000,000	110,000	9.09	11%	7%
1,000,000	120,000	8.33	12%	8%
1,000,000	130,000	7.69	13%	10%
1,000,000	140,000	7.14	14%	11%
1,000,000	150,000	6.67	15%	12%
1,000,000	160,000	6.25	16%	14%
1,000,000	170,000	5.88	17%	15%
1,000,000	180,000	5.56	18%	16%
1,000,000	190,000	5.26	19%	17%
1,000,000	200,000	5.00	20%	18%
1,000,000	210,000	4.76	21%	20%
1,000,000	220,000	4.55	22%	21%
1,000,000	230,000	4.35	23%	22%
1,000,000	240,000	4.17	24%	23%
1,000,000	250,000	4.00	25%	24%
1,000,000	260,000	3.85	26%	25%
1,000,000	270,000	3.70	27%	26%
1,000,000	280,000	3.57	28%	27%
1,000,000	290,000	3.45	29%	28%
1,000,000	300,000	3.33	30%	29%
1,000,000	310,000	3.23	31%	30%
1,000,000	320,000	3.13	32%	31%
1,000,000	330,000	3.03	33%	33%
1,000,000	340,000	2.94	34%	34%
1,000,000	350,000	2.86	35%	35%
1,000,000	360,000	2.78	36%	36%
1,000,000	370,000	2.70	37%	37%
1,000,000	380,000	2.63	38%	38%
1,000,000	390,000	2.56	39%	39%
1,000,000	400,000	2.50	40%	40%
1,000,000	410,000	2.44	41%	41%
1,000,000	420,000	2.38	42%	42%
1,000,000	430,000	2.33	43%	43%
1,000,000	440,000	2.27	44%	44%
1,000,000	450,000	2.22	45%	45%
1,000,000	460,000	2.17	46%	46%
1,000,000	470,000	2.13	47%	47%
1,000,000	480,000	2.08	48%	48%
1,000,000	490,000	2.04	49%	49%
1,000,000	500,000	2.00	50%	50%

Example of IRR Computation

Annual Energy Savings (kWh)	Tariff (SGD/kWh)	Energy Cost Savings/Year (SGD)	N (Years)	I (Rate of Return of an Alternative Investment Option)	Present Values of Energy Savings @ I% Discount Rate (SGD)	Initial Investment (S$)	Net Present Value, NPV (S$)
X	Y	Z = X x Y			A	B	C = A+B
					A = PV (I%, N Years, ,Z)		
1,500,000	0.20	300,000	20	1%	$5,413,666	-$2,000,000	$3,413,665.89
1,500,000	0.20	300,000	20	2%	$4,905,430	-$2,000,000	$2,905,430.00
1,500,000	0.20	300,000	20	3%	$4,463,242	-$2,000,000	$2,463,242.46
1,500,000	0.20	300,000	20	4%	$4,077,098	-$2,000,000	$2,077,097.90
1,500,000	0.20	300,000	20	5%	$3,738,663	-$2,000,000	$1,738,663.10
1,500,000	0.20	300,000	20	6%	$3,440,976	-$2,000,000	$1,440,976.37
1,500,000	0.20	300,000	20	7%	$3,178,204	-$2,000,000	$1,178,204.27
1,500,000	0.20	300,000	20	8%	$2,945,444	-$2,000,000	$945,444.22
1,500,000	0.20	300,000	20	9%	$2,738,564	-$2,000,000	$738,563.70
1,500,000	0.20	300,000	20	10%	$2,554,069	-$2,000,000	$554,069.12
1,500,000	0.20	300,000	20	11%	$2,388,998	-$2,000,000	$388,998.44
1,500,000	0.20	300,000	20	12%	$2,240,833	-$2,000,000	$240,833.09
1,500,000	0.20	300,000	20	13%	$2,107,425	-$2,000,000	$107,425.47
1,500,000	0.20	300,000	20	14%	$1,986,939	-$2,000,000	($13,060.83)
1,500,000	0.20	300,000	20	15%	$1,877,799	-$2,000,000	($122,200.56)
1,500,000	0.20	300,000	20	16%	$1,778,652	-$2,000,000	($221,347.73)
1,500,000	0.20	300,000	20	17%	$1,688,330	-$2,000,000	($311,669.80)
1,500,000	0.20	300,000	20	18%	$1,605,824	-$2,000,000	($394,176.05)
1,500,000	0.20	300,000	20	19%	$1,530,259	-$2,000,000	($469,741.36)
1,500,000	0.20	300,000	20	20%	$1,460,874	-$2,000,000	($539,126.08)
1,500,000	0.20	300,000	20	21%	$1,397,007	-$2,000,000	($602,992.75)
1,500,000	0.20	300,000	20	22%	$1,338,080	-$2,000,000	($661,920.17)
1,500,000	0.20	300,000	20	23%	$1,283,585	-$2,000,000	($716,415.23)





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TOMORROW'S BUILDINGS ENGINEERED TODAY

Energy Measurement and Verification (M&V)

Day 2, 10am - 11am

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What Is IPMVP ?

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- Widely Used M&V Procedure Also Known As International Performance Measurement and Verification Protocol, IPMVP
- Framework used to determine and define the 'savings' after the implementation of the Energy Savings Project
- Give Confidence To The Energy Efficiency Savings generated After The Project
- M&V and the demonstration of savings achieved has long been an area of conflict
- It Is A Standard comprising Of Internationally Agreed Procedures And Technique For Measurement and Verification, M&V

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What Is M&V ?

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M&V Is A Process Of Using Measurement To Reliably Determine Actual Savings Created Within An Individual Facility By Implementing An Energy Efficient Project

M&V Process Is Essentials:

1. It Assess Resource Savings In Regards To Performance Guarantee
2. It Ensure That Savings Will Persist Over Time

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Why Measure And Verify ?

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- Savings are the absence of energy use
- We cannot measure what we do not have
- Therefore, we do not measure savings

However:

- We Do Measure Energy Use
- We Analyse Measured Energy Use To Determine Savings
- Energy Efficiency Retrofits Cannot Be Measured Directly
- One Will Not Be Able To Value The Results Of Investment In Energy Efficiency
- Energy Reduction Gains Achieved Through The Project Will Likely Dissapear In Part Or In Totality Over Time

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M&V Purpose

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1. Improve Engineering Design And Project Costing – encourage comprehensive project design that include M&V activities
   - Good M&V plan encourage comprehensive design
   - Provide feedback for future project design
2. Increase Energy Savings Through Proactive Adjustment Of Operations And Maintenance
   - Provide information for Maintenance Manager to discover and manage operations
   - Achieve greater persistence of savings over time
3. Document Energy Savings And Financial Transaction
   - Document energy savings performance of a project in a transparent manner that could be verified by a third party
   - Form a basis of guarantee or financial payment based on the savings achieved
4. Enhance The Financing ON Energy Efficiency Project
   - Increase the transparency and credibility of the report of outcome of the project investment
   - Increase the credibility of projection for the outcome of the investment
   - Increase confidence of the investor to further finance future energy efficiency project
5. Manage Energy Budget
   - Allows Manager to evaluate and account for variance in energy usage
   - Enable Manager to adjust changing facility operations to account and manage operation cost
6. Support Evaluation And Development Of Broader Efficiency Program
   M&V technique allows evaluation of various facilities
   Enable better prediction of savings at unmeasured site on its possible performance
7. Increase awareness of public and the industries
   - EE project yield real reduction in energy cost
   - Encourage in EE project

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IPMVP – Its Benefits

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- Define Standard Approach To Measuring Savings, So as to Reassure Building Owners
- Legitimise ESCO Project Thru International Recognition Of Savings Achieved
- Create A Transparent And Repeatable Performance Contract Terms

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IPMVP – The Principles

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M&V Is A Science That Follows Some Fundamental Principles:

1. **Accurate**
   - As accurate as the M&V budget allows
   - Consistent with the financial implication of over reporting or under reporting of a project performance
   - Accuracy tradeoff should be accompanied by increased conservativeness in estimates and judgements
2. **Complete**
   - Consider all effects of the project
   - Use measurement to quantify all significant effects of a project
3. **Conservative**
   - Where judgements are made about uncertain savings quantities, best to underestimates the savings
4. **Consistent**
   - Consistent in identifying key areas of judgement
5. **Relevant**
   - Measurement of savings should measure the performance parameters of concern
6. **Transparent**
   - All M&V activities should be clear and fully disclosed

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IPMVP – The Principles

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Fundamental Formula:
(Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments = Savings

- **Routine Adjustment –** For changes in parameters that can be expected to happen throughout the post retrofit period and which had a relationship with the energy used and demand and can be identified. Such as seasonal changes, change in occupancy percentage, change in the space condition requirement

- **Non-routine Adjustment –** For changes in parameters which cannot be predicted and for which the impact on the energy used and demand is expected. Such as change of used of premises, extension of areas, change of use

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IPMVP – The Principles

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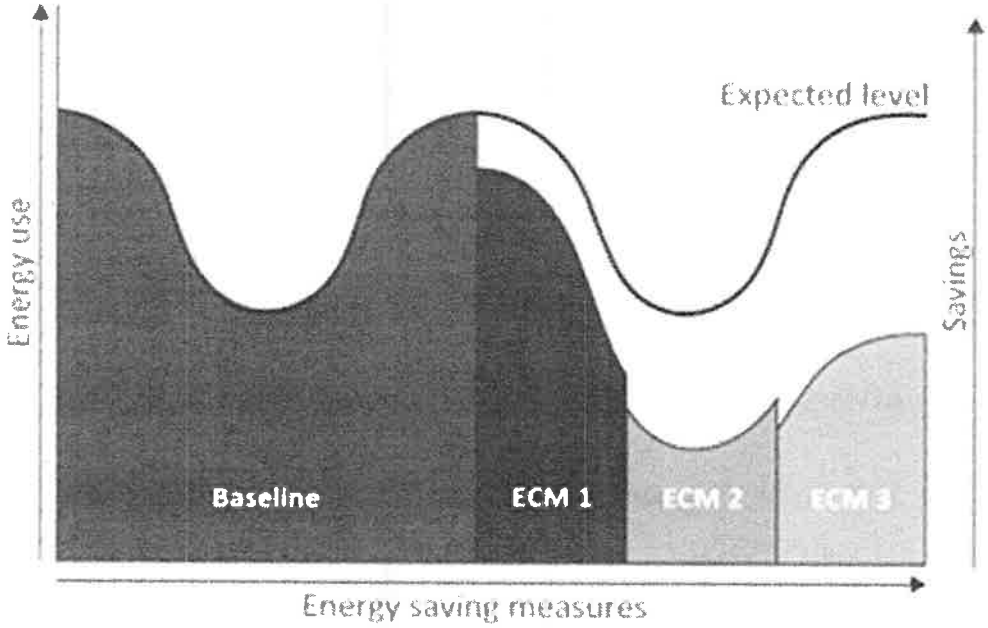
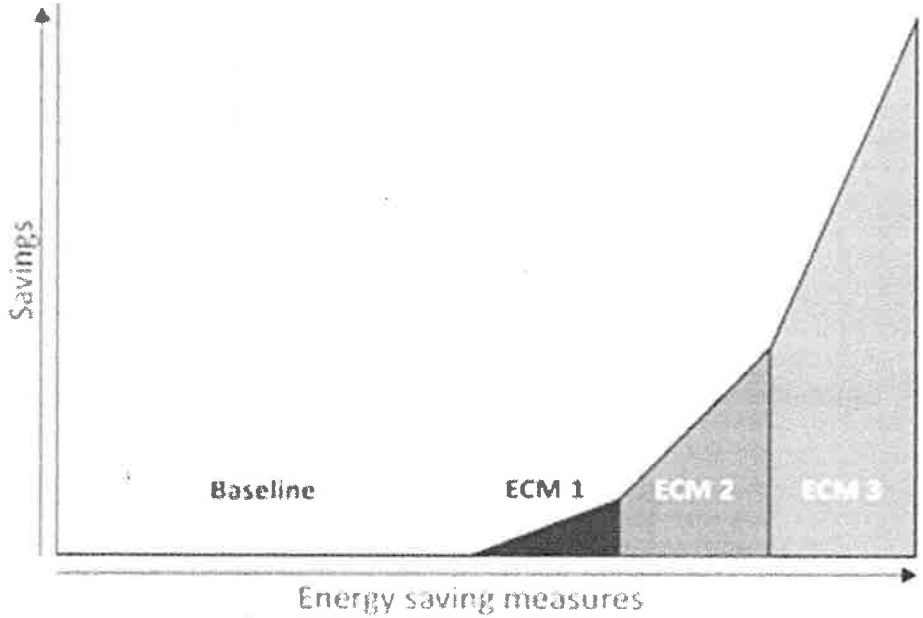


Cost Reduction After Implementing ECM



Energy Saved From Implementing The ECM

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IPMVP – The Principles

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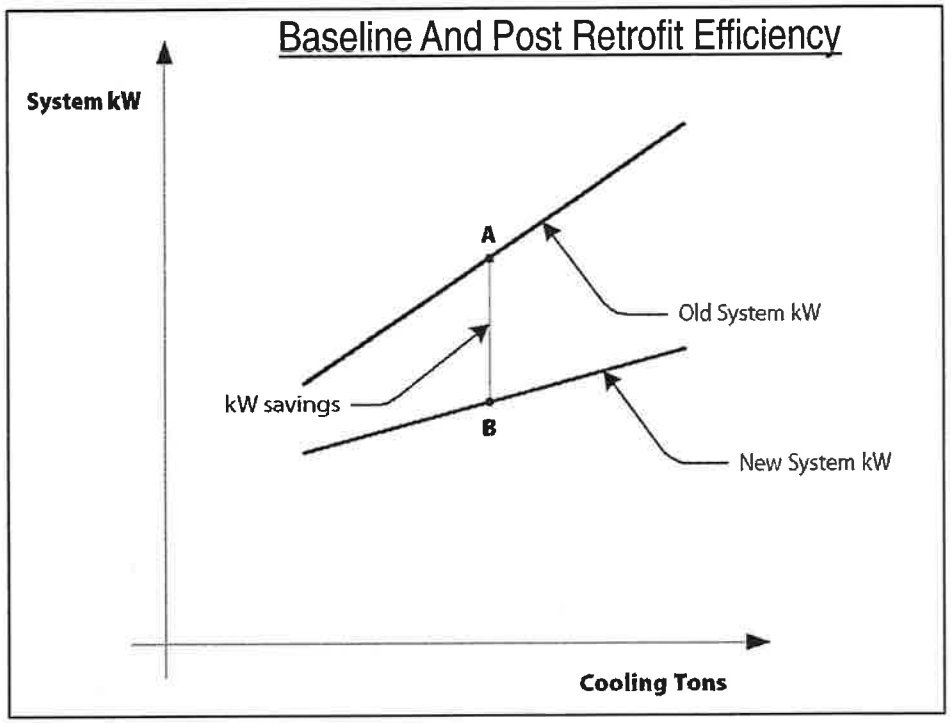

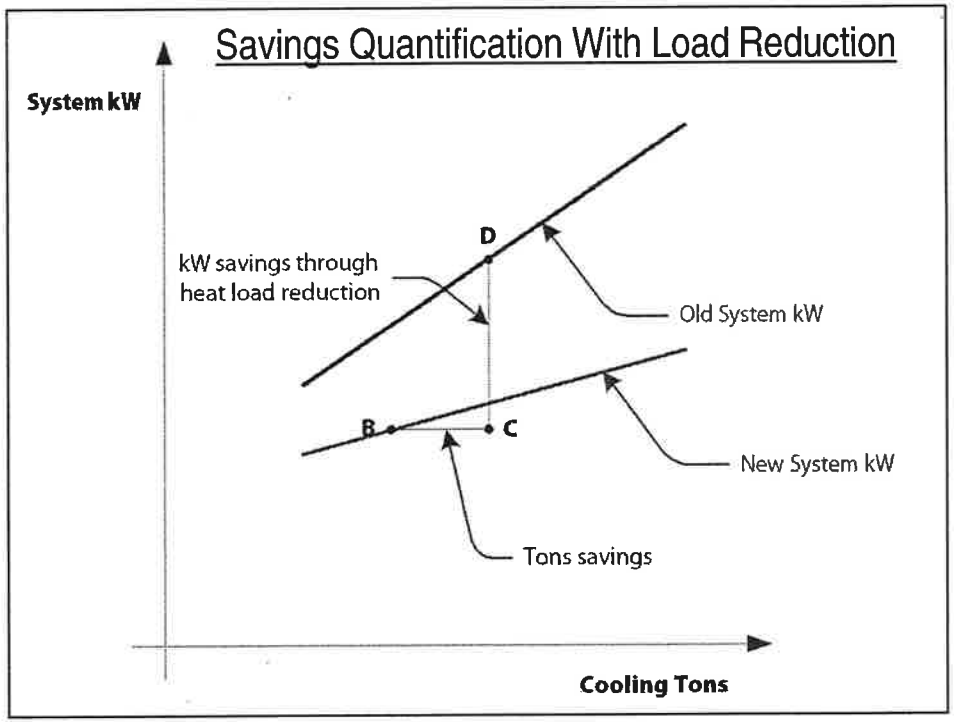

A. Saving through system efficiency improvement

Dollar saving = kWh_{saved} x electricity tariff rate

kWh_{saved} = (kW_A - kW_B) x number of operation hour

Where;

kW_A = Ton_B at Base line model equation

kW_B = Measured kW

Ton_B = New system tonnage, calculated from measured parameter

Dollar saving = kWh_{saved} x electricity tariff rate

kWh_{saved} = (kW_D – kW_B) x number of operation hour

Where;

kW_D = Ton_C at Base line model equation

kW_B = Measured kW

Ton_B = New system tonnage, calculated from measured parameter

Ton_C = Ton_B + Parasitic load

Parasitic Load or Ton_{saved} = (kW reduction due to retrofit works) / 3.52

Maximum Demand Saving

Maximum demand (kW) reduction can be calculated from the trend data of baseline system kW and new system kW.

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IPMVP – The Different Options

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Fundamental Formula:
(Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments = Savings

Option A

IPMVP Option – Retrofit Isolation: Key Parameter Measurement

1. Savings are determined by field measurement of key performance parameters
2. Measurement frequency ranges from short to continuous, depending on the expected variations in the measured parameters and the length of reporting period
3. Parameters not selected for measurement are estimated. Documentation of the estimation and justification of the cause

Savings Calculated

1. Engineering calculation of baseline and reporting period energy used from measurement of key operating data
2. Estimated value of non measured data
3. Document routine and non-routine adjustment, if necessary

Typical Application

1. Lighting retrofit
2. Power draw is key performance parameter of the retrofit
3. Estimates the operating hours based on schedule and occupant behaviour

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IPMVP – The Different Options

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Fundamental Formula:
(Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments = Savings

Option B

IPMVP Option – Retrofit Isolation: All Parameter Measurement

1. Savings are determined by field measurement of the energy use of the affected system
2. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameters and the length of reporting period

Savings Calculated

1. Short term or continuous measurement of baseline and reporting period energy used
2. Engineering computation using measurement of proxies of energy use
3. Document routine and non-routine adjustment, if necessary

Typical Application

1. Installing a VSD on a pump motor to control the flow rate
2. Measure the power to the motor which read the power every minute. In the baseline period, the power measurement is done for a week to verify the loading.
3. During the reporting period, the power measurement is in place to track the variation throughout the reporting period

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IPMVP – The Different Options

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Fundamental Formula:
(Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments = Savings

Option C

IPMVP Option – Whole Facility
1. Savings are determined by measuring energy use of the whole facility or sub facility
2. Continuous measurement of the entire facility's energy use are taken throughout the reporting period

Savings Calculated
1. Analysis of whole facility baseline and reporting period meter data
2. Routine adjustment as required.
3. Non routine adjustment as required
4. Document routine and non-routine adjustment, if necessary

Typical Application
1. Multifaceted energy management program affecting many system in the facility
2. Measure energy use with gas and electric utility for 12-month baseline period and throughout the reporting period

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IPMVP – The Different Options

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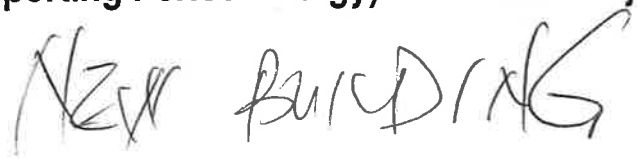
Fundamental Formula:
(Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments = Savings

Option D



IPMVP Option – Calibrated Simulation

1. Savings are determined through simulation of the energy use of the whole facility or sub-facility
2. Simulation routines are to demonstrate adequately model after the actual energy performance of the facility
3. Requires a considerably higher skill set for calibrated simulation

Savings Calculated

1. Energy use in simulation, calibrated with hourly or monthly utility billing data
2. Energy from the power measurement could be used to help refine input data

Typical Application

1. Multifacetd energy management program affecting many system in the facility; but where no metering existed during the baselining
2. Energy use measurement after installation of gas and electric meters are use to calibrate simulation
3. Baseline energy use, are determine using calibrated simulation and compared to a simulation of reporting period energy used

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IPMVP – Common Pitfalls & Affects

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1. Data Collection Errors – minimal standard of data performance should be established
2. Non-recoverable Data – lost data, sensor failure, archive failure, etc
    - Establish a maximum acceptable level of data loss and how it will be measured
    - Methodology by which missing or errornous data could be interpolated for final analysis

<u>Factors Affecting Savings Performance</u>

1. Weather
2. Occupancy level, schedule
3. Installed equipment intensity, schedule
4. Occupant or user demand for services (e.g. space temperature, plant throughput)
5. Ability of the ECM as designed to achieve the intended savings
6. ECM implementation effectiveness in meeting the design intent
7. Occupant or operator cooperation in using ECM related equipment in accordance with direction
8. Occupant or operator cooperation in using non-ECM related equipment in accordance with direction
9. Equipment deterioration, both ECM related equipment and non-ECM related
10. Equipment life, both ECM and non-ECM related

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Energy Management – Strategy

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1. Achieve A The Required Design Condition For Space, Hot Water And Intent (Space Temp: 23 ° C ± 1° C, RH; 65% ±5%; Hot Water Temp: 55 - 60° C; Proper Billing, etc)
2. Achieve A Plant Efficiency Of: Chilled Water System Better 0.65 kW/Ton; Hot Water System Of Better Than COP of 4
3. Sustaining The Plant Efficiency/Energy Savings Through The Years
4. Management Report Of Plant Performance On A Monthly Basis.

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What's On Your Plate ?

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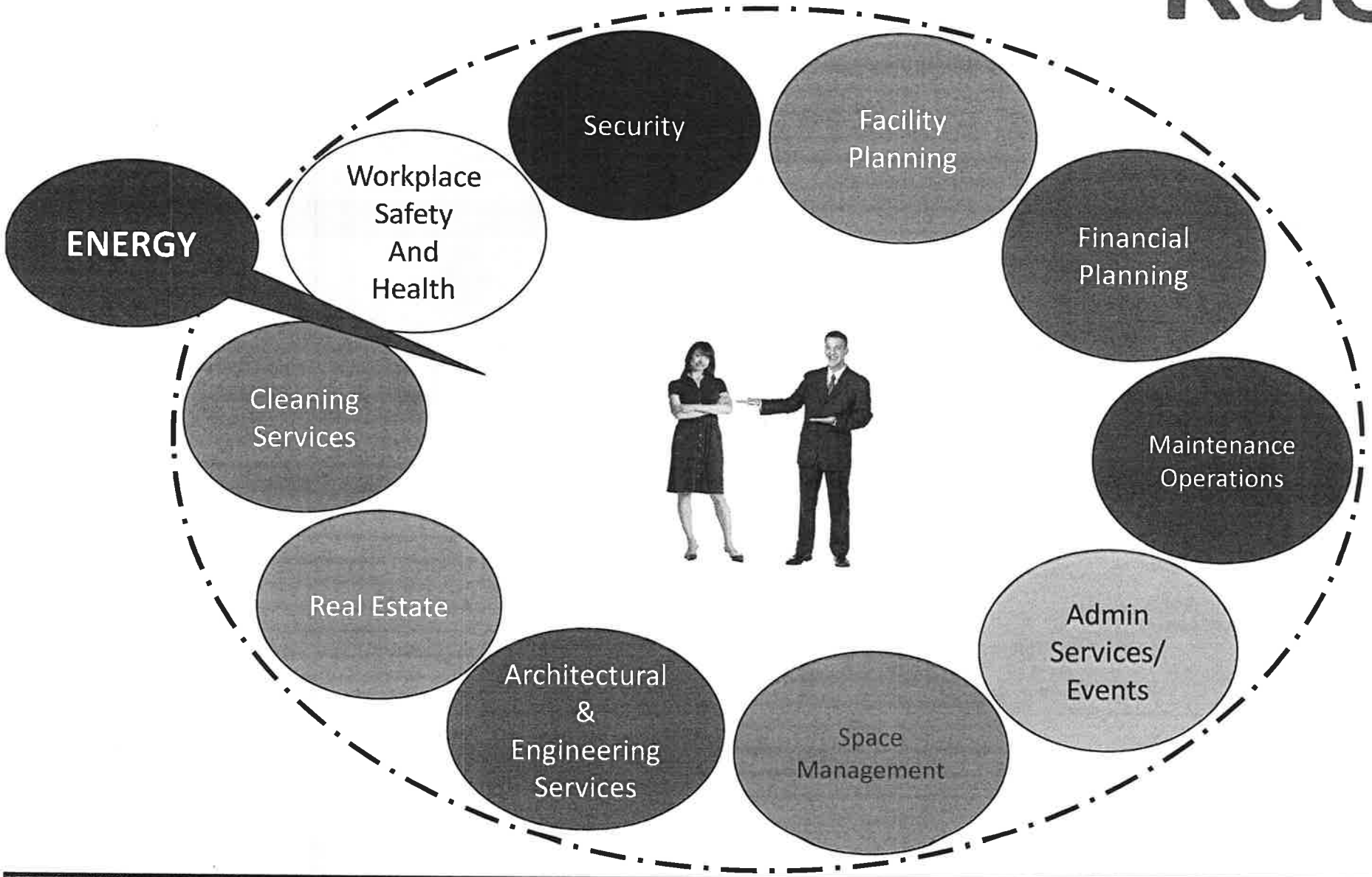

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Strategy – Required Condition

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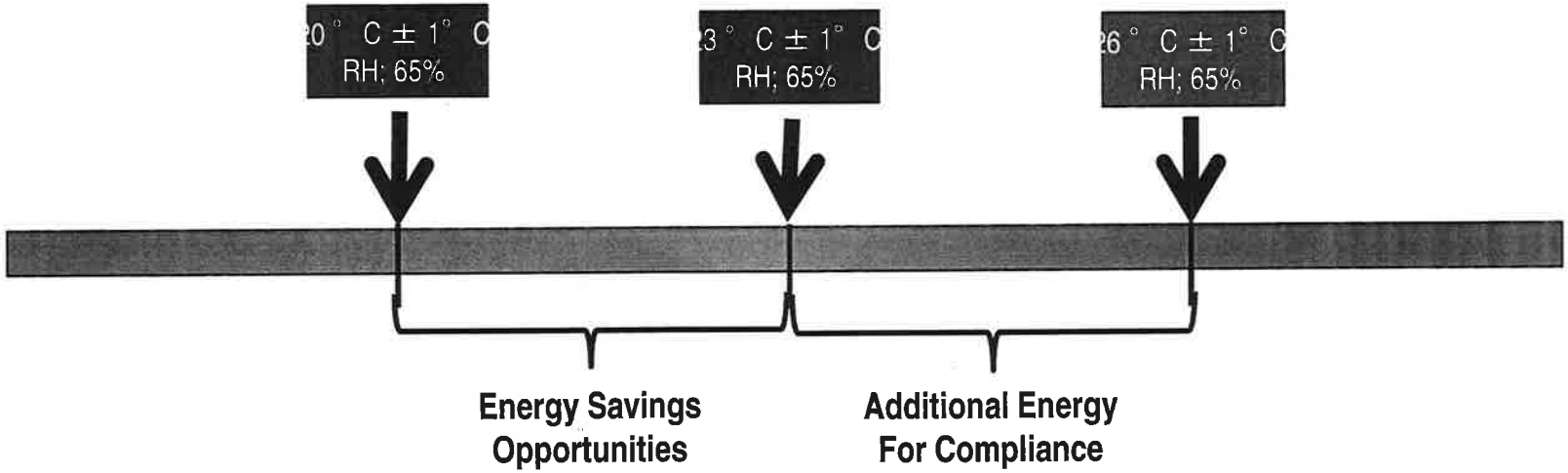
Achieve A The Required Design Condition At All Time:

a. For Space Condition: 24 ° C ± 1° C, RH: < 65%

b. Hot Water: 55 - 60° C

c. IPMVP, Monthly Energy Report And Benchmarking



How Do You Manage The Customer On Both Side Of The Scale And Yet Manage Your Energy Objectives?

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Strategy – Required Condition

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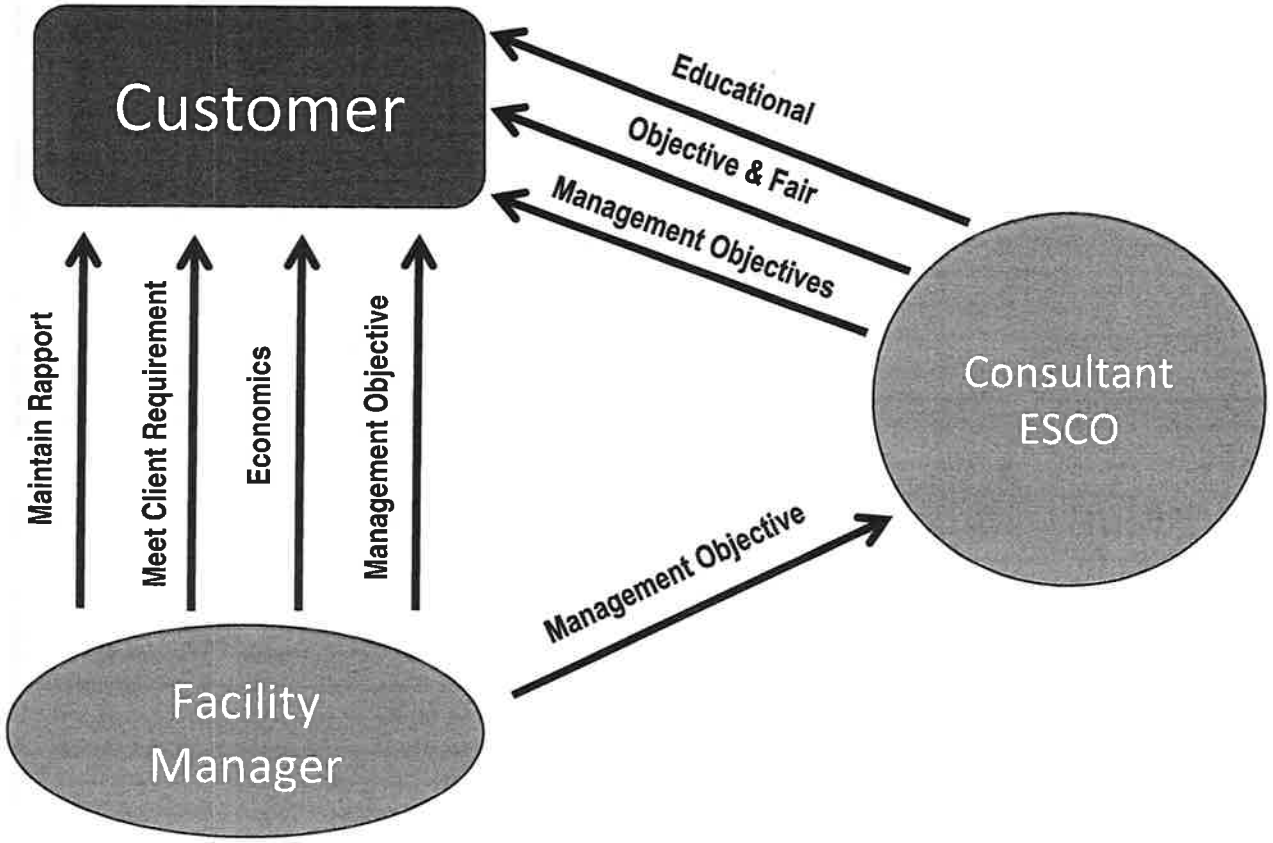
Scenario: You Have A Customer That Demanded A 20° C Space Condition?



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Strategy – Plant Efficiency

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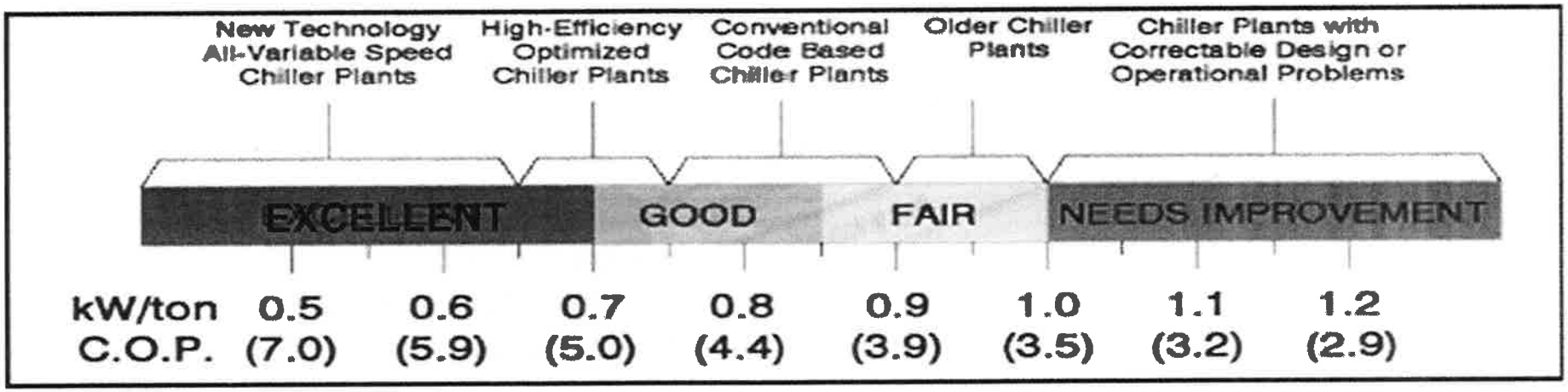
Achieve An Optimal Plant Efficiency Throughout The Operations Consistently

a. Chilled Water System Efficiency 0.65 kW/Ton

b. Hot Water System Performance Of COP Better Than 4



Could You Measure Efficiency On A Single Dimension ?

Could We Measure A F1 Race Car Using A Standard Stop Watch ?

Will There Be Dispute Among The Racer ?

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Strategy – Plant Efficiency - Integrity

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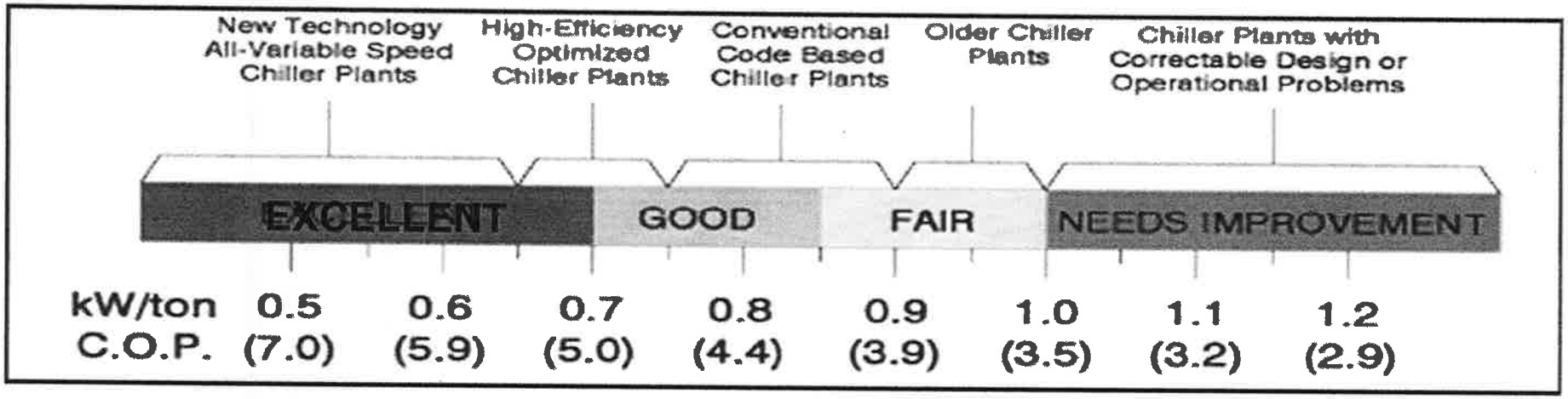

kW/Ton (COP)

- Chilled Water Flow
- CHWS Temp
- CHWR Temp
- Power Measurement

- Cond Water Flow
- CWS Temp
- CWR Temp
- Power Measurement

Heat Balance

Due To Various Measurement Required; Everytime An Efficiency Nos Is Obtained; Heat Balance Need To Be Ratified !!

Could You Do It On Your Own ?

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Strategy – Plant Efficiency - Visibility

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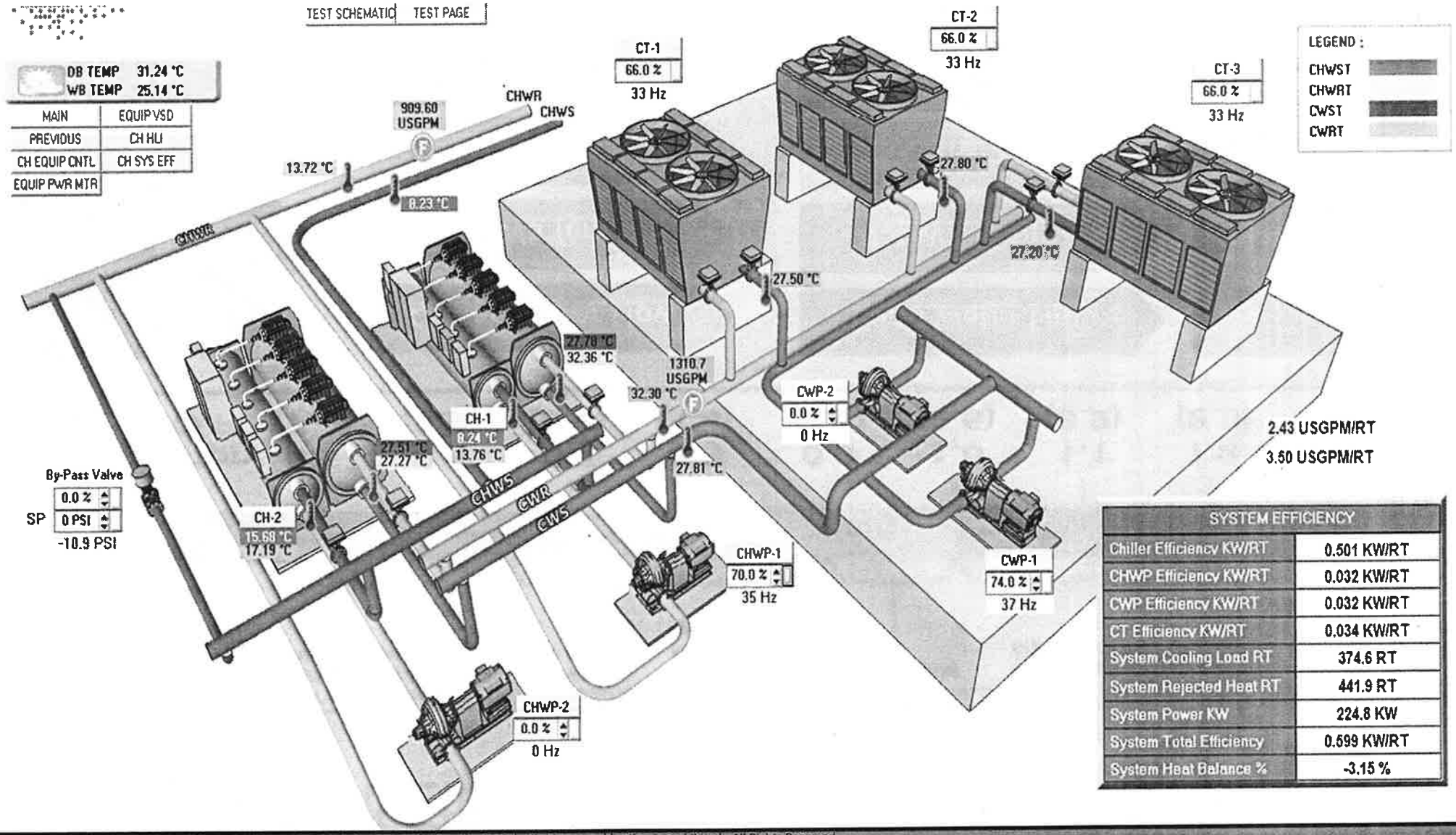

SYSTEM EFFICIENCY	
Chiller Efficiency KW/RT	0.501 KW/RT
CHWP Efficiency KW/RT	0.032 KW/RT
CWP Efficiency KW/RT	0.032 KW/RT
CT Efficiency KW/RT	0.034 KW/RT
System Cooling Load RT	374.6 RT
System Rejected Heat RT	441.9 RT
System Power KW	224.8 KW
System Total Efficiency	0.599 KW/RT
System Heat Balance %	-3.15 %

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Strategy – Plant Efficiency - Visibility

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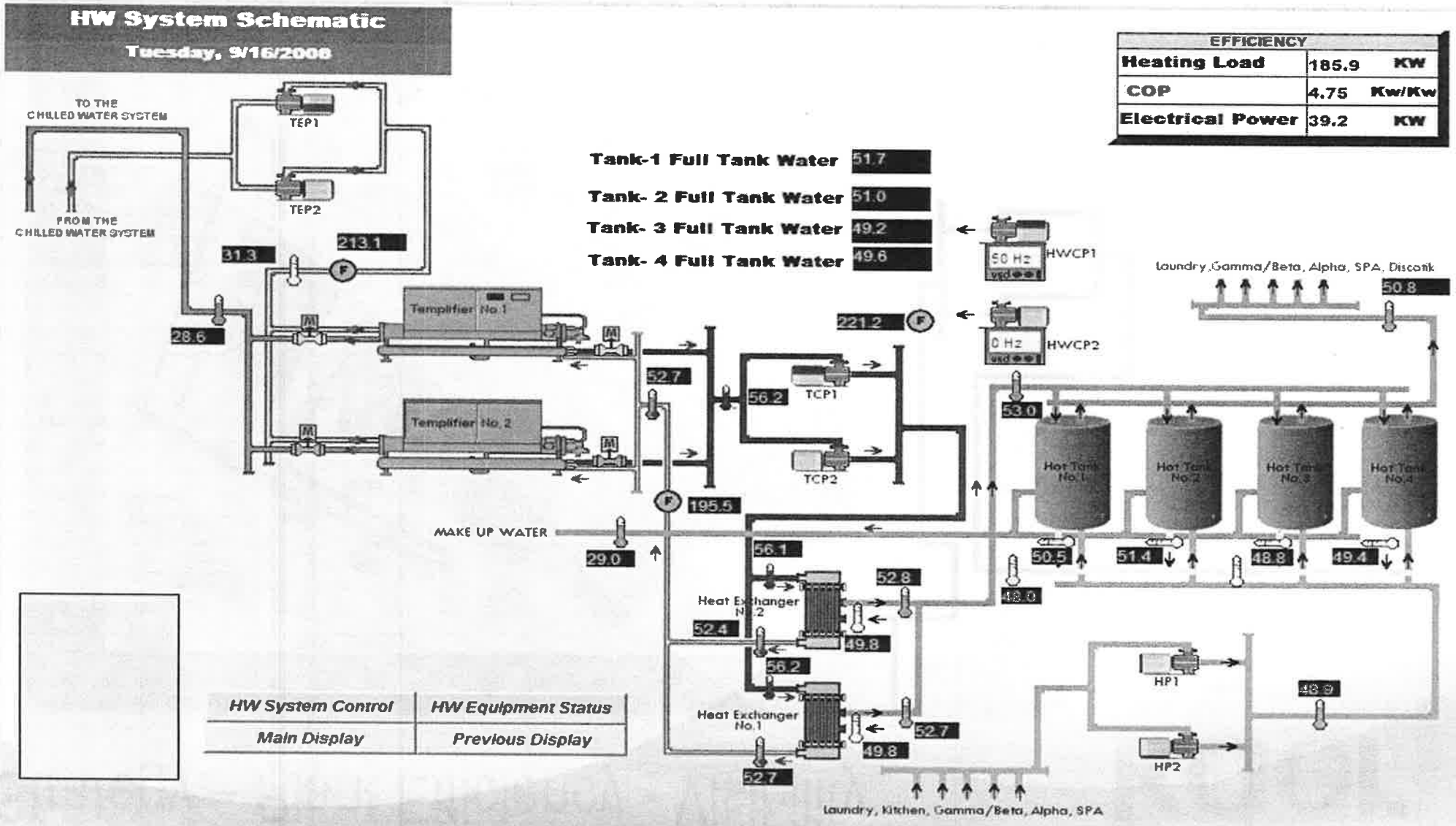

Strategy – Plant Efficiency - Visibility

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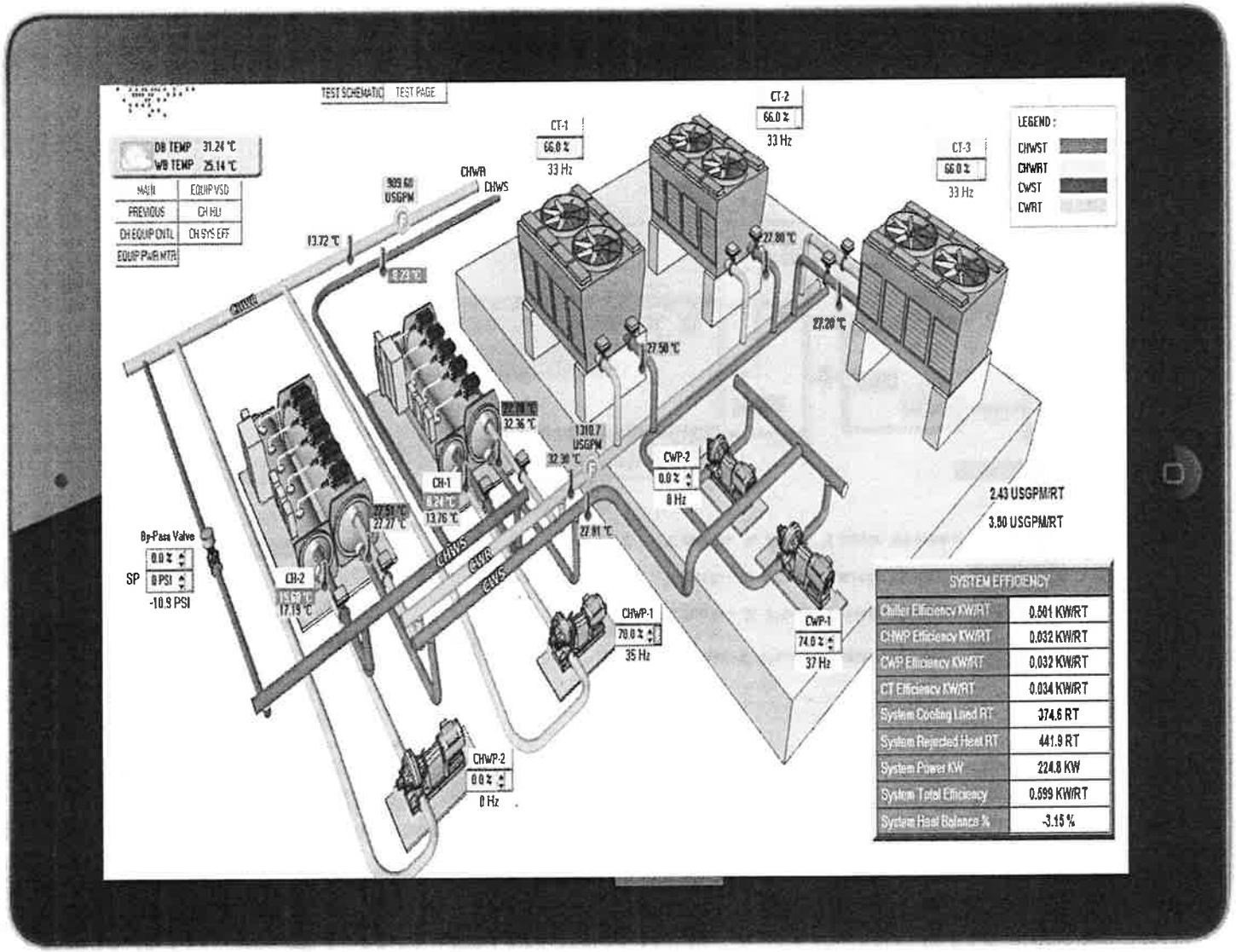

Remote Monitoring

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Strategy – Sustaining The Efficiency

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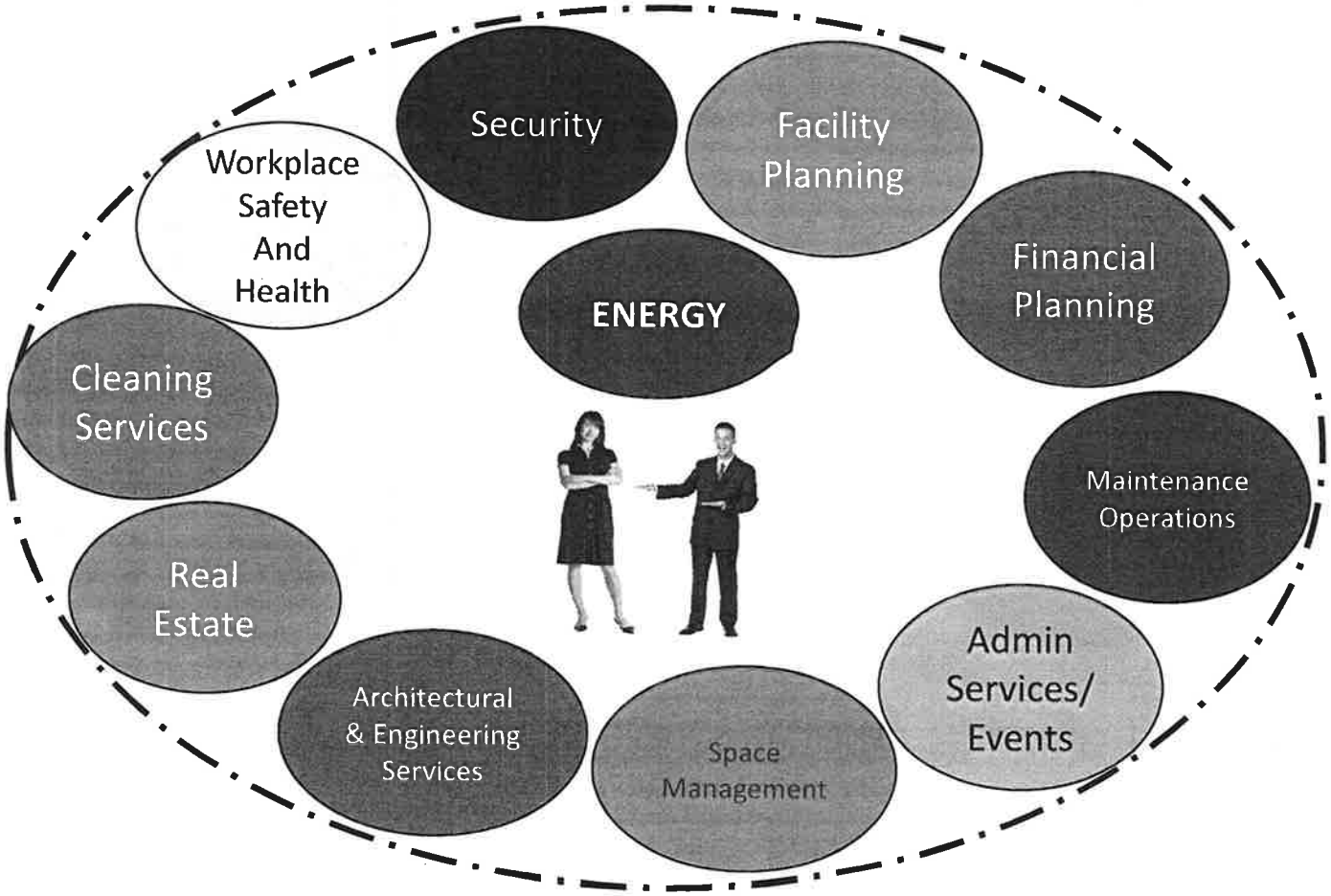
Sustaining The Plant Efficiency/Energy Savings Through The Months Or Years



In Most Cases, Facility Manager Absorb The Additional Responsibility !!!

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Strategy – Sustaining The Efficiency - Structure

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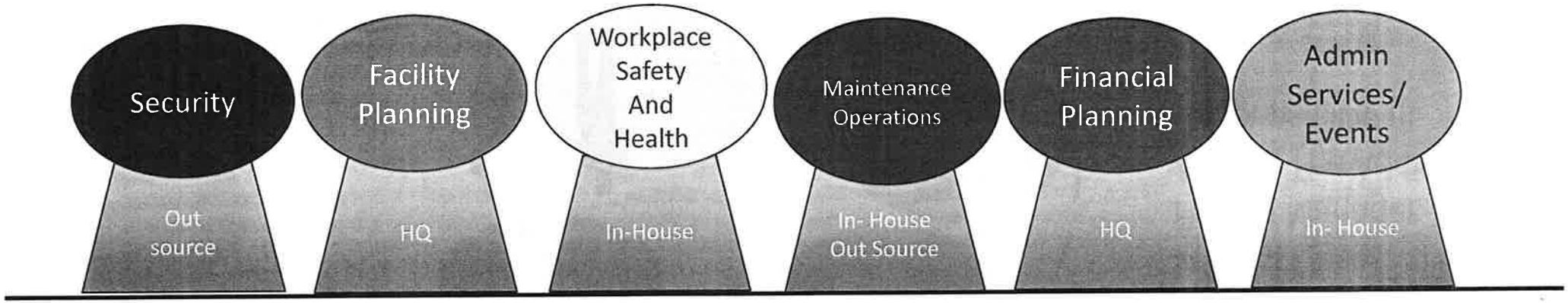
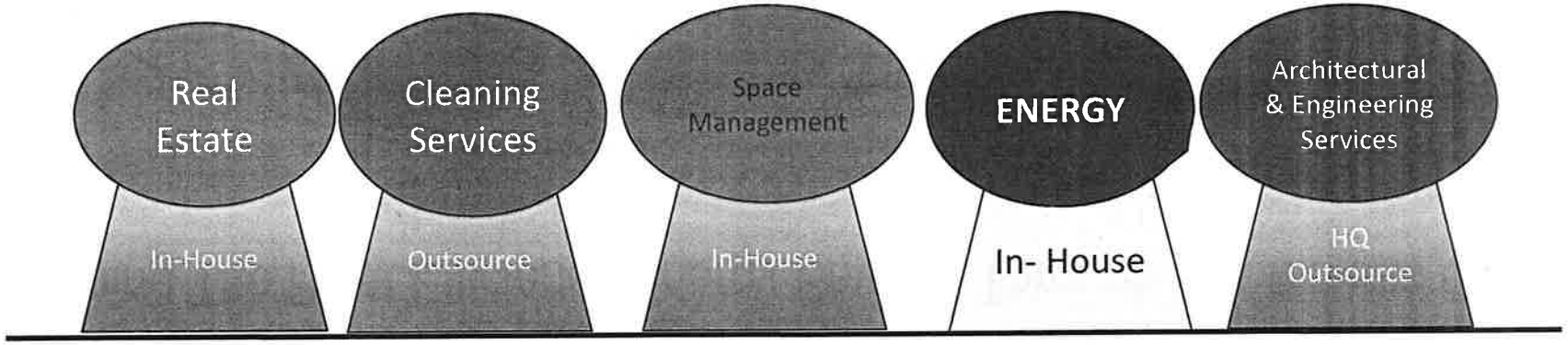
Sustaining The Plant Efficiency/Energy Savings Through The Months Or Years





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Strategy – Sustaining The Efficiency - Structure

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Strategy – Sustaining The Efficiency - Structure

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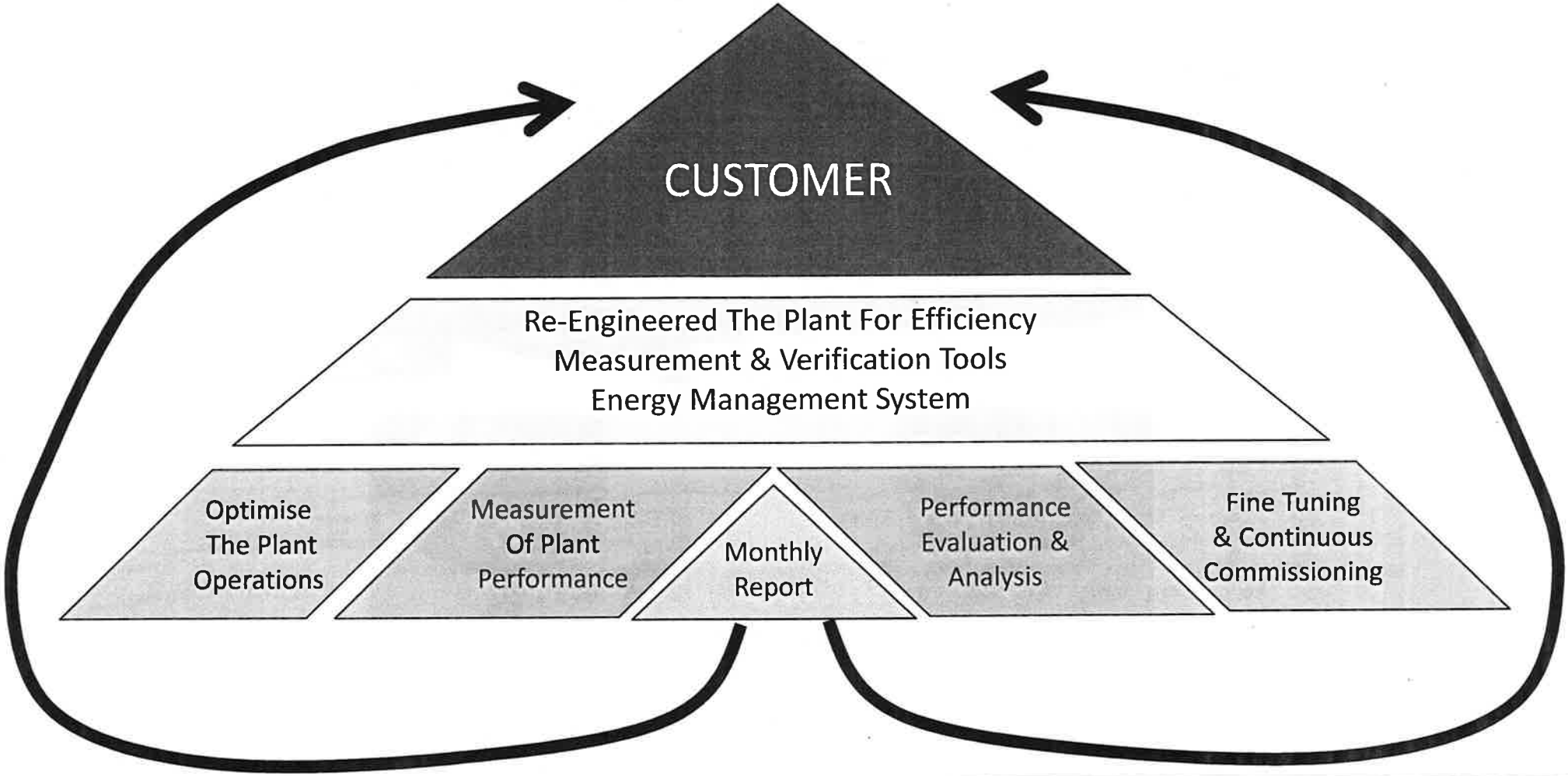

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Strategy – Sustaining The Efficiency - Report

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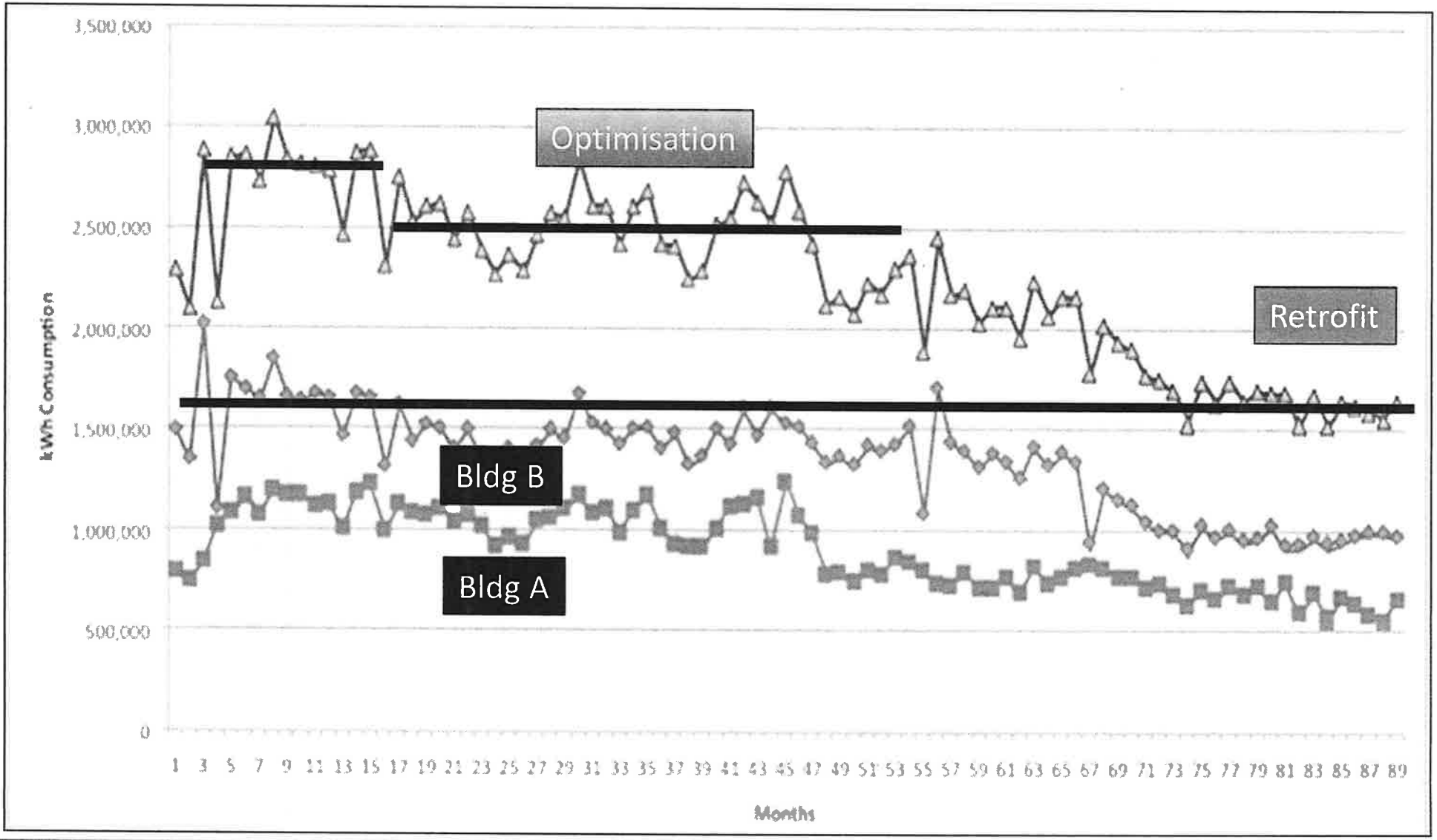

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Strategy – Sustaining The Efficiency - Report

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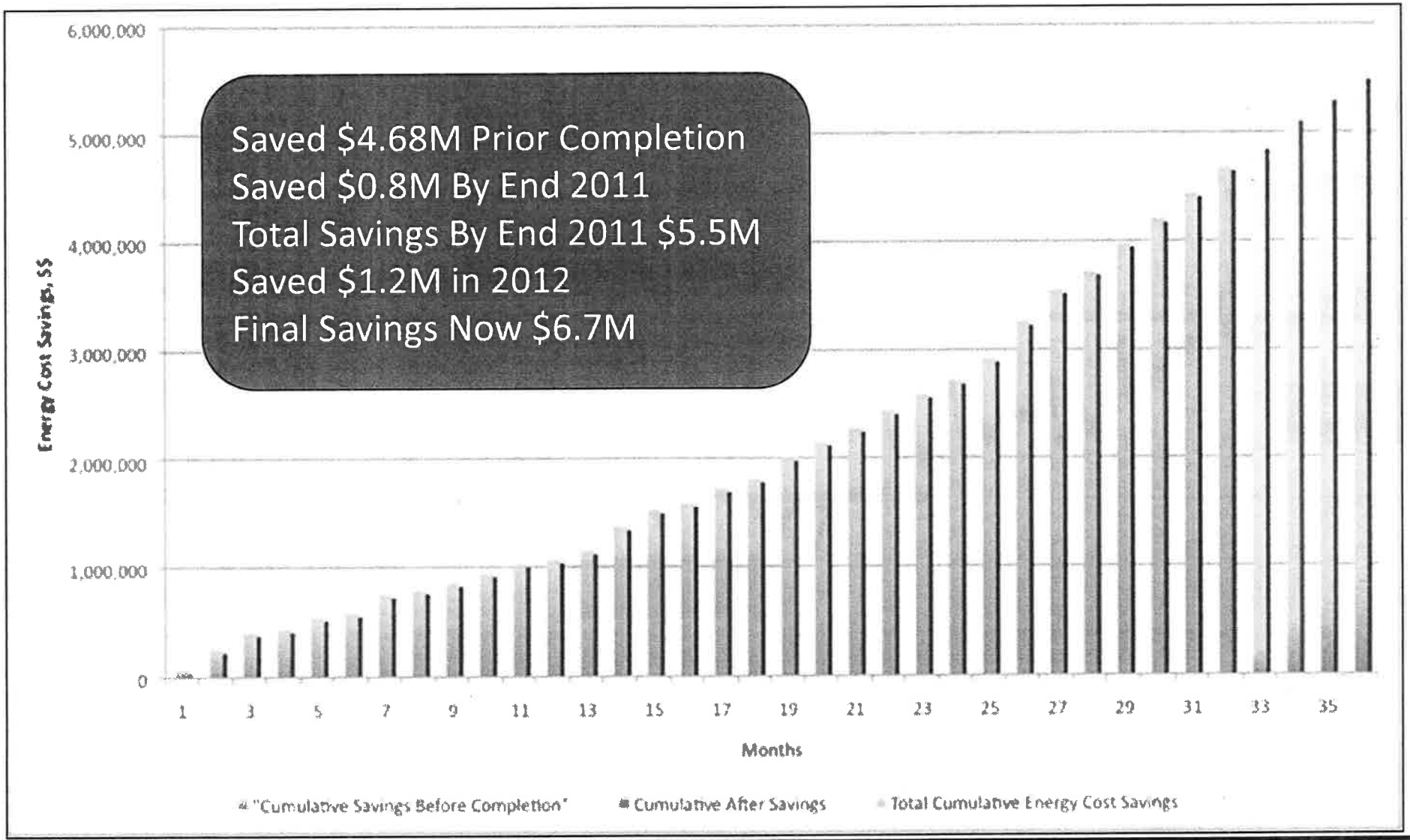

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Conclusion – Energy Management

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- You Do Not Have To Do It Alone
- Manage Your Daily Operations Objectively
- Re-Organise Your Structure Within Your Structure
- Get Support To Provide You With Quality Information
- Deliver The Results With Confidence

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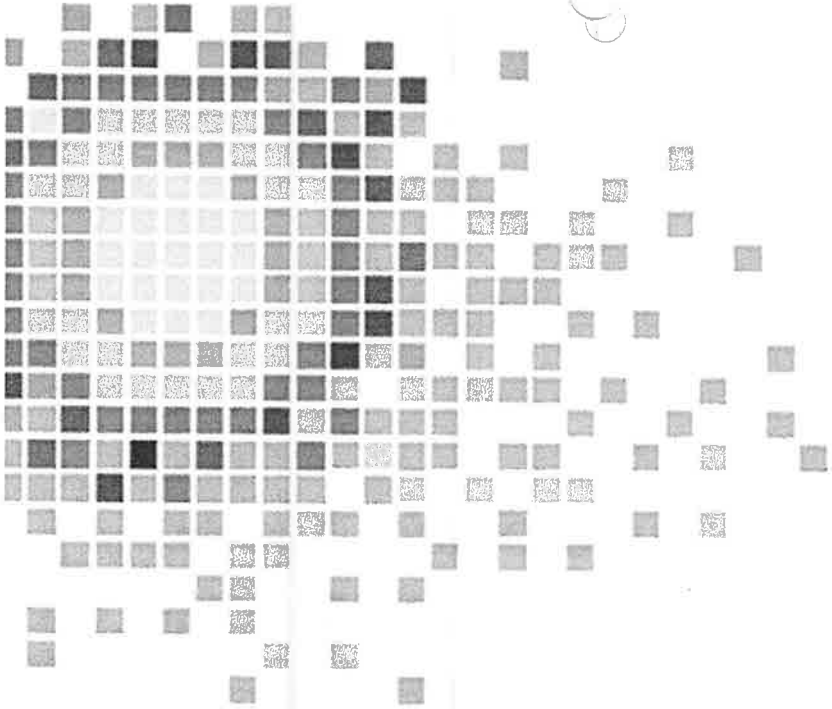

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TOMORROW'S BUILDINGS ENGINEERED TODAY

Energy Audit Report – Level 3 Analysis

Day 2, 2pm – 3.30pm

Case Study 1: Institution Of Higher Learning

Brief Description Of The Facility

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1. GFA : 13,000 m2
2. Used For: Institute Of Higher Learning
3. Population Density: 1,000 students to grow 4,000 students
4. Operation Hours: 8 am to 6 pm
5. Type Of Plant Available: Chilled water plant system
6. Design Space Condition: 23° C ±1° C RH < 70%
7. Ambient Temperature: 32° C RH 75% – 90%

Chiller Details

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Chiller
- Chiller Model 19XR-3536347CNS52
- Starter / VFD ..... Starter - Freestanding
- Refrigerant Type R-134a

Cooler
- Size 35
- Waterbox Type ..... Nozzle-in-Head, 150 psi
- Passes 2
- Nozzle Arrangement ..... D
- Tubing ..... Super E2 (SUPE2), .025 in, Copper
- Fluid Type ..... Fresh Water
- Fouling Factor (hr-sqft-F)/BTU 0.00010

Compressor
- Size 347

Flow Controls
- Float Valve Size 5
- Flasc Orifice 22

Weights
- Total Rigging Weight ..... 14572 lb
- Total Operating Weight ..... 15692 lb
- Refrigerant Weight ..... 710 lb

Condenser
- Size 36
- Waterbox Type ..... Nozzle-in-Head, 150 psi
- Passes 2
- Nozzle Arrangement ..... Will Advise
- Tubing ..... Spike Fin III (SPK3), .025 in, Copper
- Fluid Type ..... Fresh Water
- Fouling Factor (hr-sqft-F)/BTU 0.00025

Motor
- Size ..... CNS
- Line Voltage/Hertz 415-3-50

Output Type	Full Load
Percent Load	100.00
Chiller Capacity	385 Tons
Chiller Input kW	267 kW
Chiller Input Power	0.692 kW/Ton
Cooler	
Entering Temp.	51.96 F
Leaving Temp.	42.00 F
Flow Rate	924.0 gpm
Pressure Drop	42.5 ft wg
Condenser	
Leaving Temp.	96.62 F
Entering Temp.	87.00 F
Flow Rate	1155.0 gpm
Pressure Drop	34.9 ft wg
Motor	
Motor Rated Load Amps	437
Motor OLTA	472
Motor LRYA	1015
Motor LRDA	3174
Max Fuse/CB Amps	800
Min Circuit Ampacity	547

Chiller Details

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Chiller
- Chiller Model 19XR-3536347CNS52
- Starter / VFD ..... Starter - Freestanding
- Refrigerant Type R-134a

Cooler
- Size 35
- Waterbox Type ..... Nozzle-in-Head, 150 psi
- Passes 2
- Nozzle Arrangement ..... D
- Tubing ..... Super E2 (SUPE2), .025 in, Copper
- Fluid Type ..... Fresh Water
- Fouling Factor (hr-sqft-F)/BTU 0.00010

Compressor
- Size 347

Flow Controls
- Float Valve Size 5
- Flasc Orifice 22

Weights
- Total Rigging Weight ..... 14572 lb
- Total Operating Weight ..... 15692 lb
- Refrigerant Weight ..... 710 lb

Condenser
- Size 36
- Waterbox Type ..... Nozzle-in-Head, 150 psi
- Passes 2
- Nozzle Arrangement ..... Will Advise
- Tubing ..... Spike Fin III (SPK3), .025 in, Copper
- Fluid Type ..... Fresh Water
- Fouling Factor (hr-sqft-F)/BTU 0.00025

Motor
- Size ..... CNS
- Line Voltage/Hertz 415-3-50

Output Type	Full Load
Percent Load	100.00
Chiller Capacity	385 Tons
Chiller Input kW	267 kW
Chiller Input Power	0.692 kW/Ton
Cooler	
Entering Temp.	51.96 F
Leaving Temp.	42.00 F
Flow Rate	924.0 gpm
Pressure Drop	42.5 ft wg
Condenser	
Leaving Temp.	96.62 F
Entering Temp.	87.00 F
Flow Rate	1155.0 gpm
Pressure Drop	34.9 ft wg
Motor	
Motor Rated Load Amps	437
Motor OLTA	472
Motor LRYA	1015
Motor LRDA	3174
Max Fuse/CB Amps	800
Min Circuit Ampacity	547

Chiller Details

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Chiller
- Chiller Model 19XR-55574S5DGS52
- Starter / VFD ..... Starter - Freestanding
- Refrigerant Type R-134a

Cooler
- Size 55
- Waterbox Type ..... Nozzle-in-Head, 150 psi
- Passes 2
- Nozzle Arrangement ..... D
- Tubing ..... Super E2 (SUPE2), .025 in, Copper
- Fluid Type ..... Fresh Water
- Fouling Factor (hr-sqft-F)/BTU 0.00010

Compressor
- Size 4S5

Flow Controls
- Float Valve Size 8
- Flasc Orifice 30

Weights
- Total Rigging Weight ..... 22676 lb
- Total Operating Weight ..... 25445 lb
- Refrigerant Weight ..... 1360 lb

Condenser
- Size 57
- Waterbox Type ..... Nozzle-in-Head, 150 psi
- Passes 2
- Nozzle Arrangement ..... Will Advise
- Tubing ..... Spike Fin III (SPK3), .025 in, Copper
- Fluid Type ..... Fresh Water
- Fouling Factor (hr-sqft-F)/BTU 0.00025

Motor
- Size ..... DGS
- Line Voltage/Hertz 415-3-50

Output Type	Full Load
Percent Load	100.00
Chiller Capacity	733 Tons
Chiller Input kW	445 kW
Chiller Input Power	0.607 kW/Ton
Cooler	
Entering Temp.	51.96 F
Leaving Temp.	42.00 F
Flow Rate	1759.2 gpm
Pressure Drop	37.2 ft wg
Condenser	
Leaving Temp.	96.43 F
Entering Temp.	87.00 F
Flow Rate	2199.0 gpm
Pressure Drop	26.2 ft wg
Motor	
Motor Rated Load Amps	730
Motor OLTA	789
Motor LRYA	1522
Motor LRDA	5350
Max Fuse/CB Amps	1600
Min Circuit Ampacity	913

AHU Design Parameters

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AHU No.	Block	Design		Capacity
		CHWS Temp (_C)	CHWR Temp (_C)	kW
AHU-LIB-B/1	Library	5.55	13.33	50
AHU-LIB-B/2	Library	5.55	13.33	47.1
AHU-LIB-1/1	Library	5.55	13.33	144.6
AHU-LIB-1/2	Library	5.55	13.33	120
AHU-LIB-1/3	Library	5.55	13.33	65.8
AHU-LIB-1/4	Library	5.55	13.33	60.5
AHU-LIB-2/1	Library	5.55	13.33	142.9
AHU-LIB-2/2	Library	5.55	13.33	102.7
AHU-LIB-2/3	Library	5.55	13.31	21
AHU-LIB-2/4	Library	5.55	13.31	64
AHU-LIB-2/5	Library	5.55	13.31	51.4
AHU-LIB-3/1	Library	5.55	12.22	170.3
AHU-LIB-3/2	Library	5.55	13.33	169.3
AHU-LIB-4/1	Library	5.55	13.33	186.1
AHU-LIB-4/2	Library	5.55	13.33	194.3
AHU-AMB-L1/1	Admin L1	5.55	13.33	88
AHU-AMB-L1/2	Admin L1	5.55	13.33	51.2
AHU-AMB-L2/1	Admin L2	5.55	13.33	154.5
AHU-AMB-L2/2	Admin L2	5.55	13.33	101.5
AHU-AMB-L2/3	Admin L2	5.55	13.33	98.2
AHU-AMB-L3/1	Admin L3	5.55	13.33	104.8
AHU-AMB-L3/2	Admin L3	5.55	13.33	158.7
AHU-AMB-L3/3	Admin L3	5.55	13.33	84.8
AHU-AMB-L3/4	Admin L3	5.55	13.33	20
AHU-AMB-L3/5	Admin L3	5.55	13.33	50

FCU Design Parameters

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Floor	Unit No.	Served	Total Load	Airflow	Chilled Water	Entering Chilled Water (°F)	Leaving Chilled water (°F)	Fan Motor	
			TONS	CFM	GPM			kW	FLA
Level 1	FCU-BUS-1-1	Classroom 1/1	7.2	1773	12.43	42	56	1.47	8.6
	FCU-BUS-1-2	Classroom 1/2	7.1	1677	12.17	42	56	1.47	8.6
	FCU-BUS-1-3	Classroom 1/3	6.6	1561	11.33	42	56	1.43	8.6
	FCU-BUS-1-4	Classroom 1/4	6.8	1630	11.66	42	56	1.43	8.6
	FCU-BUS-1-5	Classroom 1/5	6.6	1569	11.38	42	56	1.43	8.6
	FCU-BUS-1-6	Classroom 1/6	5.8	1448	9.98	42	56	1.43	8.6
	FCU-BUS-1-7	Classroom 1/7	6.1	1440	10.45	42	56	1.43	8.6
	FCU-BUS-1-8	Classroom 1/8	7.1	1667	12.17	42	56	1.47	8.6
	FCU-BUS-1-9	Classroom 1/9	7.3	1800	12.55	42	56	1.47	8.6
	FCU-BUS-1-10	Classroom 1/10	6.6	1568	11.37	42	56	1.43	8.6
	FCU-BUS-1-11	Classroom 1/11	6.6	1569	11.38	42	56	1.43	8.6
	FCU-BUS-1-12	Classroom 1/12	6.8	1610	11.66	42	56	1.43	8.6
	FCU-BUS-1-13	IT Room	0.8	385	1.71	42	56	0.03	0.18
Level 2	FCU-BUS-2-1	Classroom 2/1	7.2	1773	12.43	42	56	1.47	8.6
	FCU-BUS-2-2	Classroom 2/2	7.1	1677	12.17	42	56	1.47	8.6
	FCU-BUS-2-3	Classroom 2/3	6.6	1561	11.33	42	56	1.43	8.6
	FCU-BUS-2-4	Classroom 2/4	6.8	1630	11.66	42	56	1.43	8.6
	FCU-BUS-2-5	Classroom 2/5	6.6	1569	11.38	42	56	1.43	8.6
	FCU-BUS-2-6	Classroom 2/6	5.8	1448	9.98	42	56	1.43	8.6
	FCU-BUS-2-7	Classroom 2/7	6.1	1440	10.45	42	56	1.43	8.6
	FCU-BUS-2-8	Classroom 2/8	7.1	1667	12.17	42	56	1.47	8.6
	FCU-BUS-2-9	Classroom 2/9	7.3	1800	12.55	42	56	1.47	8.6
	FCU-BUS-2-10	Classroom 2/10	6.6	1568	11.38	42	56	1.43	8.6
	FCU-BUS-2-11	Classroom 2/11	6.6	1569	11.38	42	56	1.43	8.6
	FCU-BUS-2-12	Classroom 2/12	6.8	1610	11.27	42	56	1.43	8.6
	FCU-BUS-2-13	IT Room	0.8	385	1.38	42	56	0.03	0.18

System Designed Based On A Lo-Flow System

Current Energy Usage

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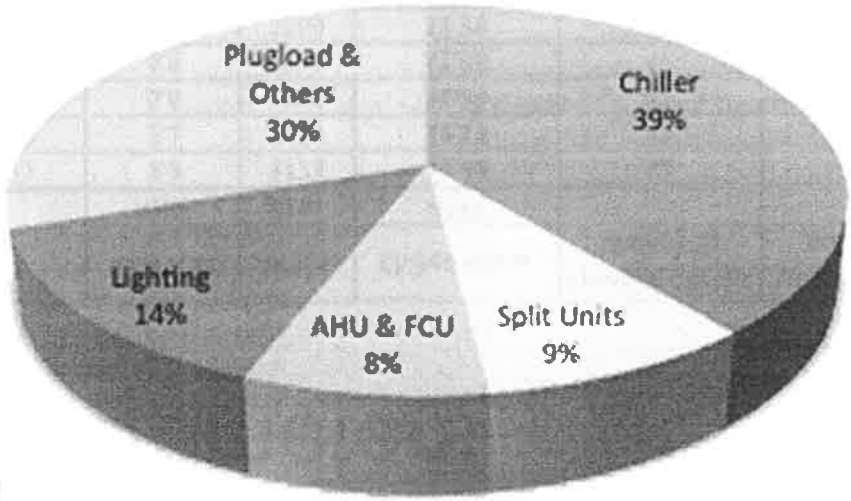
Month	kWh consumption			Max. Demand			Total
Month	Peak	Rate	S$	MD	S$	S$	S$
Sep-12	126,005	0.288	36,289.44	920	23.93	**22,015.60**	58,305.04
Oct-12	445,991	0.288	128,445.41	1,000	23.93	**23,930.00**	152,375.41
Nov-12	261,755	0.288	75,385.44	620	23.93	**14,841.39**	90,226.83
Dec-12	305,036	0.288	87,850.37	978	23.93	**23,403.54**	111,253.91
Jan-13	270,837	0.288	78,001.06	994	23.93	**23,786.42**	101,787.48
Feb-13	236,850	0.288	68,212.80	990	23.93	**23,690.70**	91,903.50
Mar-13	278,522	0.288	80,214.34	984	23.93	**23,547.12**	103,761.46
Apr-13	278,834	0.288	80,304.19	949	23.93	**22,709.57**	103,013.76
May-13	281,306	0.288	81,016.13	928	23.93	**22,207.04**	103,223.17
Jun-13	285,386	0.312	89,040.43	947	25.90	**24,527.30**	113,567.73
Jul-13	303,434	0.312	94,671.41	1,019	25.90	**26,392.10**	121,063.51
Aug-13	311,378	0.312	97,149.94	1,046	25.90	**27,091.40**	124,241.34
Average	**282,111**		**996,581**	**948**		**23,179**	**106,227**
Total	**3,385,334**		**996,581**	**11,375**		**278,142**	**1,274,723**



Energy Usage Benchmarking

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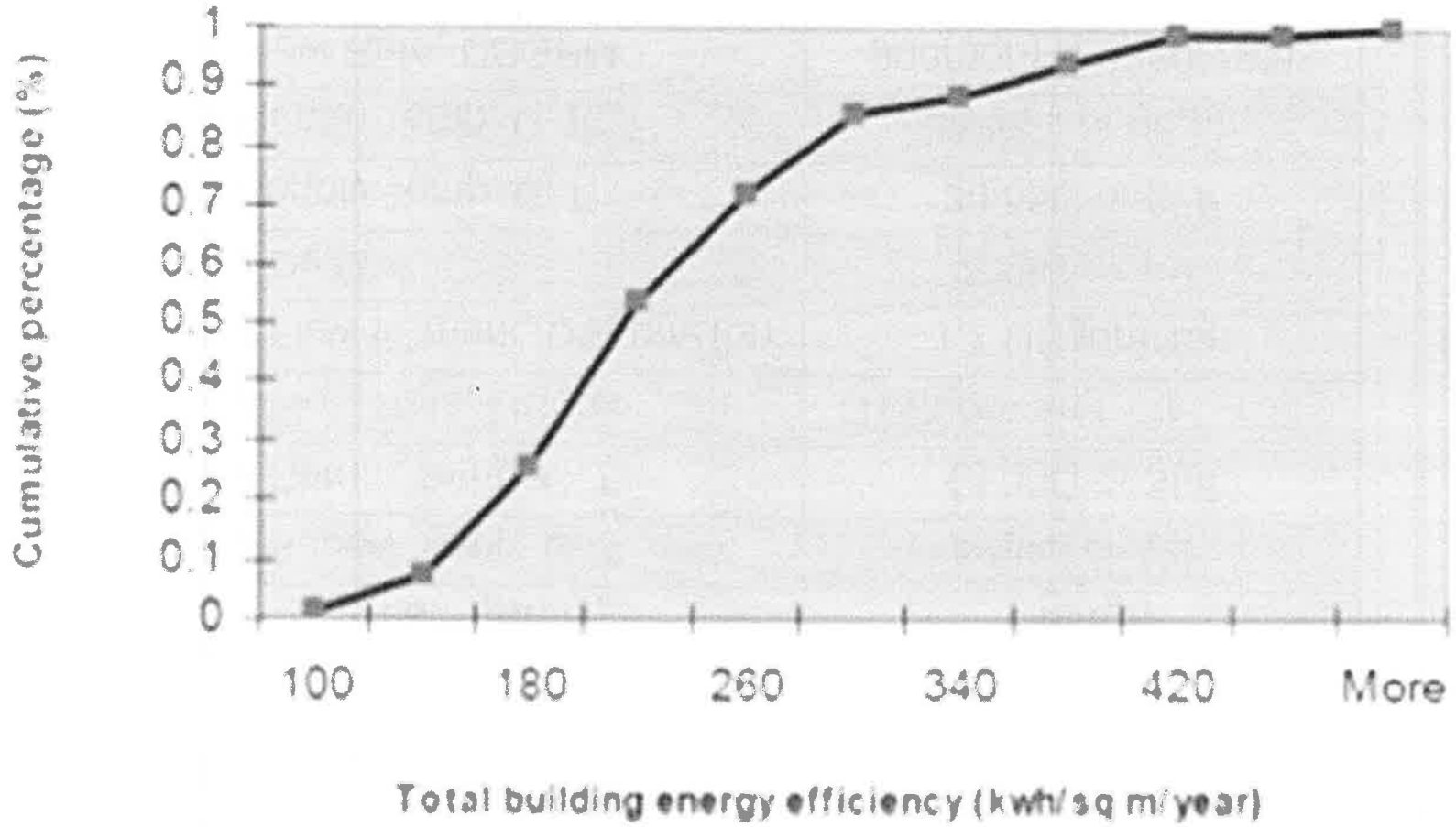
Actual Building : xxx ft^2/ RT
Actual Cooling Load : xxx RT



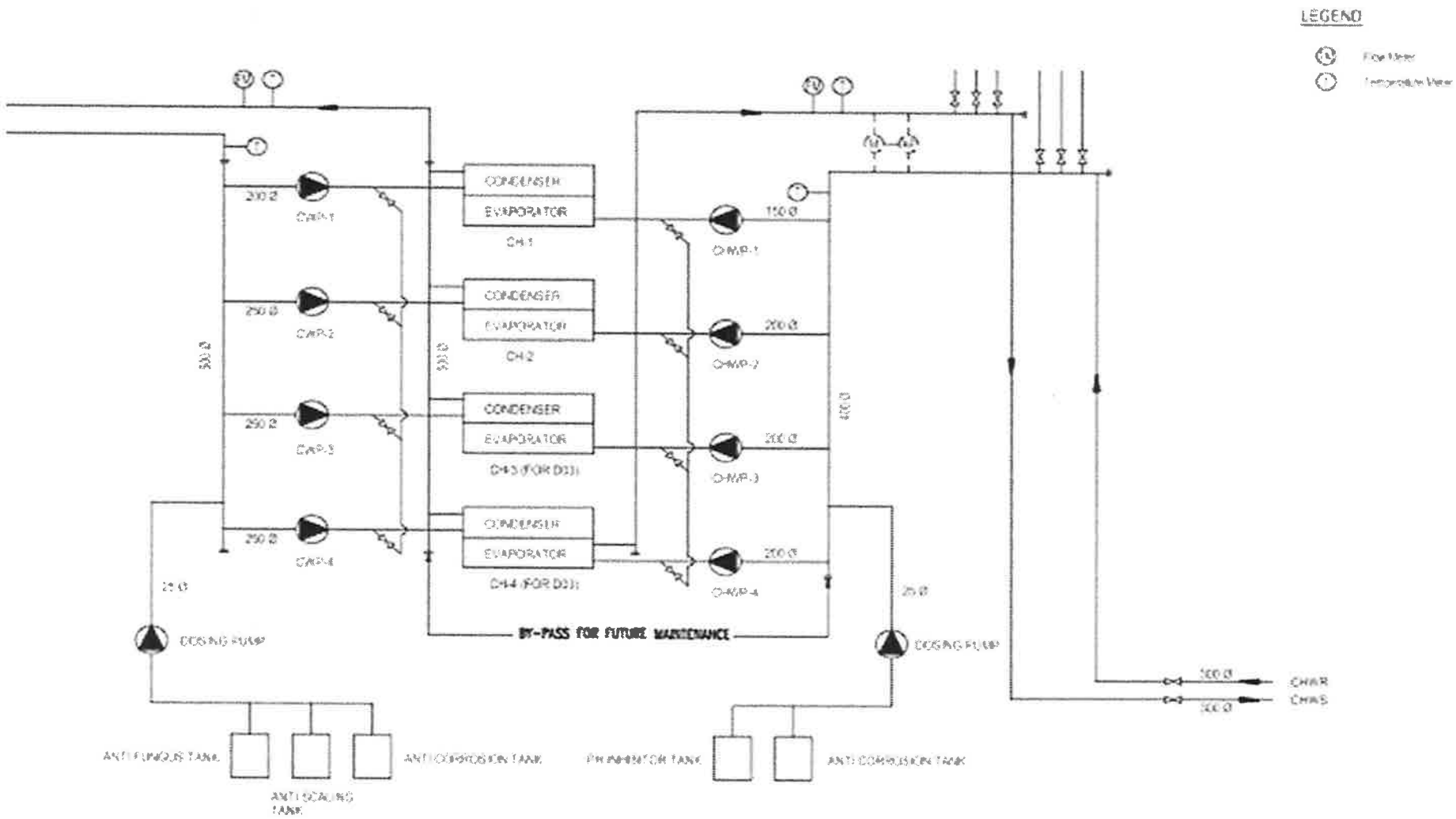
CHW Plant System Design

kaer

Description	Design
CHW Supply Temp, C, F	5.55C or 42F
CHW Return Temp, C, F	13.33C or 56F
CHW Flow Rate, USgpm	515(300) and 1257(733)
CHW Flow B' mark, USgpm/Ton	1.7 USgpm/Ton
CHW Delta T	7.78C or 14F
CW Supply Temp, C, F	30.55C or 87F
CW Return Temp, C, F	35.83C or 96.5F
CW Flow Rate, USGPM	900(300) & 2220(733)
CW Flow B' mark	3 USgpm/Ton
CW Delta T	5.28C or 9F
FCU CHWS/R Temp, C	5.55C or 42F
AHU CHW/R Temp, C	13.33C or 56F
FCU/AHU CHW Flow B' mark	1.7 USgpm/Ton

CHW Plant Room Schematic

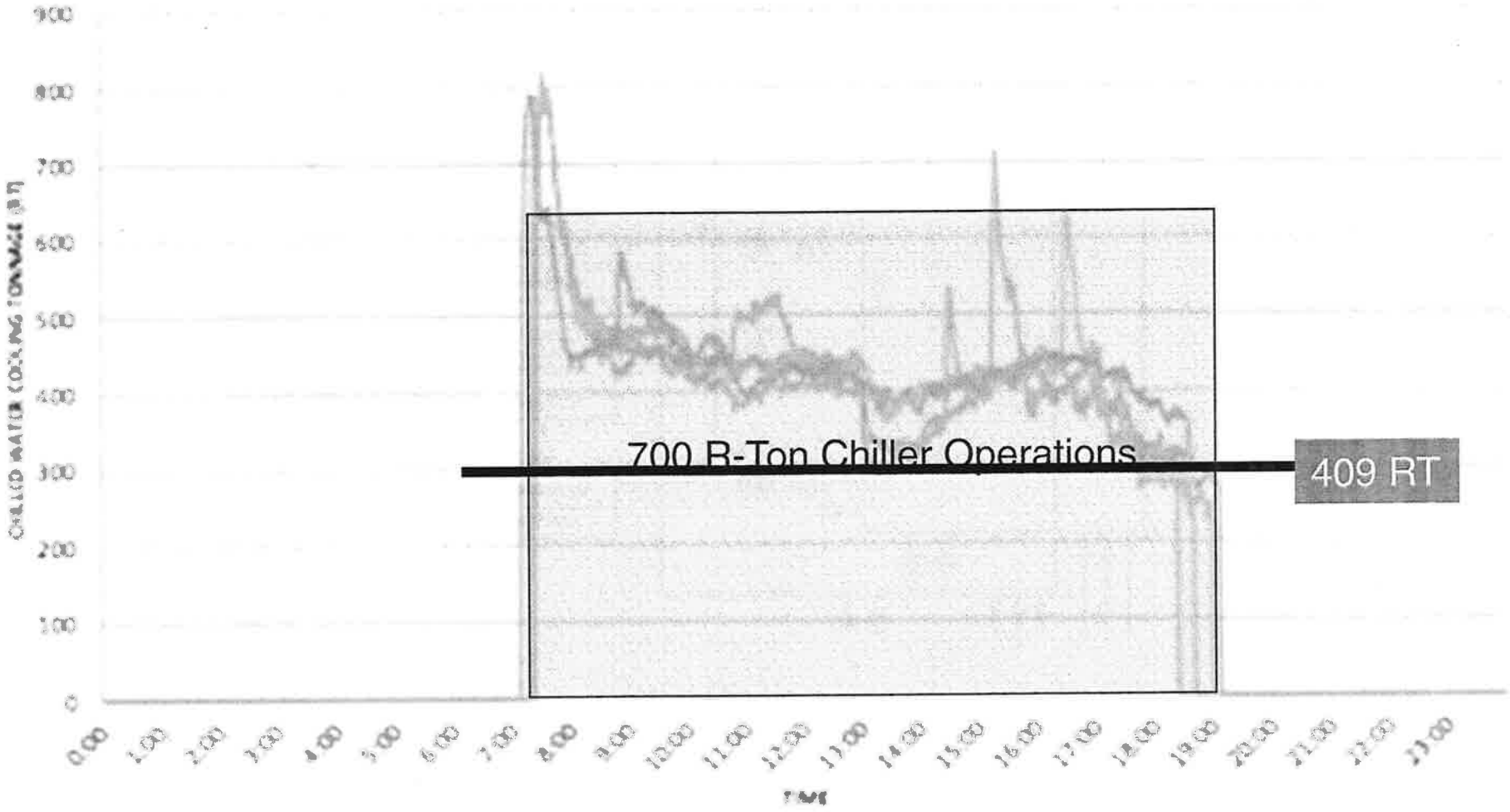
kaer



CHILLER PLANT DIAGRAMMATIC LAYOUT
(Proposed Instrumentation Location)
N.T.S.

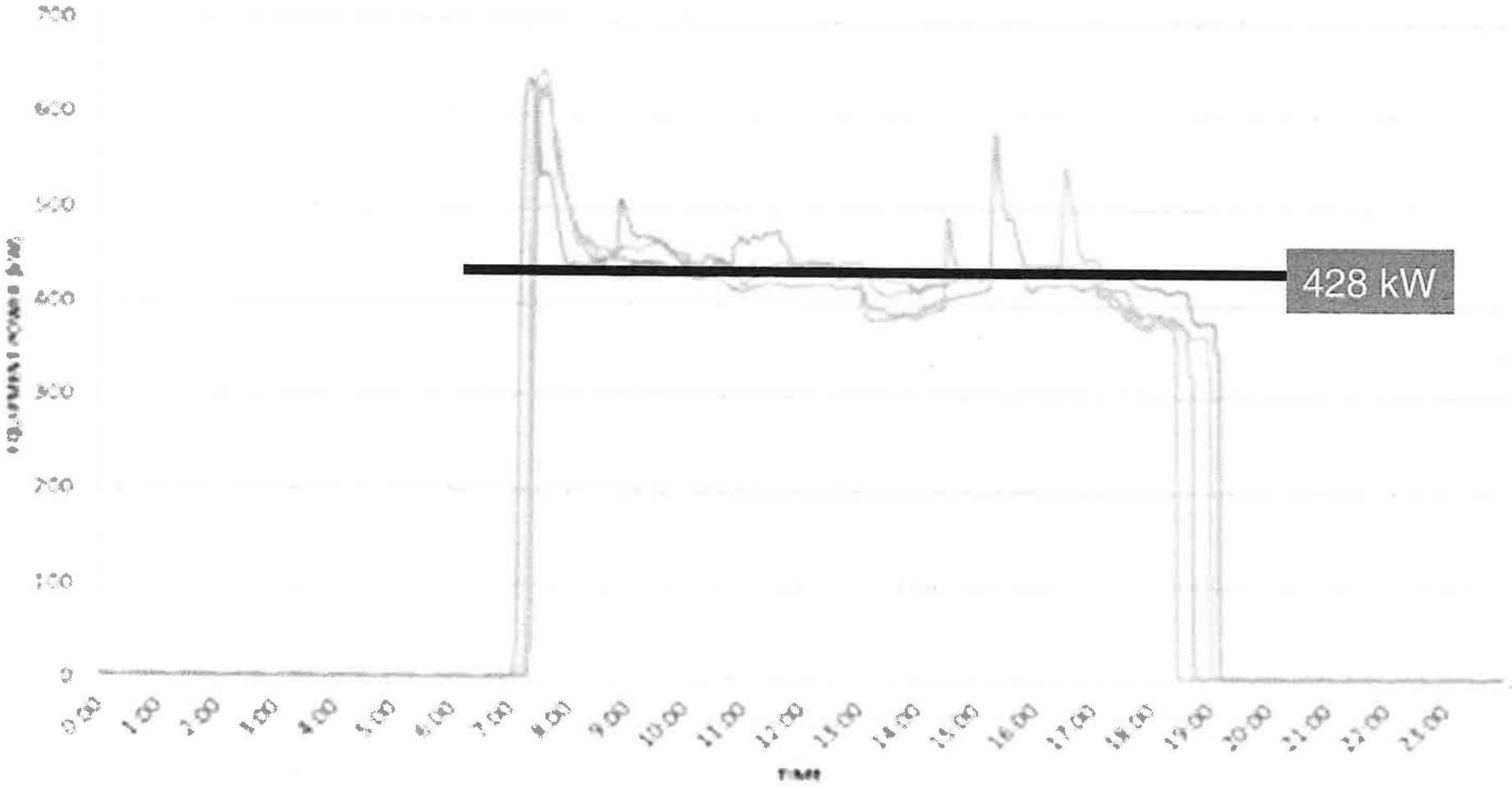
Cooling Load Profile – Ref-Ton

kaer



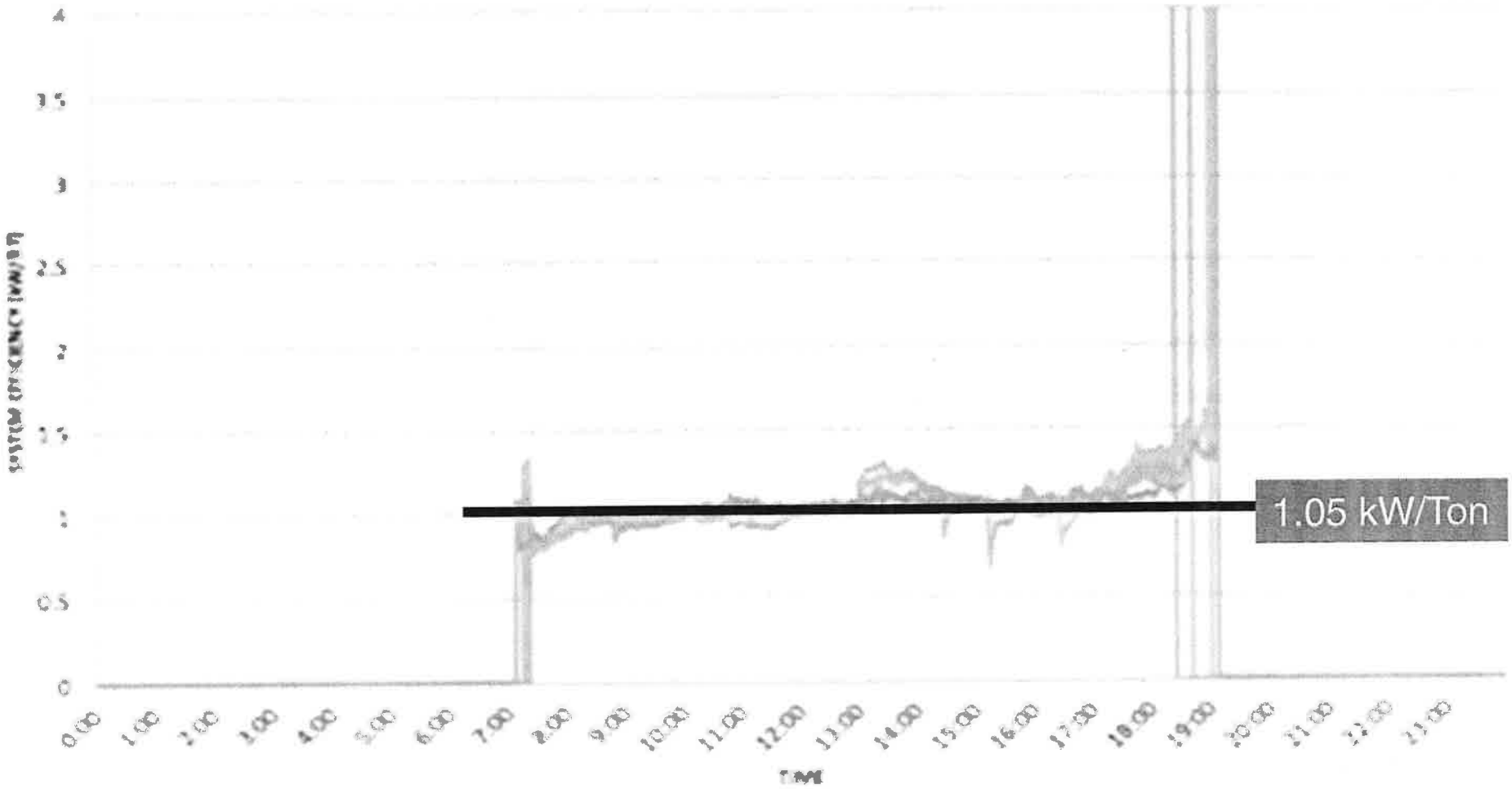
Chilled Water Plant System Power

kaer



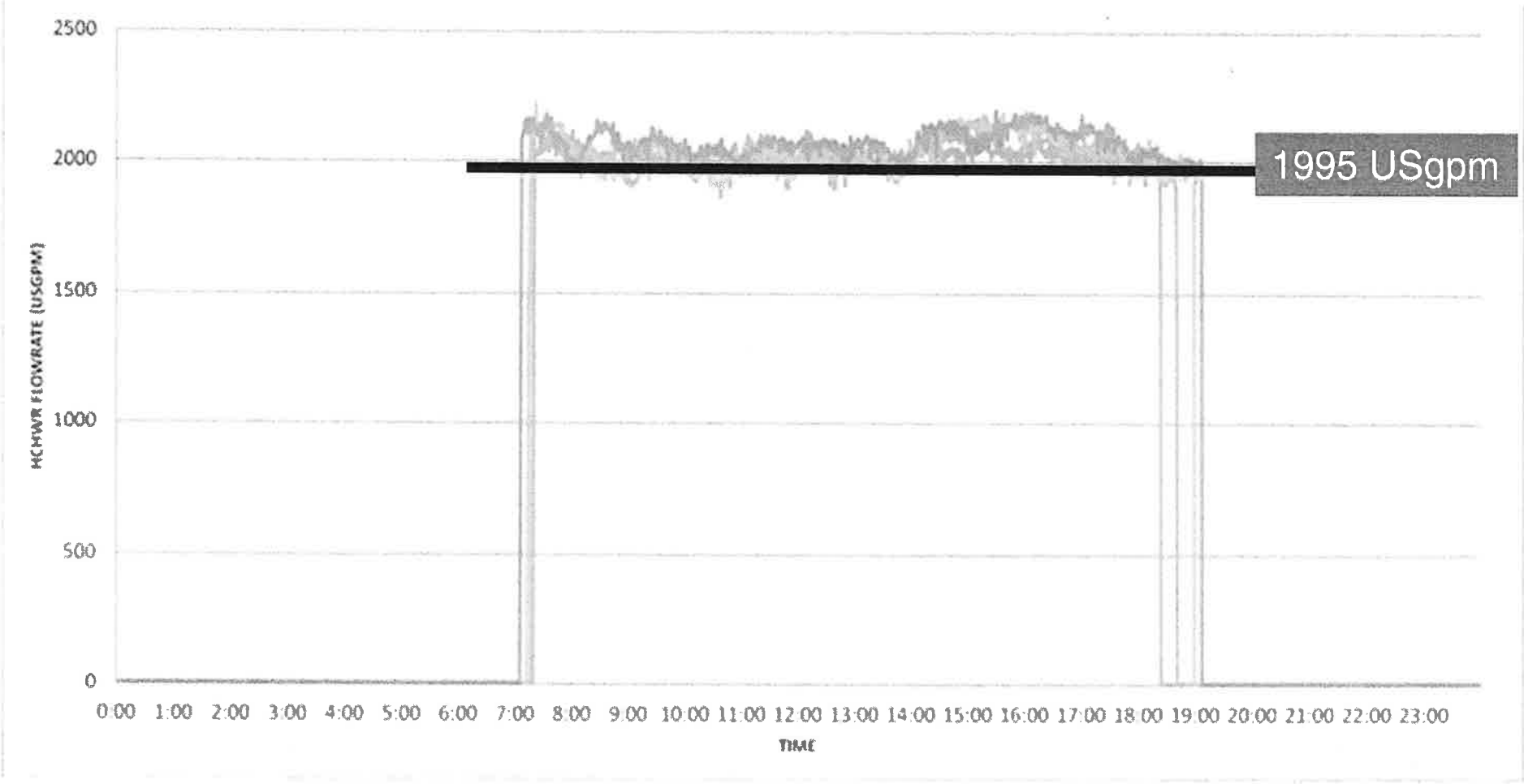
Chilled Water Plant System Efficiency

kaer



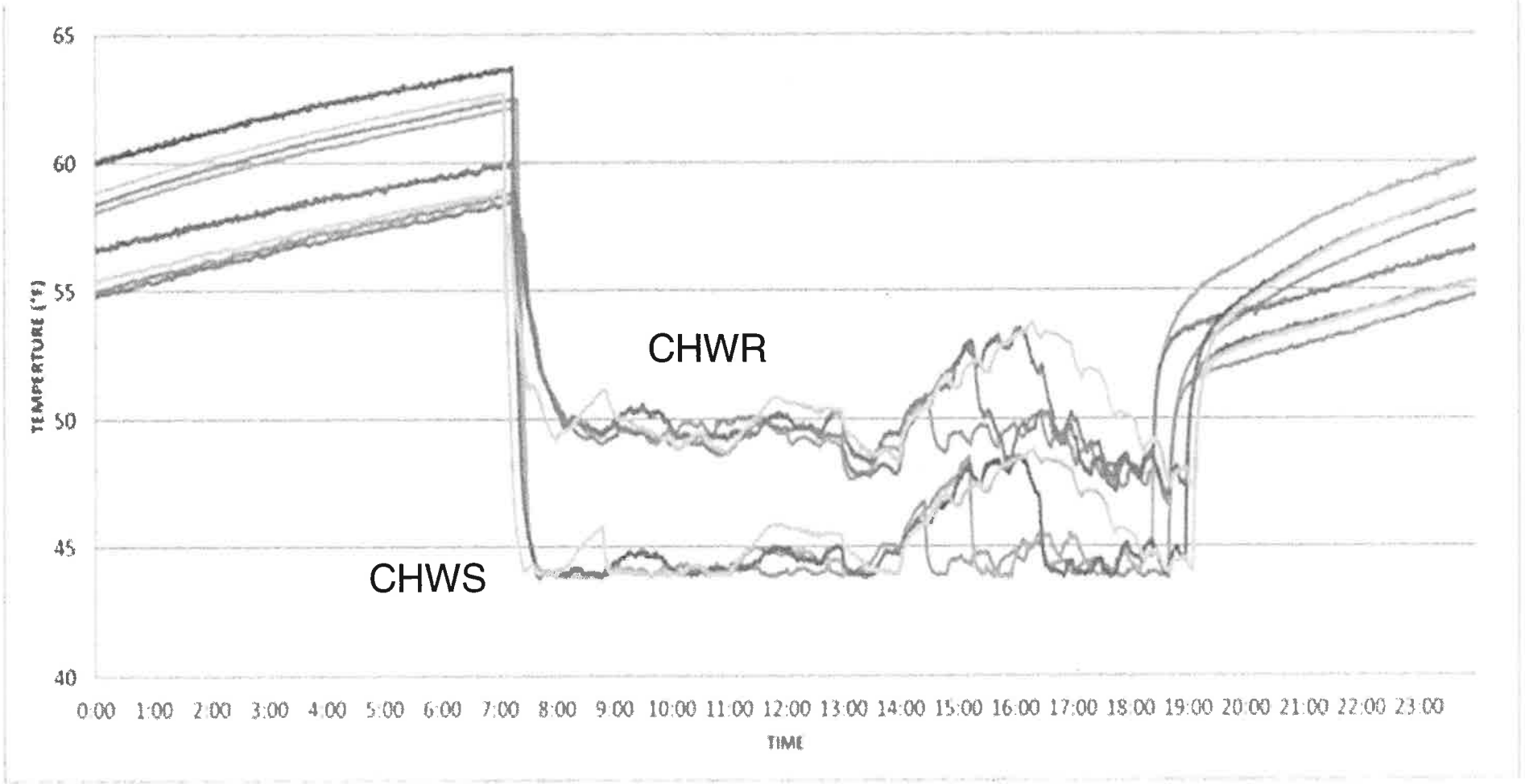
Chilled Water Flow Rate, USgpm

kaer



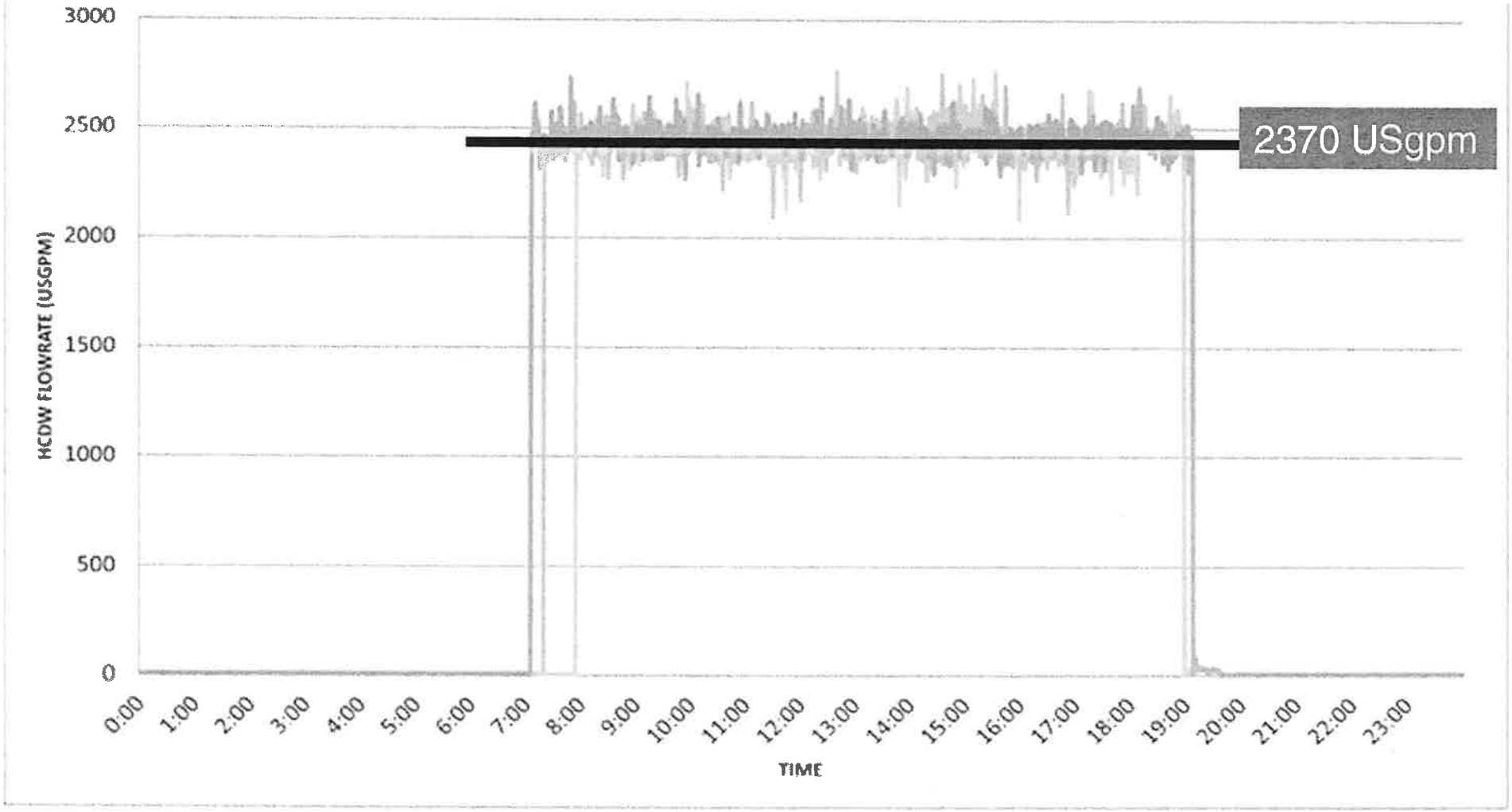
Header - Chilled Water Temperature

kaer



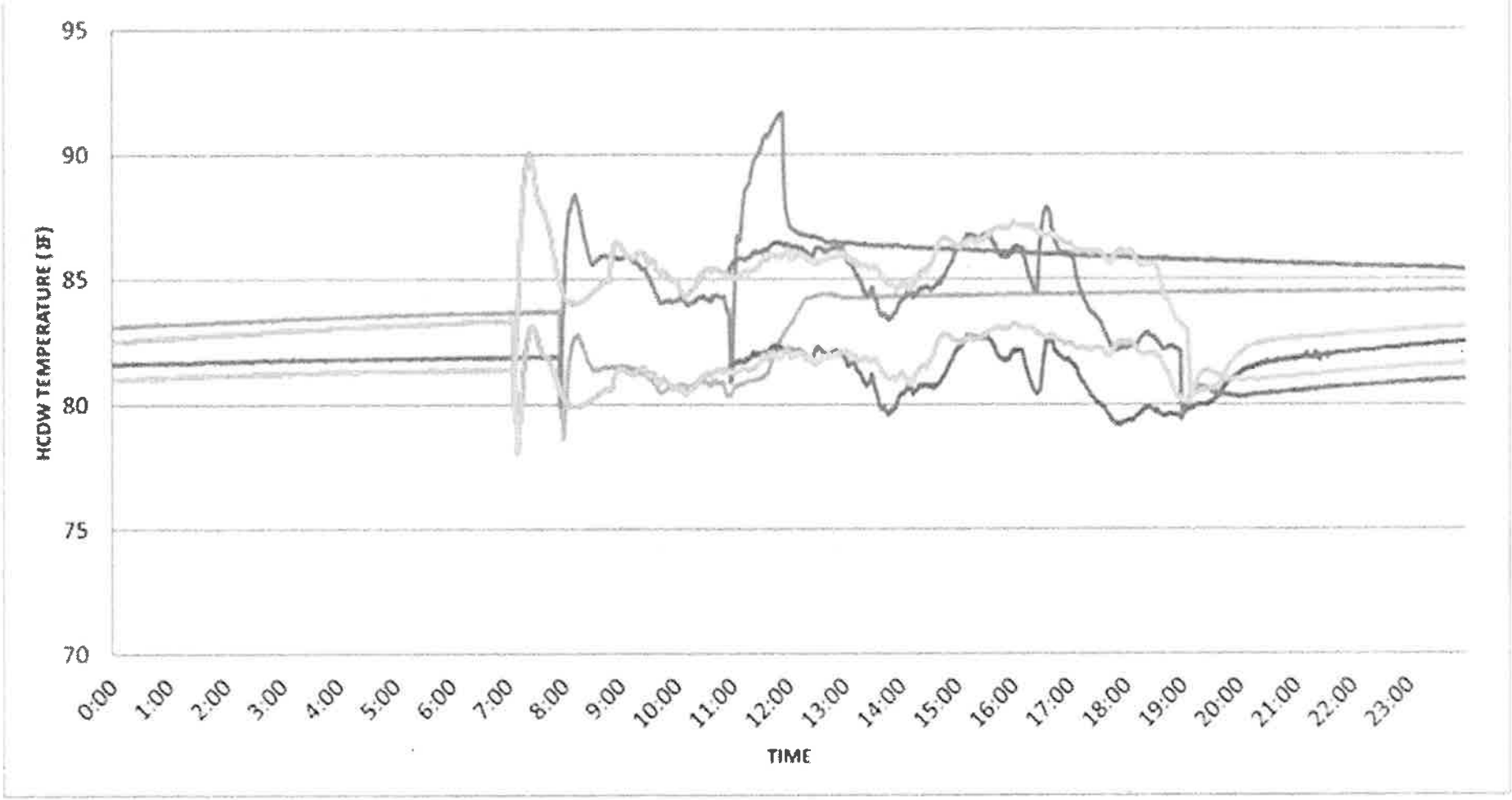
Condenser Water Flow Rate, USgpm

kaer



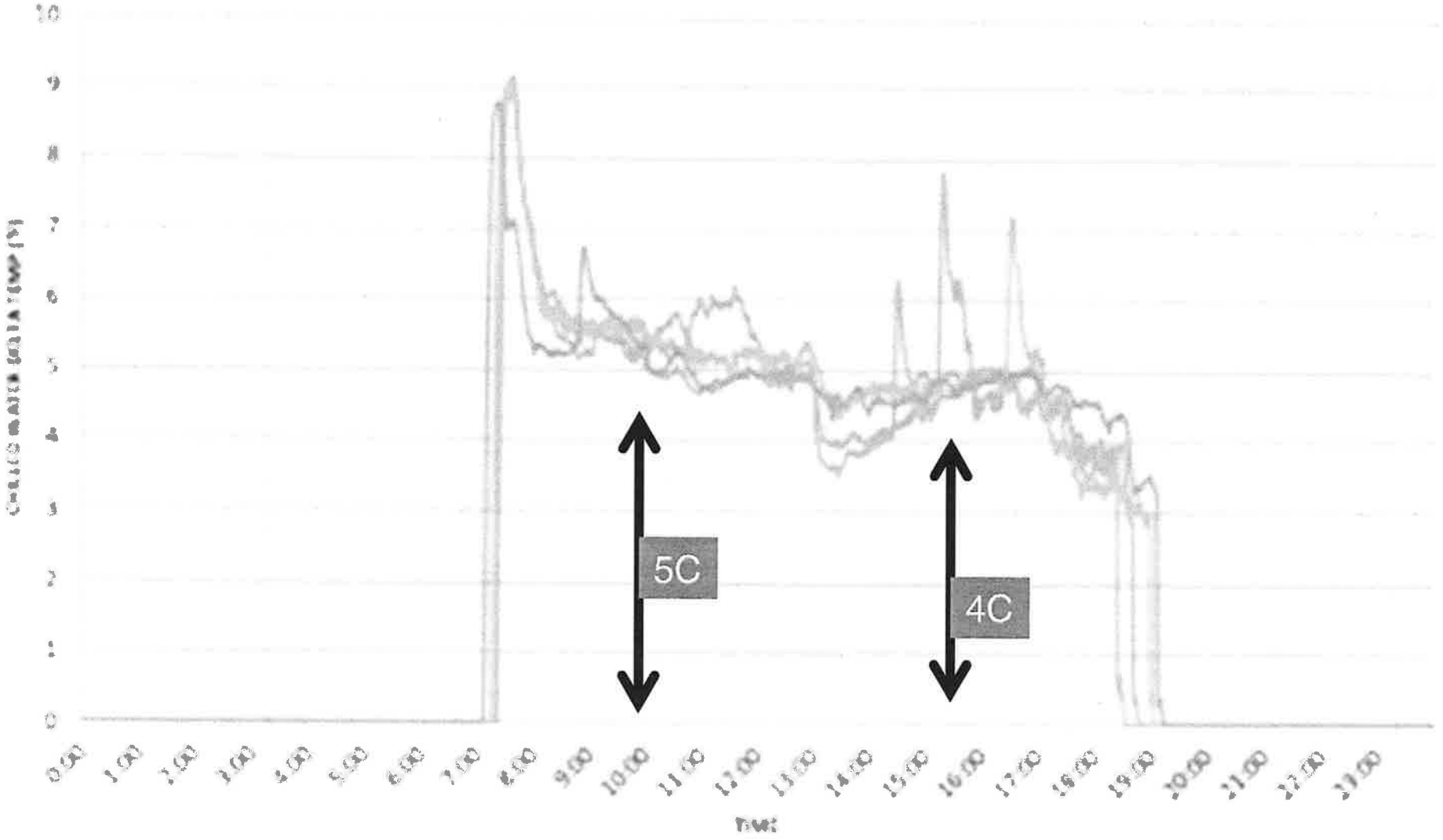
Condenser Water Supply & Return

kaer



Header – CHW Delta Temp

kaer



CHW Plant System Design Vs Actual

kaer

Description	Design	Actual Ops
CHW Supply Temp, C, F	5.55C or 42F	44F
CHW Return Temp, C, F	13.33C or 56F	49F
CHW Flow Rate, USgpm	515(300) and 1257(733)	1995(2 x CHWP)
CHW Flow B' mark, USgpm/Ton	1.7 USgpm/Ton	2.72(733) – 4.9(409)
CHW Delta T	7.78C or 14F	5F
CW Supply Temp, C, F	30.55C or 87F	82
CW Return Temp, C, F	35.83C or 96.5F	85.6
CW Flow Rate, USGPM	900(300) & 2220(733)	2370
CW Flow B' mark	3 USgpm/Ton	3.2(733) – 5.8(409)
CW Delta T	5.28C or 9F	3.6
FCU CHWS/R Temp, C	5.55C or 42F	45F
AHU CHW/R Temp, C	13.33C or 56F	52F
FCU/AHU CHW Delta T	14F	7F

AHU 1 - CHWS & R Temp

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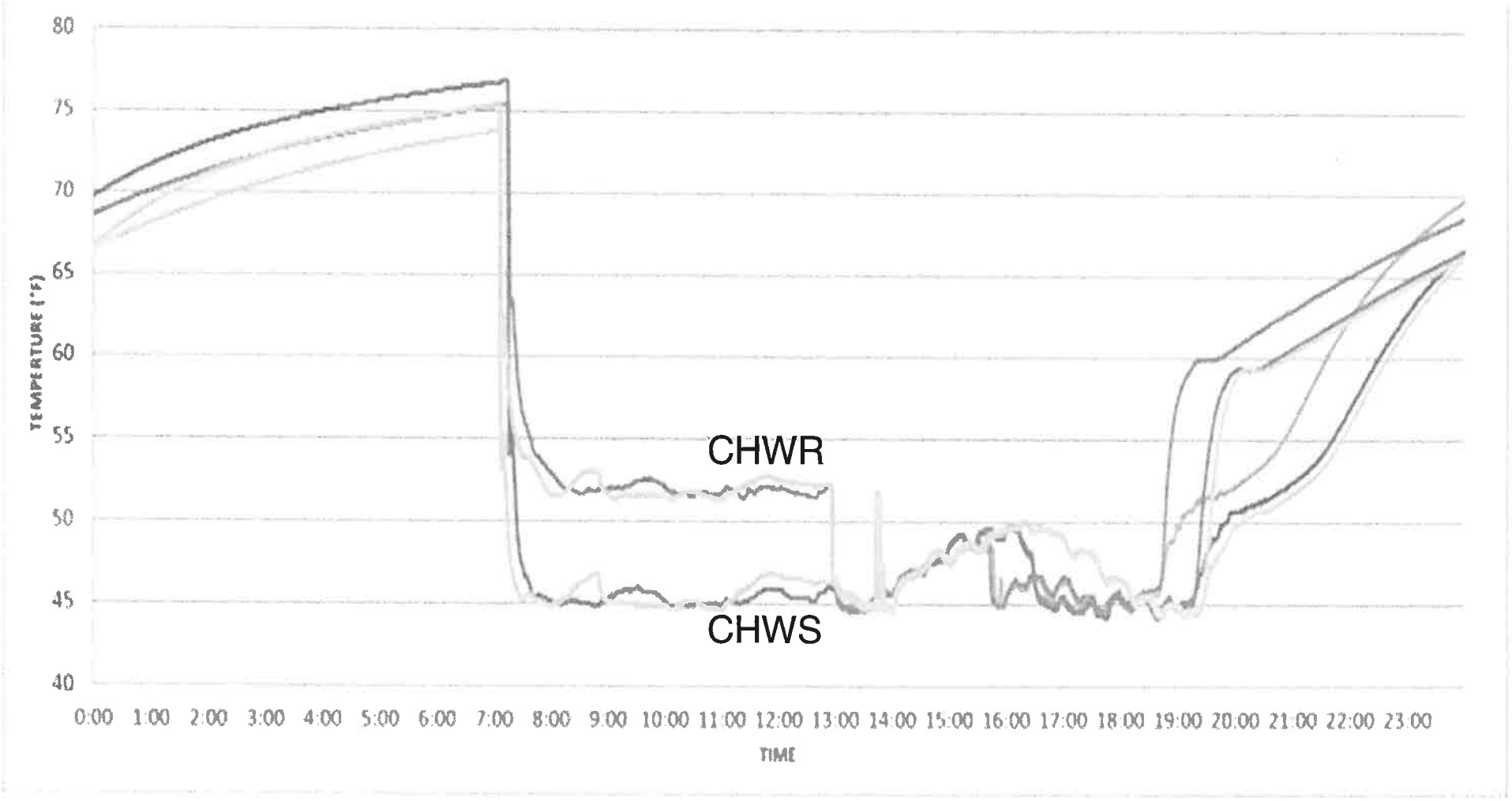
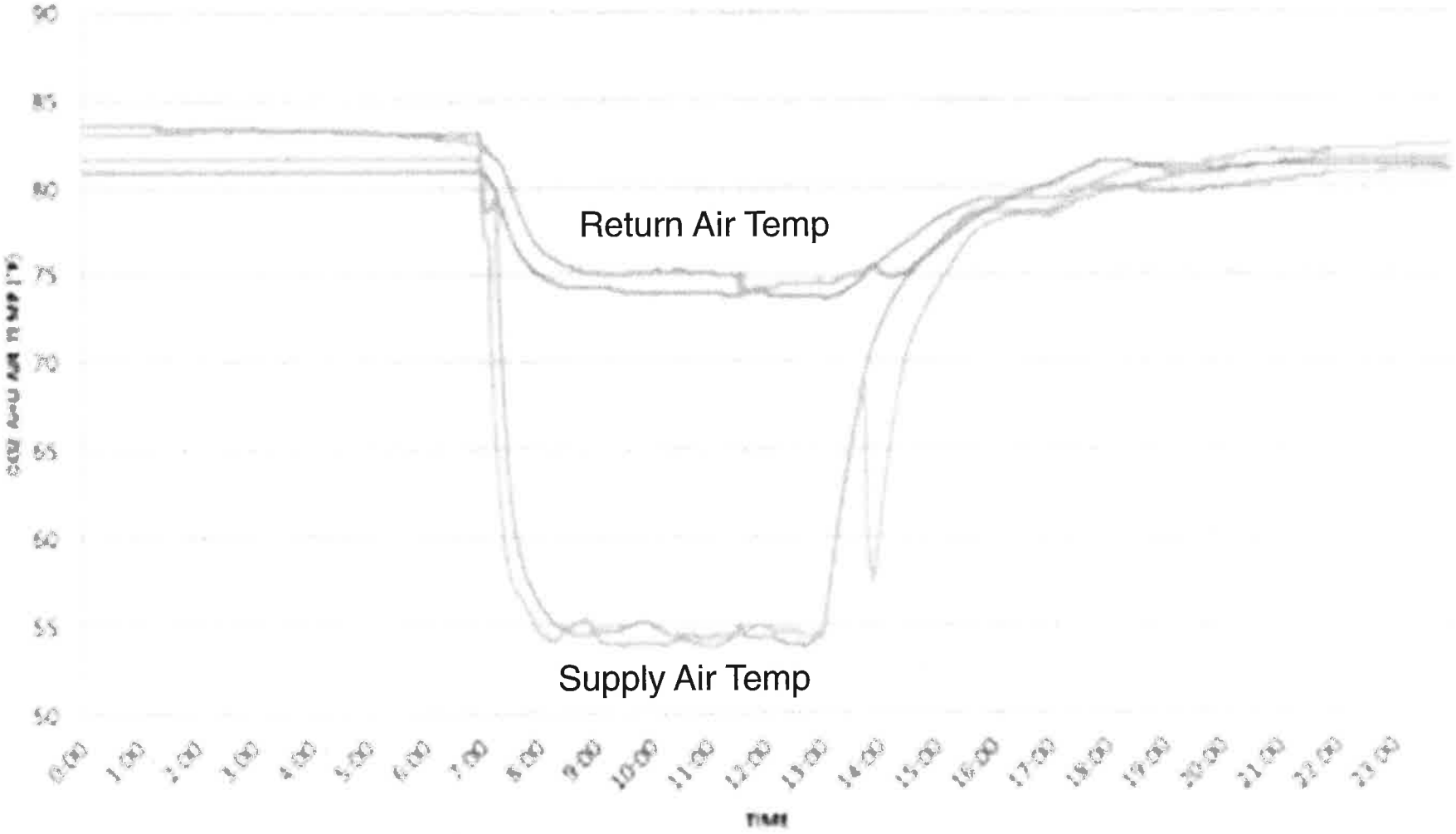


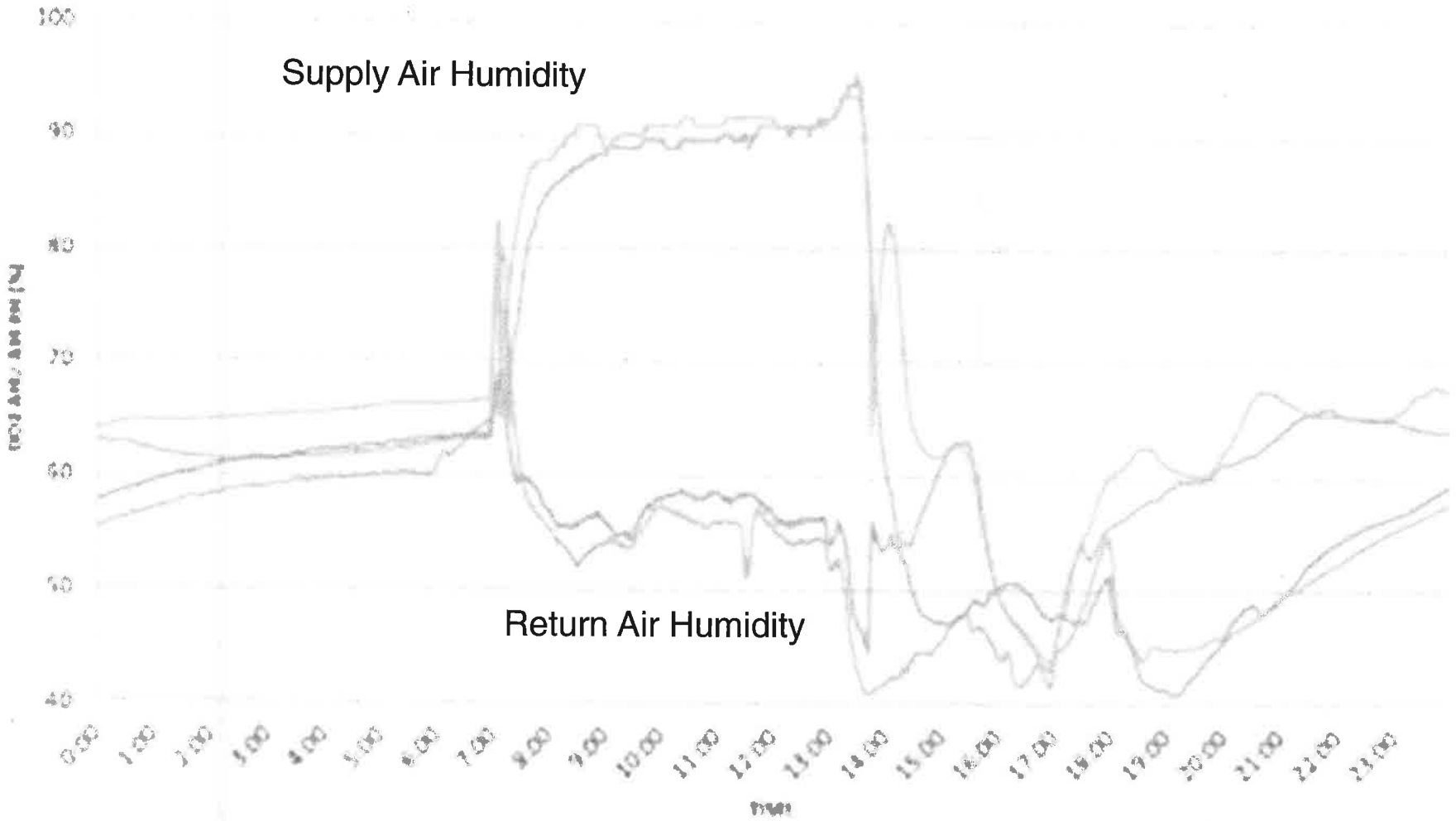
AHU 1 – Return & Off Coil Temp.

kaer



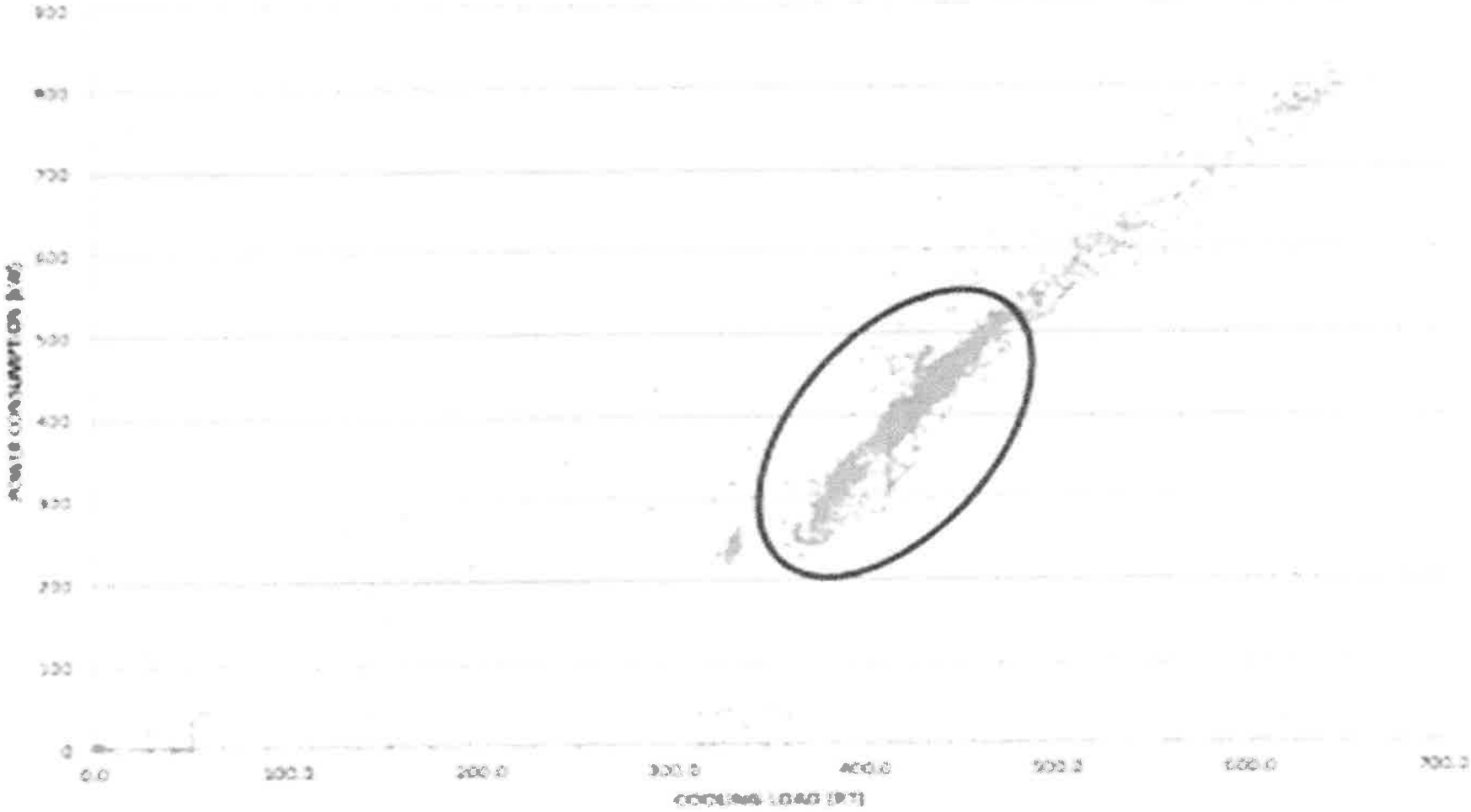
AHU 1 – Return & Off Coil Humidity

kaer



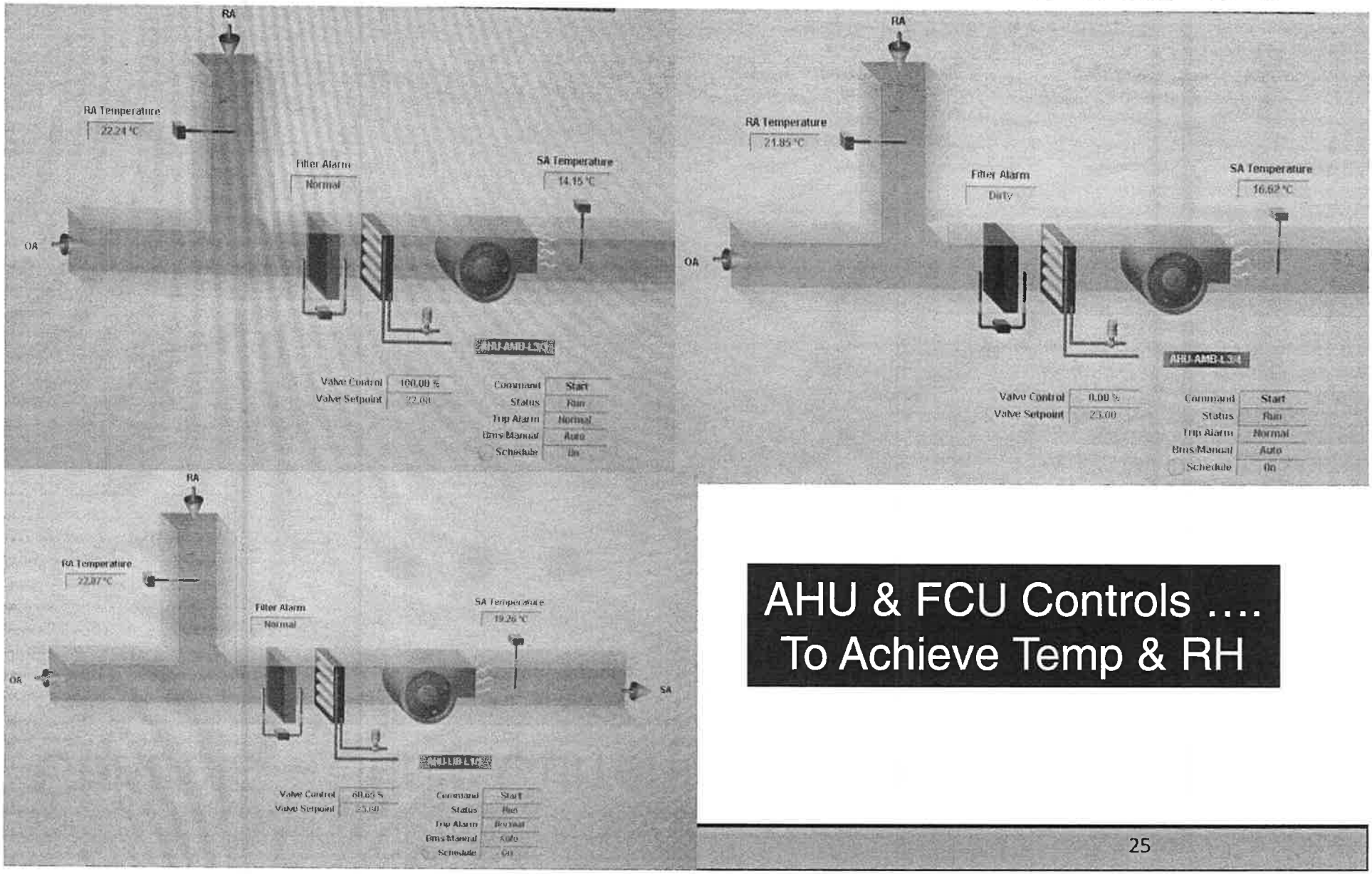
CHW PLANT Baseline Curve

kaer



Airside – Control Deficit

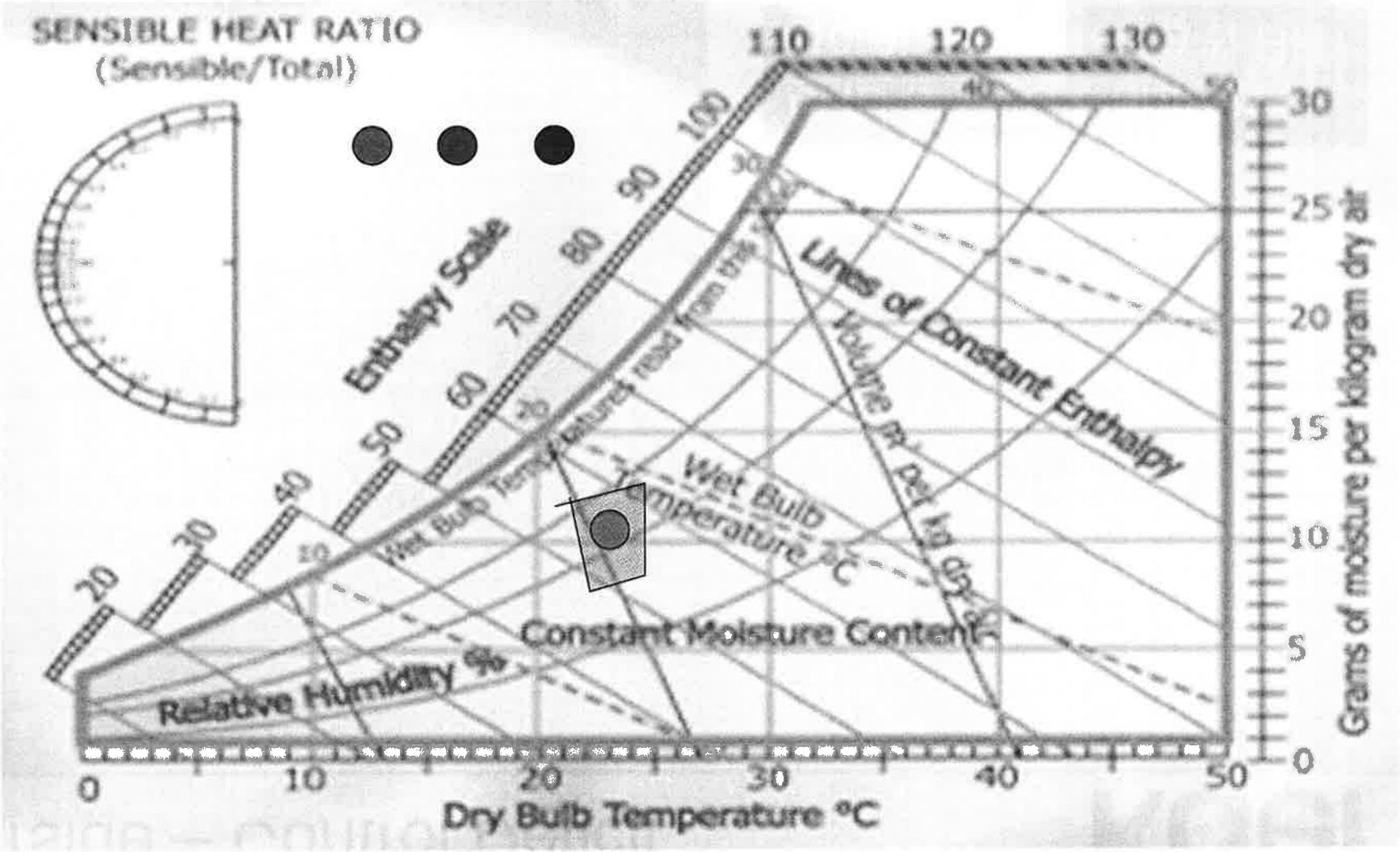
kaer



AHU & FCU Controls ….
To Achieve Temp & RH

Controls – Show Current Condition

kaer



CHWS Plant Benchmarking

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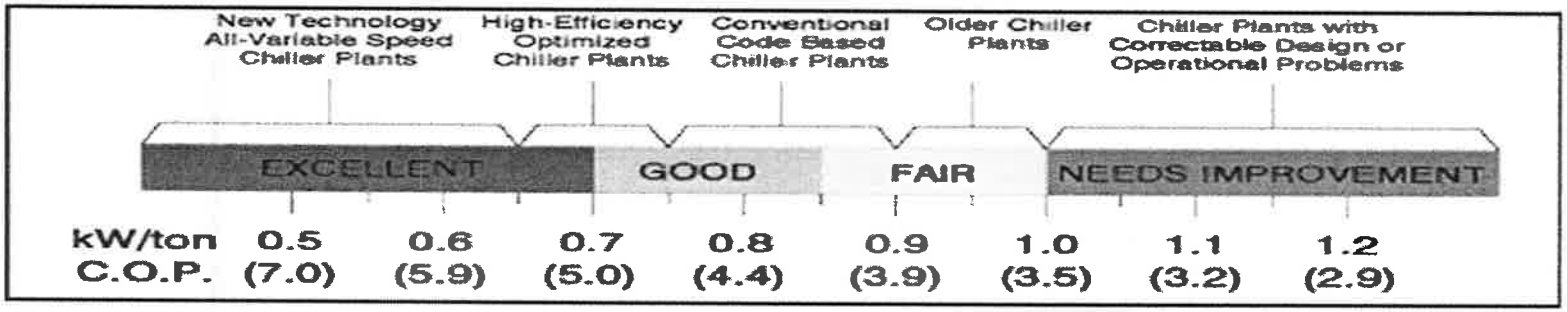
TARGET
< x.xx kW/Ton

Design
x.xxkW/Ton

Current Plant
Efficiency 1.05
kW/Ton

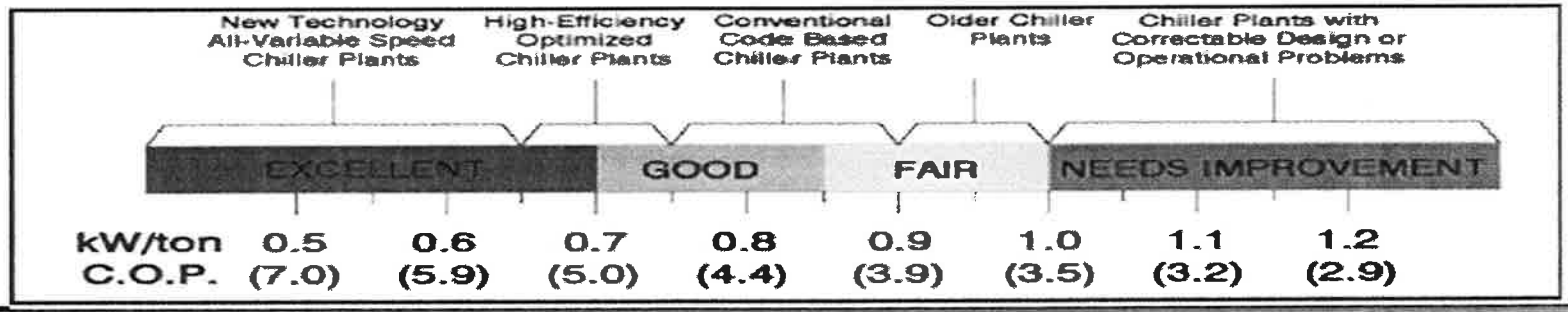


Option 1

Enhancement Of Current System

kaer

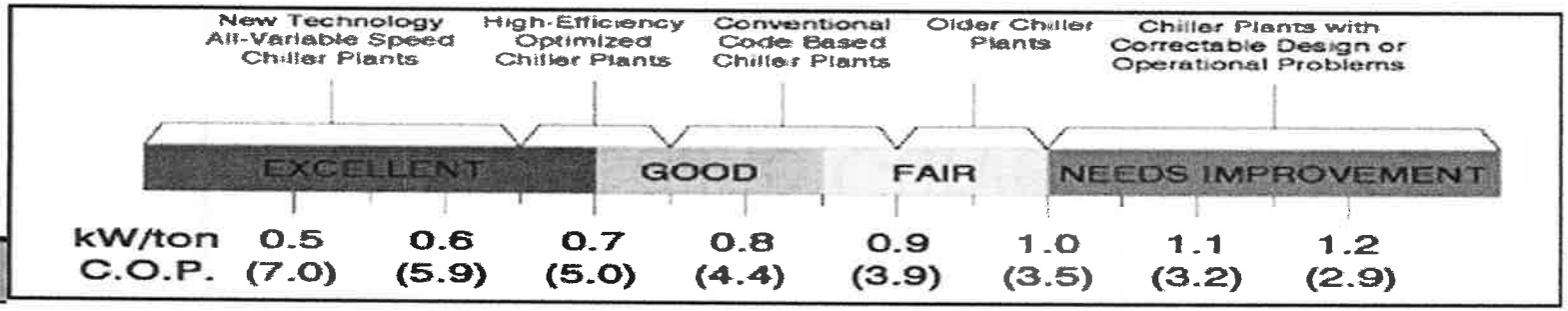
Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback
Enhancement Of The Current System				



Option 2

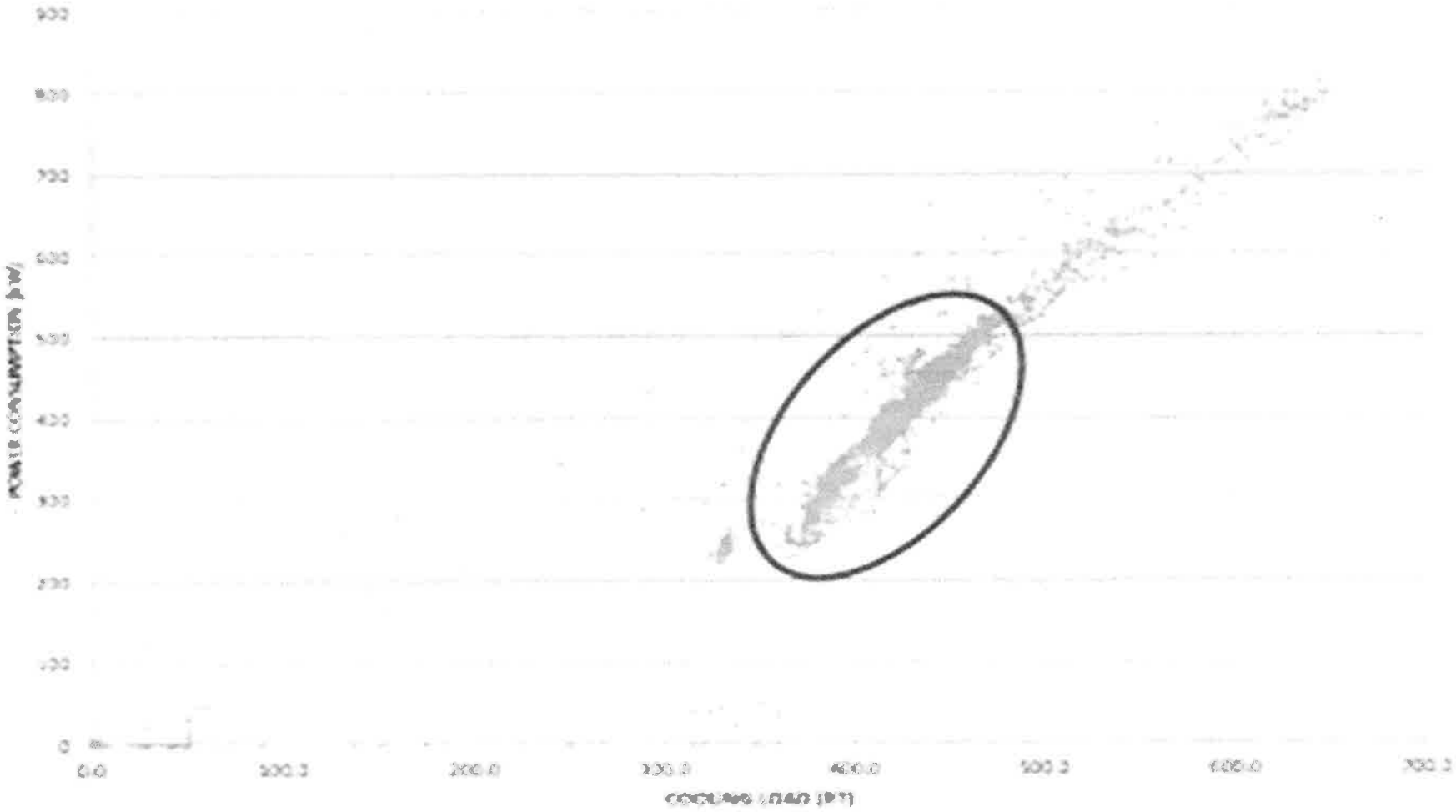
kaer

Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback



Estimated New Baseline Curve

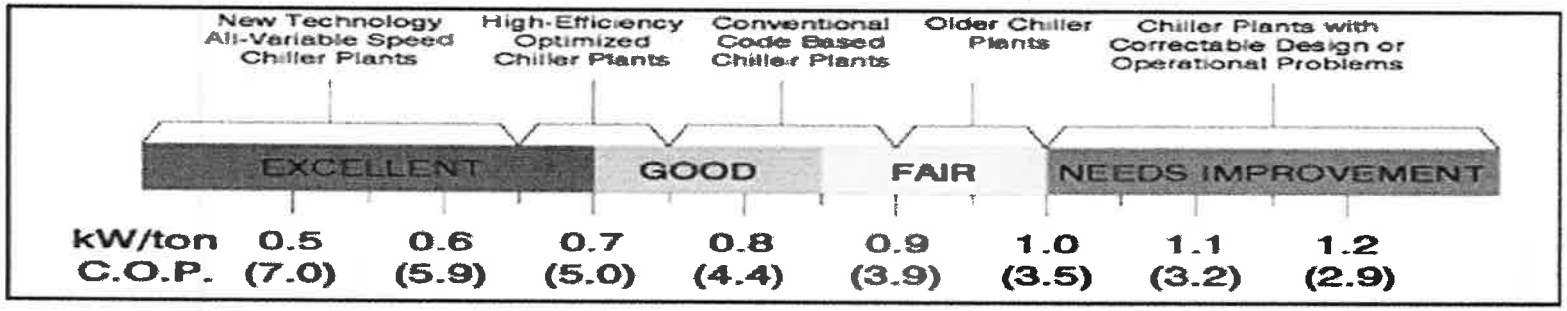
kaer



Option 3

kaer

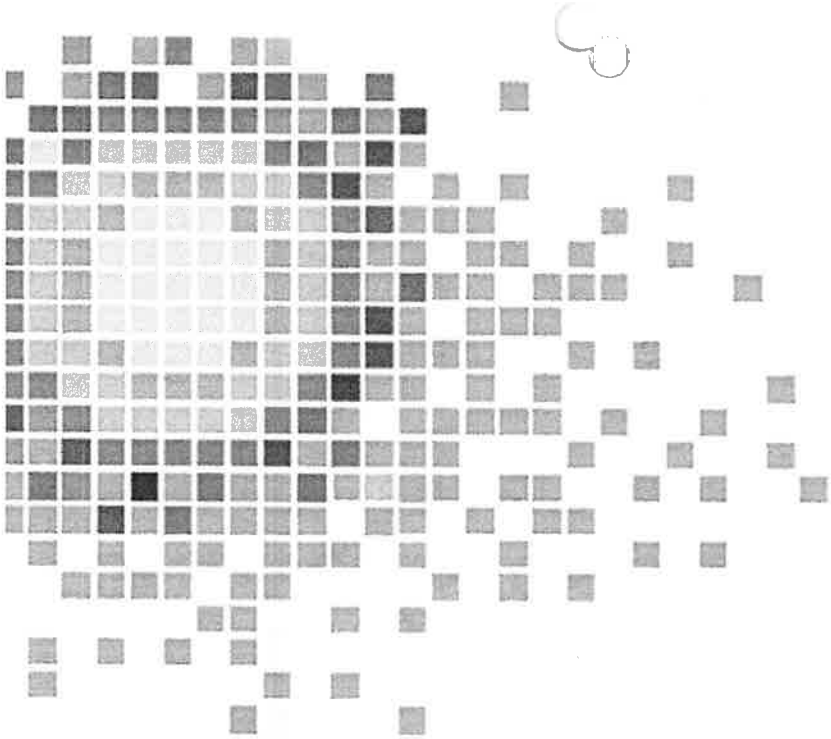
Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback



Way Forward

kaer

1. Aaaaa…
2. Bbbbb…
3. Ccccc…..



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TOMORROW'S BUILDINGS ENGINEERED TODAY

Energy Audit Report – Level 3 Analysis

Day 2, 2pm – 3.30pm

Case Study 2: Hotel

Description Of Hotel Facility

kaer

1. GFA : 30,000 m2
2. Air-conditioning Space : 10,000 m2
3. Rooms : 344 rooms
4. Operation Hours: 24 hours
5. Amenities : Ballrooms, Function Rooms, F&B Outlet
6. Type Of Plant Available: Chilled water plant system
7. Design Space Condition: 23° C ±1° C RH < 70%
8. Ambient Temperature: 32° C RH 75% – 90%

Hotel Energy Consumption

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Month	Electricity Usage (kWh)	Electricity Cost (MYR)	MD Usage (kW)	MD Cost (MYR)	Diesel Usage (Litre)	Diesel Cost (MYR)	LPG Usage (Litre)	LPG Cost (MYR)	Total Cost (MYR)
Oct-06	512,410	101,457	1,070	31,030	5,790	9,148	7,737	18,105	**159,741**
Nov-06	512,470	101,469	1,030	29,870	6,590	10,412	8,036	18,805	**160,556**
Dec-06	529,420	104,825	1,000	29,000	7,390	11,676	8,673	20,294	**165,796**
Jan-07	509,590	100,899	950	27,550	6,590	10,412	8,030	18,790	**157,651**
Feb-07	510,230	101,026	930	26,970	7,390	11,676	9,055	21,188	**160,860**
Mar-07	460,940	91,266	980	28,420	7,390	11,676	5,383	12,595	**143,958**
Apr-07	551,150	109,128	1,030	29,870	6,590	10,412	8,898	20,820	**170,230**
May-07	551,010	109,100	1,040	30,160	6,190	9,780	4,373	10,232	**159,272**
Jun-07	583,460	115,525	1,040	30,160	11,835	18,699	5,966	13,960	**178,344**
Jul-07	557,810	110,446	1,020	29,580	11,953	18,886	6,969	16,308	**175,220**
Aug-07	594,370	117,685	1,030	29,870	17,181	27,146	9,102	21,299	**196,000**
Sep-07	549,160	108,734	1,020	29,580	13,443	21,240	9,436	22,079	**181,633**
Total	**6,422,020**	**1,271,560**	**12,140**	**352,060**	**108,332**	**171,165**	**91,656**	**214,476**	**2,009,260**

The peak electricity rate is 0.234 MYR/kWh

The off-peak electricity rate is 0.144 MYR/kWh

The MD rate is 29.00

The diesel rate is 1.58 MYR/Litre

The LPG rate is 2.34 MYR/Litre

Energy Consumption

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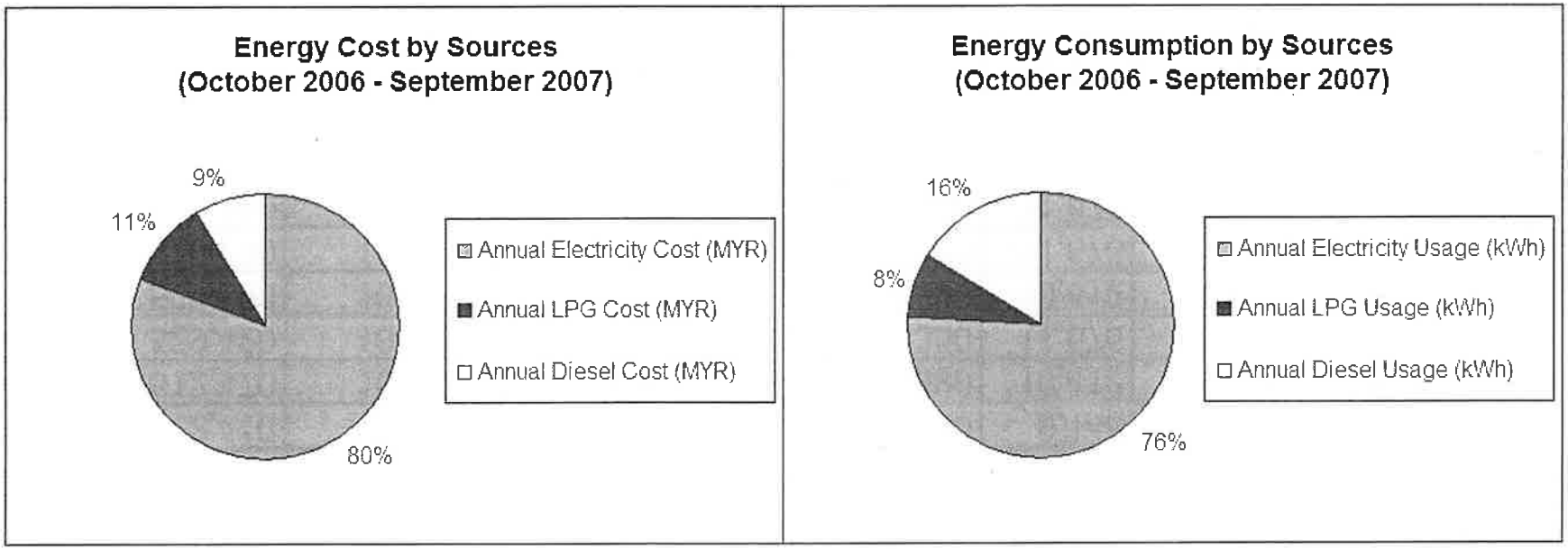
- Annual energy cost = RM 2 Mil
- Annual energy consumption = 8,500,000 kWH



Source : Utility bills Oct ' 06~ Sept '07

Energy Consumption

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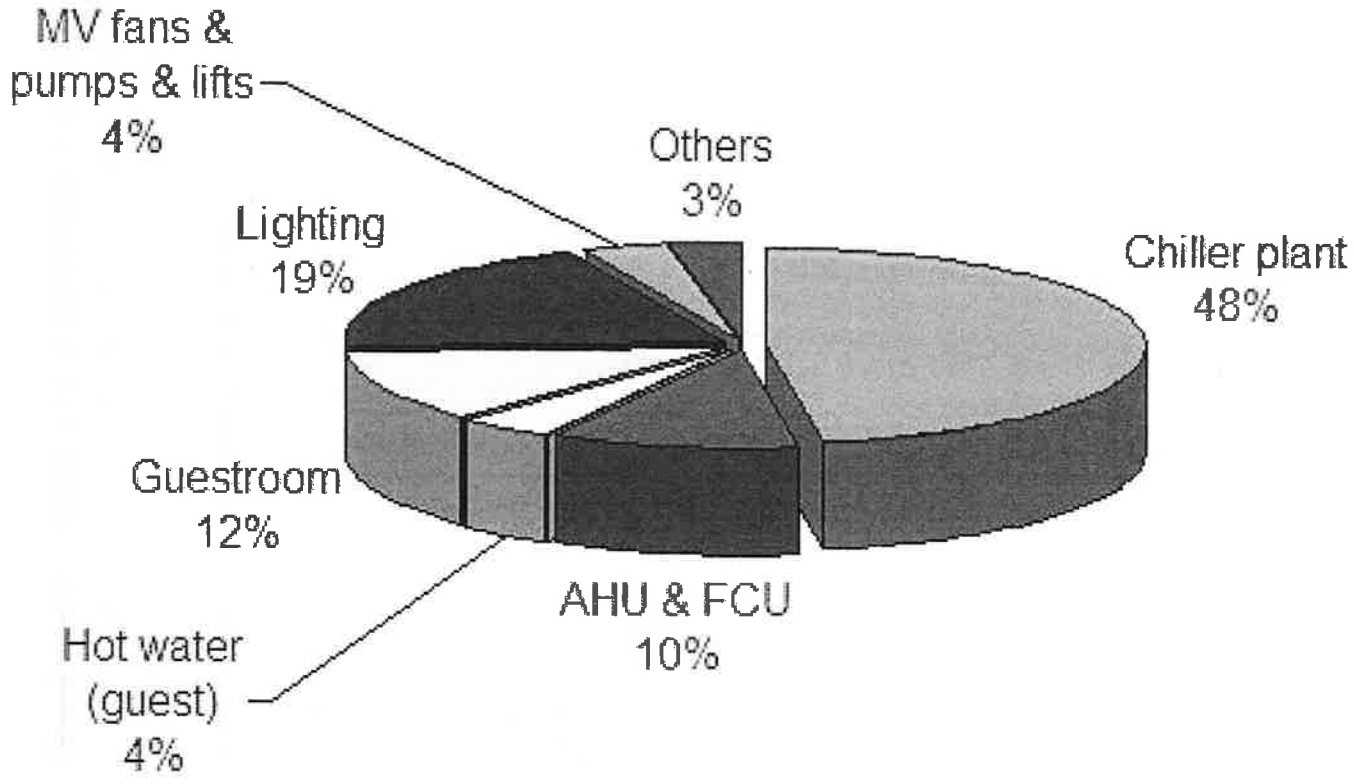
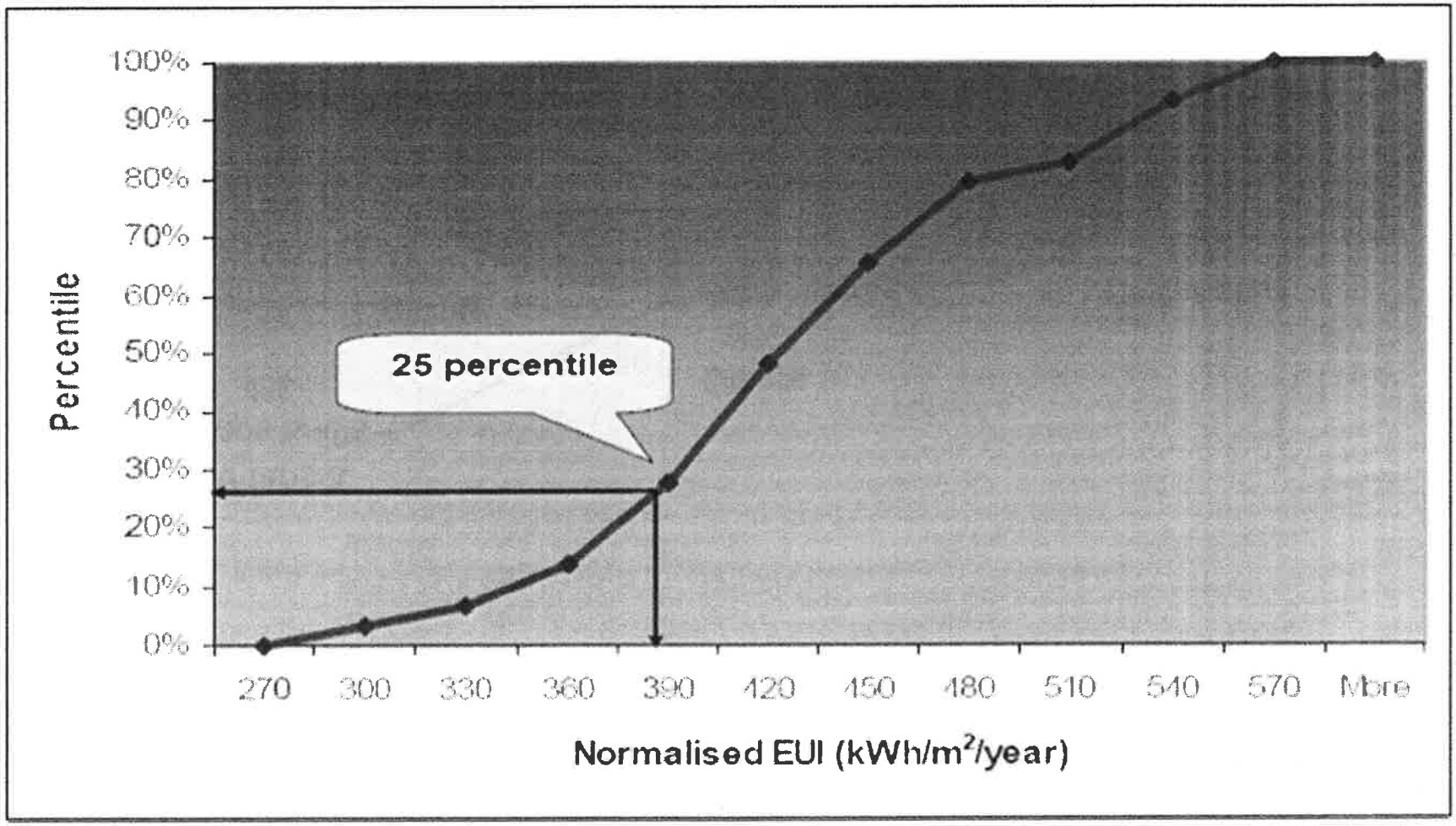


Hotel Benchmarking

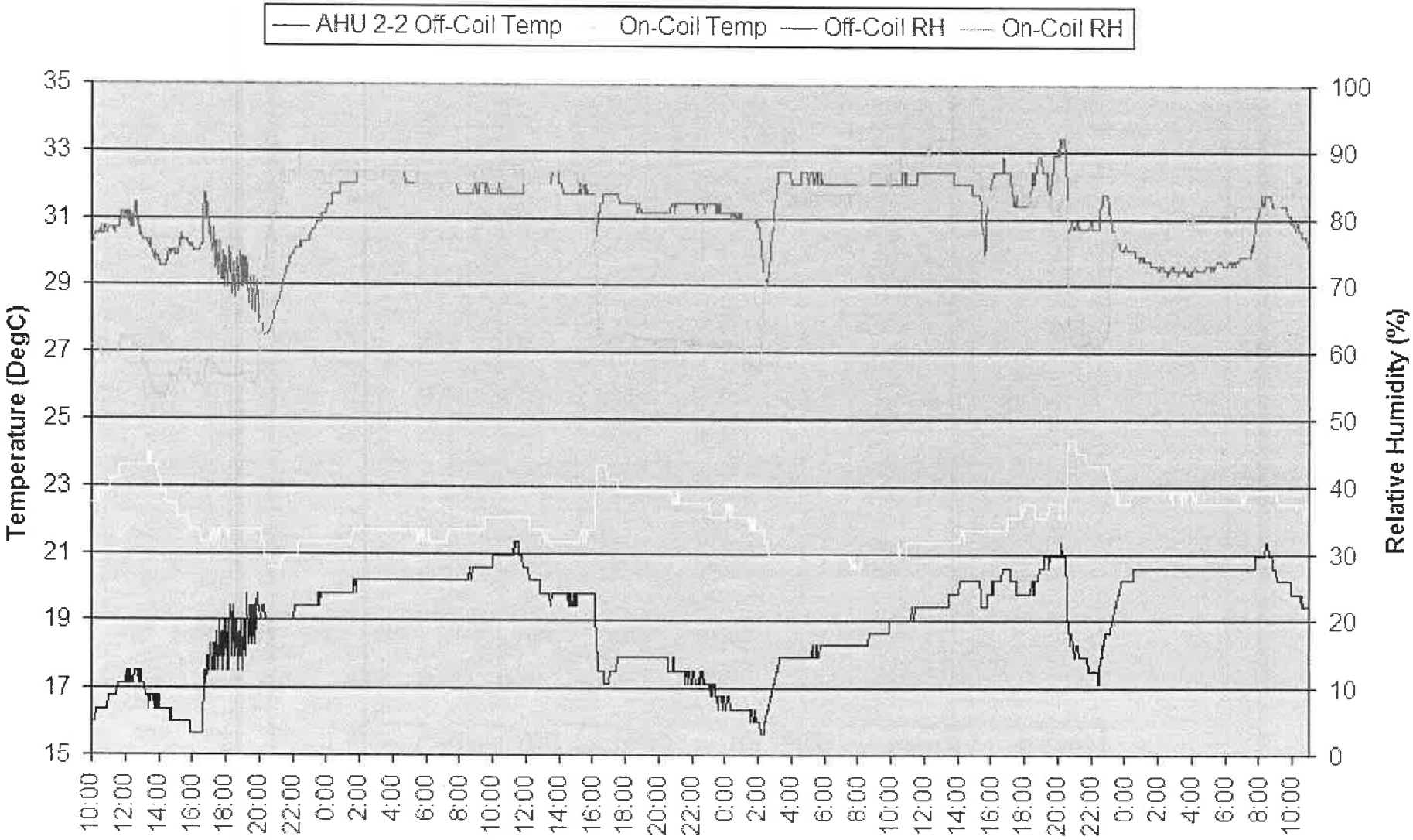
kaer

Actual Hotel : xxx ft^2/ RT
Actual Cooling Load : xxxx RT



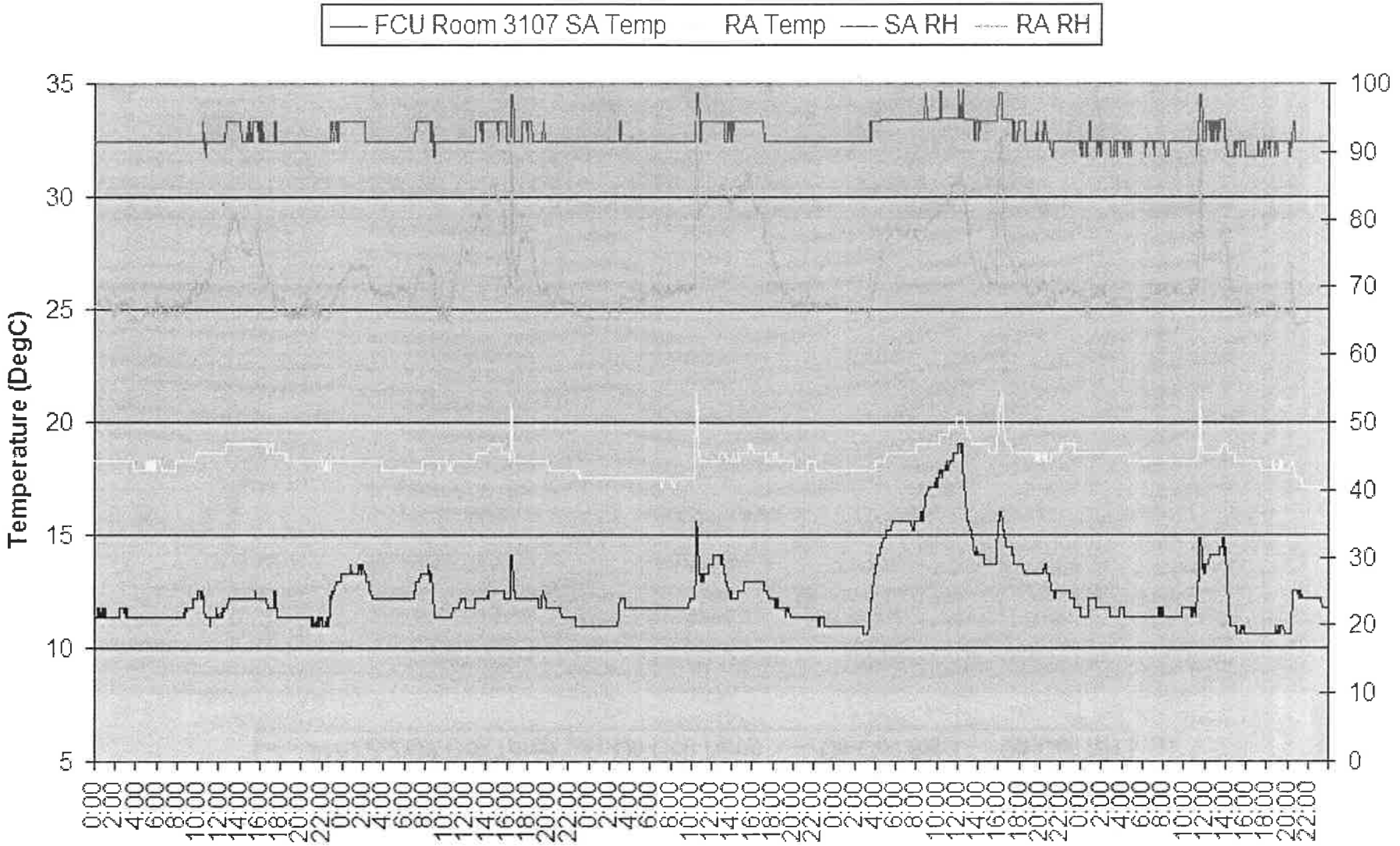
Ballroom Condition

kaer



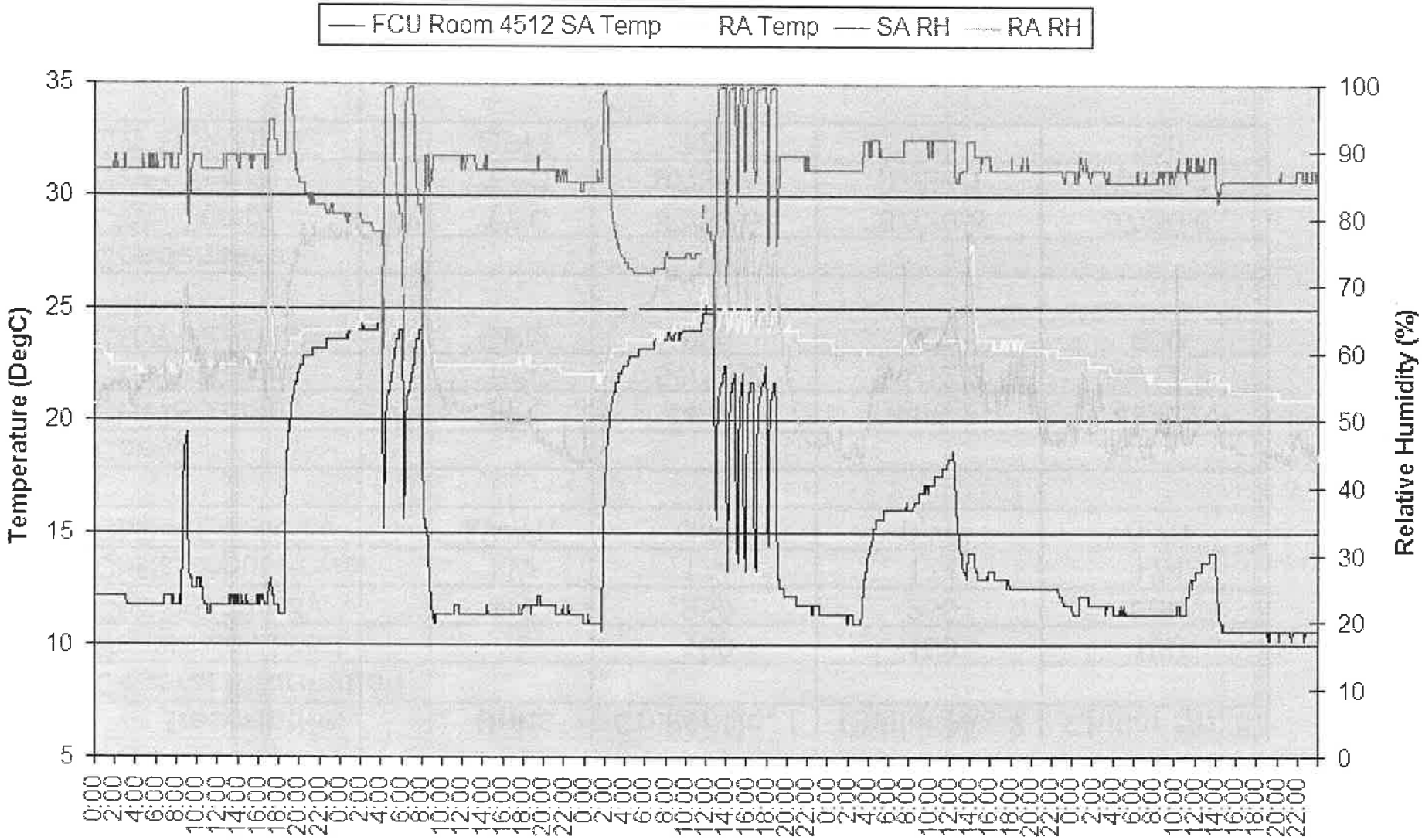
Guest Room 3107

kaer



Guest Room 4512 Condition

kaer



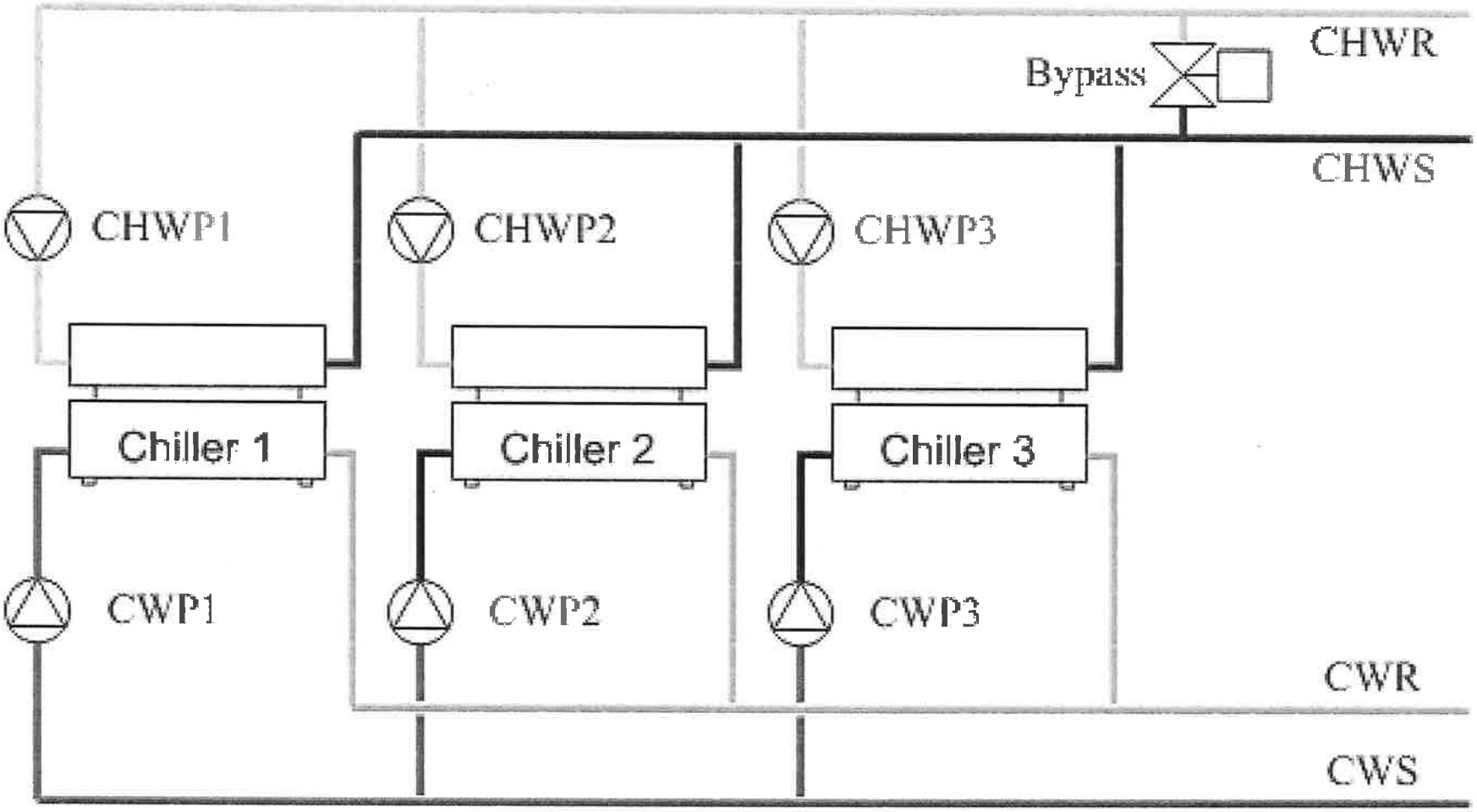
Chiller Design

kaer

Description	Units	Chiller No. 1	Chiller No. 2	Chiller No. 3
General Information				
Percentage Load	%	100	100	100
Chiller Capacity	RT	250	250	250
Chiller Input Power	kW	174	174	174
Chiller Efficiency	kW/RT	0.70	0.70	0.70
Cooler				
CHWS Temp.	°F/°C	44/6.7	44/6.7	44/6.7
CHWR Temp.	°F/°C	54/12.2	54/12.2	54/12.2
CHW Flow Rate	GPM	600	600	600
Condenser				
CWS Temp.	°F/°C	87/30.6	87/30.6	87/30.6
CWR Temp.	°F/°C	97/36.1	97/36.1	97/36.1
CW Flow Rate	GPM	720	720	720

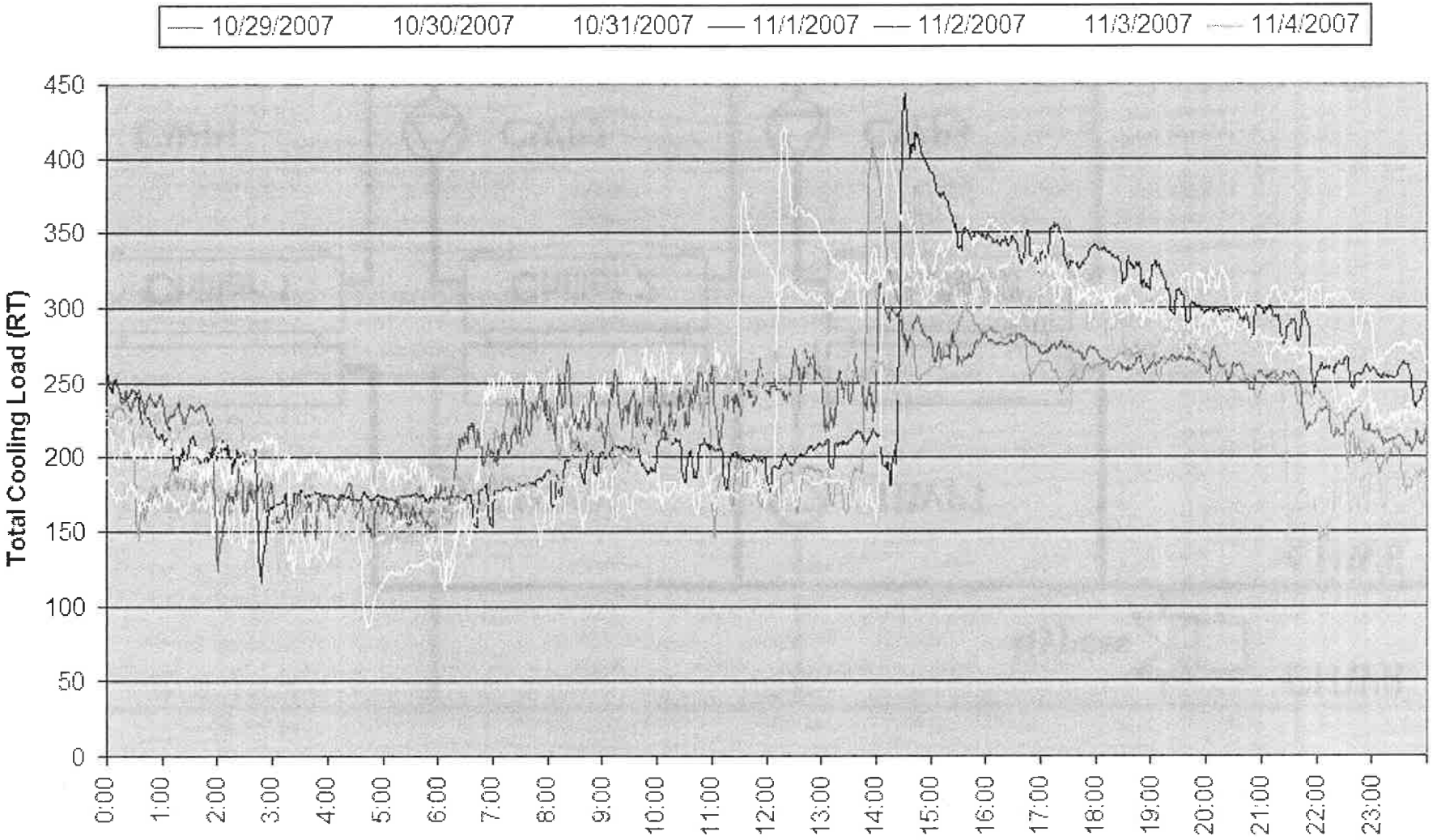
CHW Plant Schematic Drawing

kaer



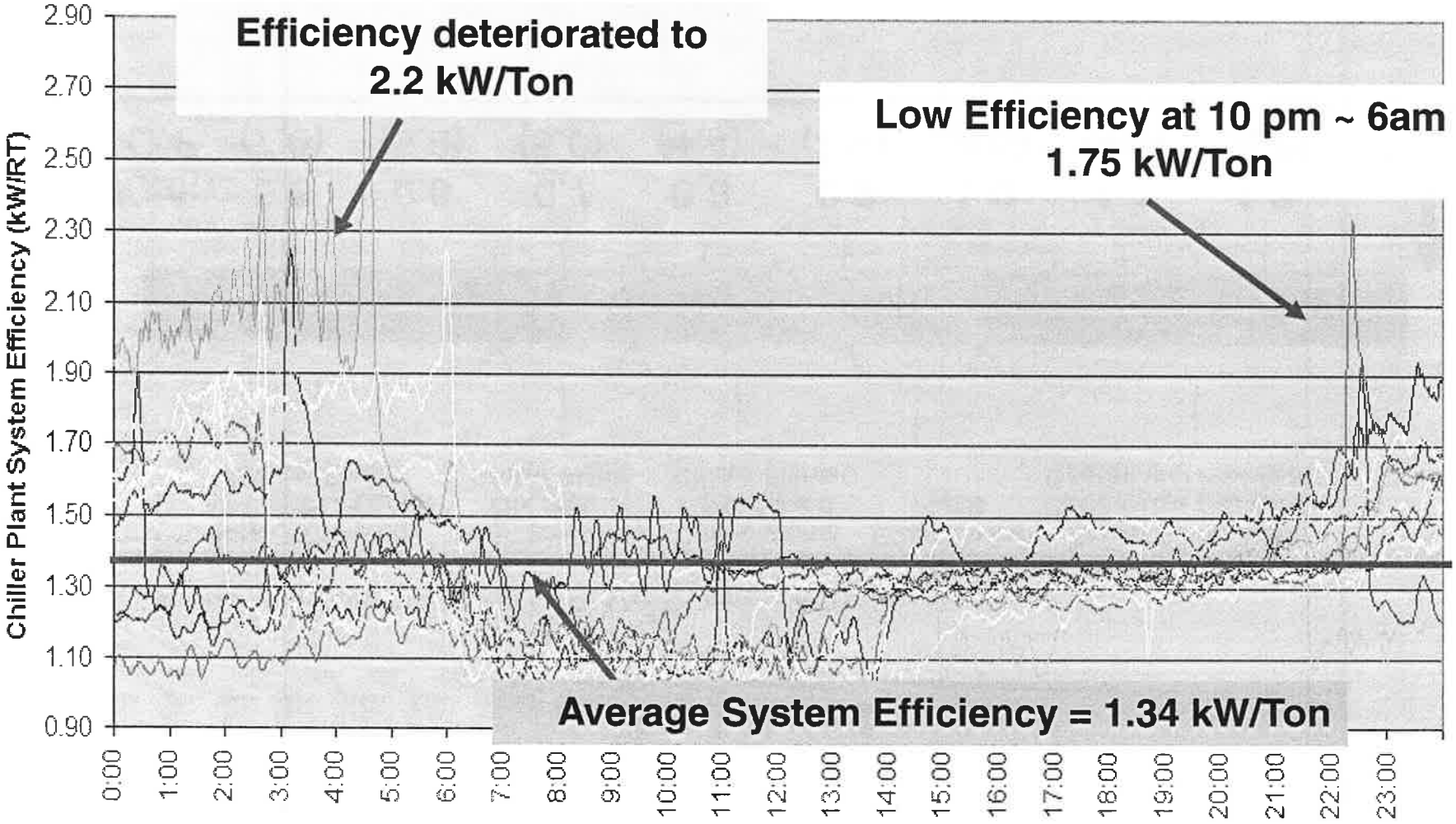
Hotel Cooling Load Profile

kaer



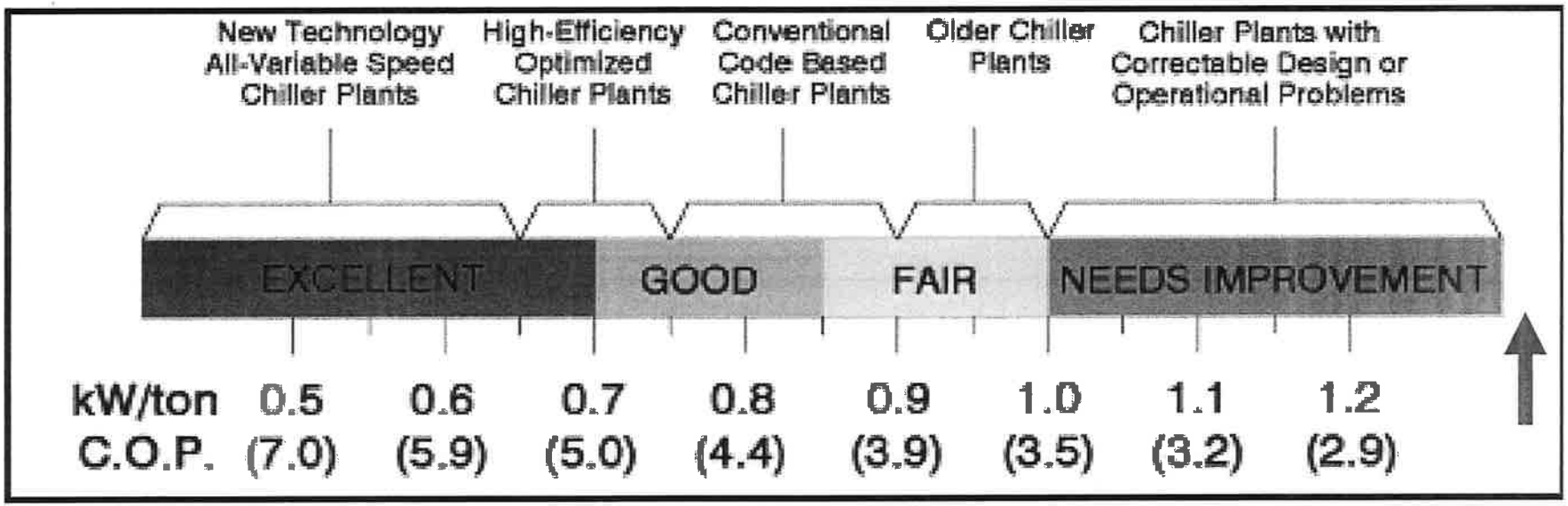
CHW System Efficiency

kaer



CHW System Eff. Benchmarking kaer

ASHRAE Benchmark for Chiller Plant System Efficiency



Current Average Chiller Plant System = x.xxx kW/RT

Chillers Performance

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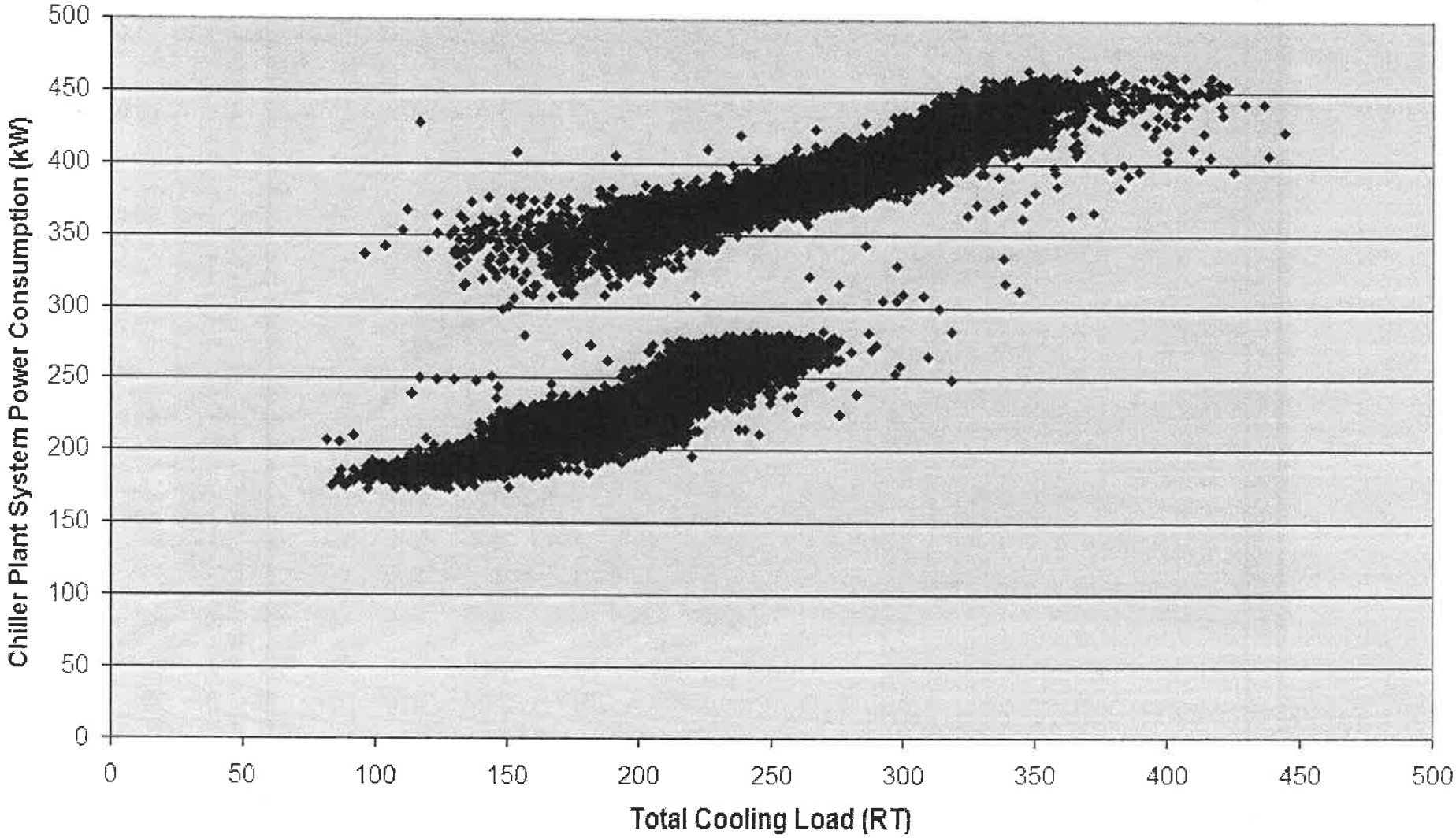
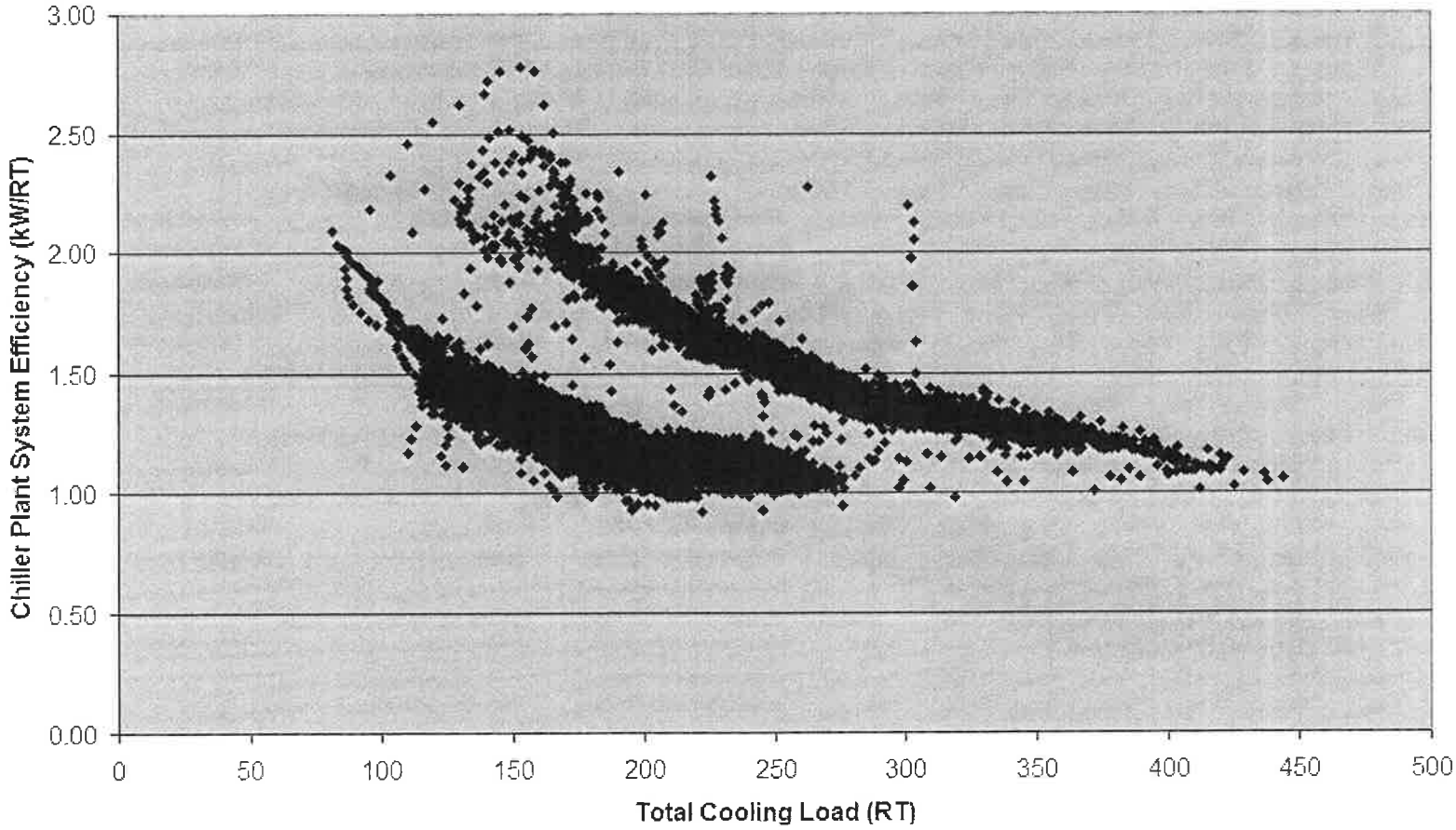


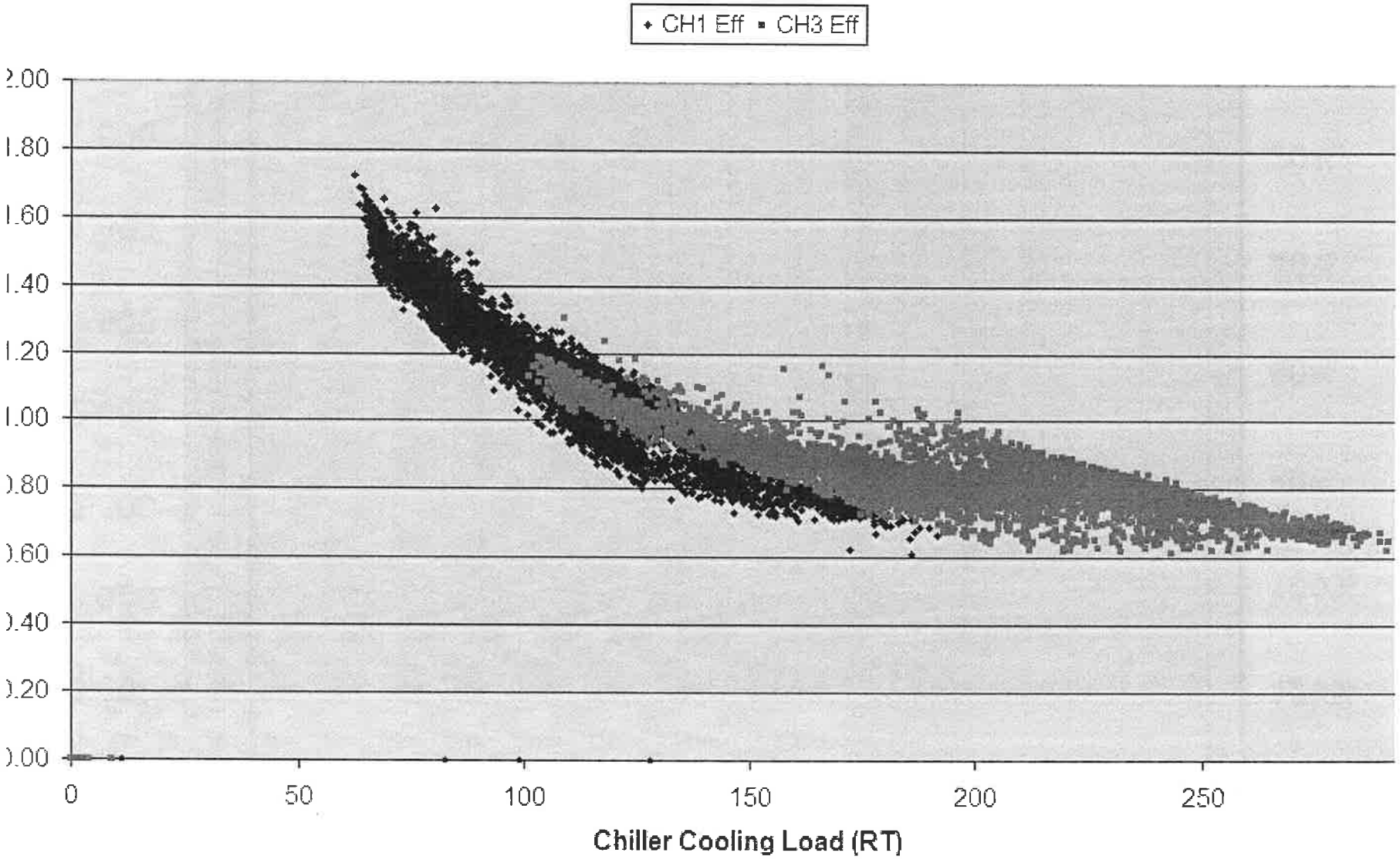
CHW Plant Performance

kaer



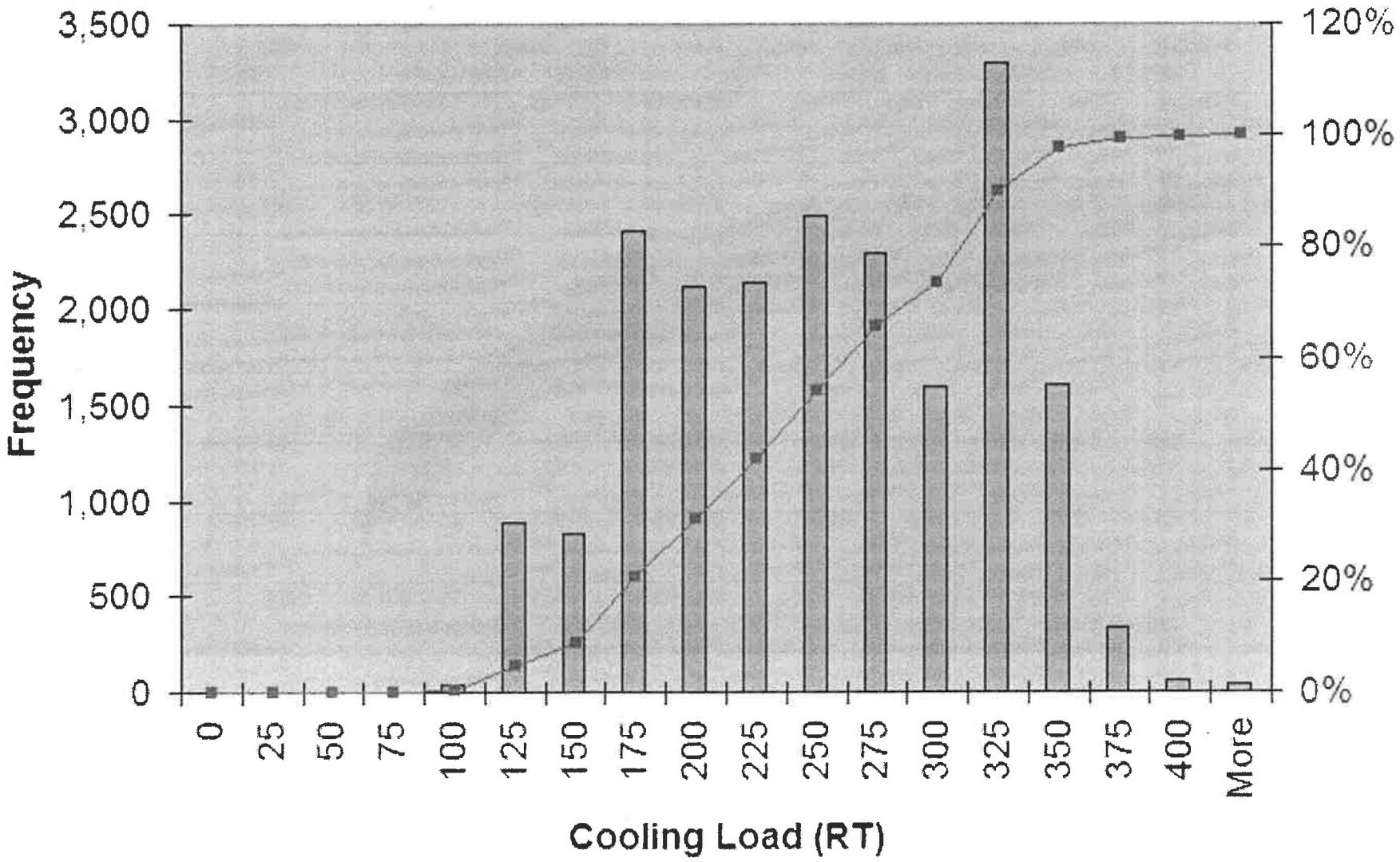
Chillers Efficiency

kaer



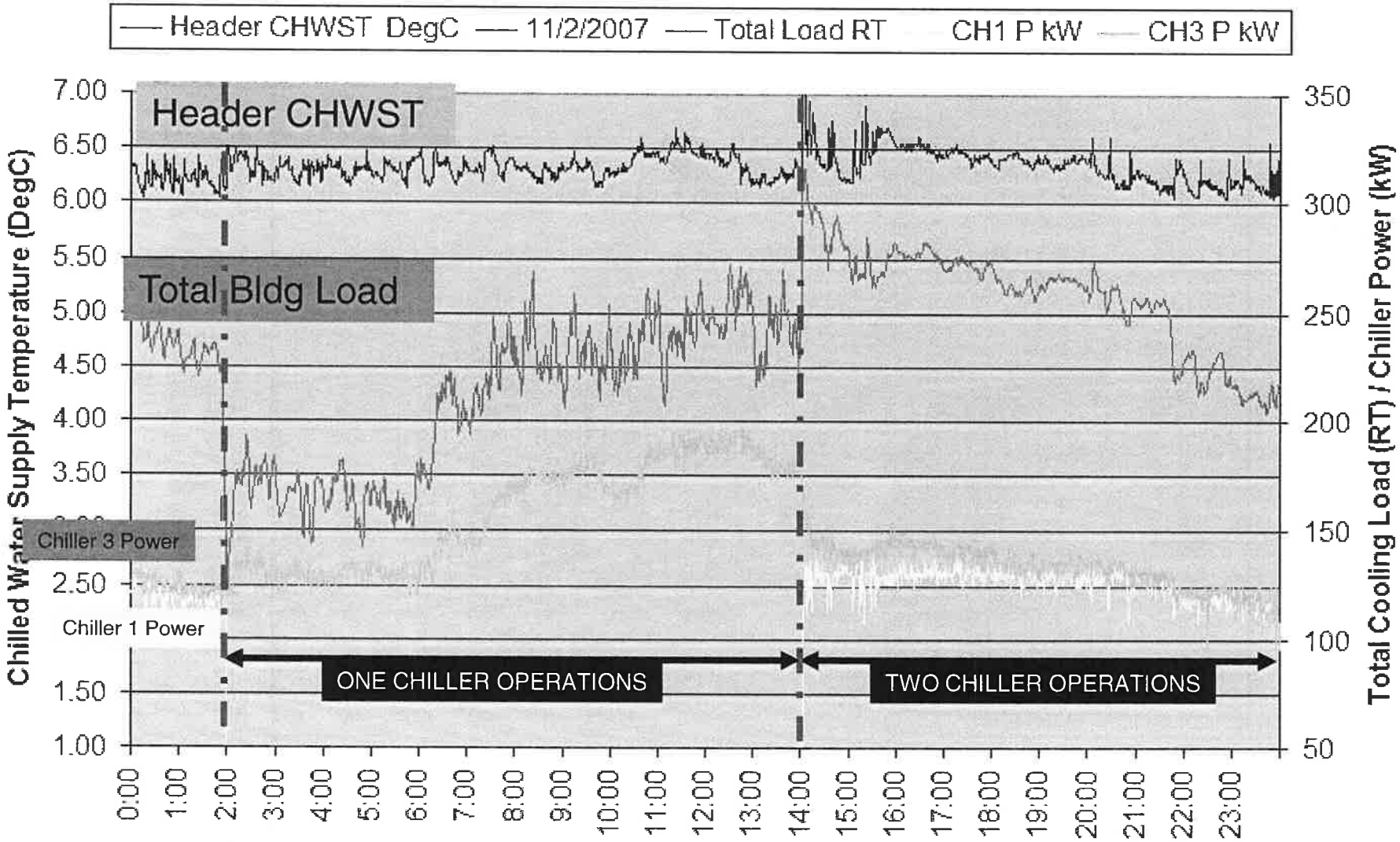
CHW System Histogram

kaer



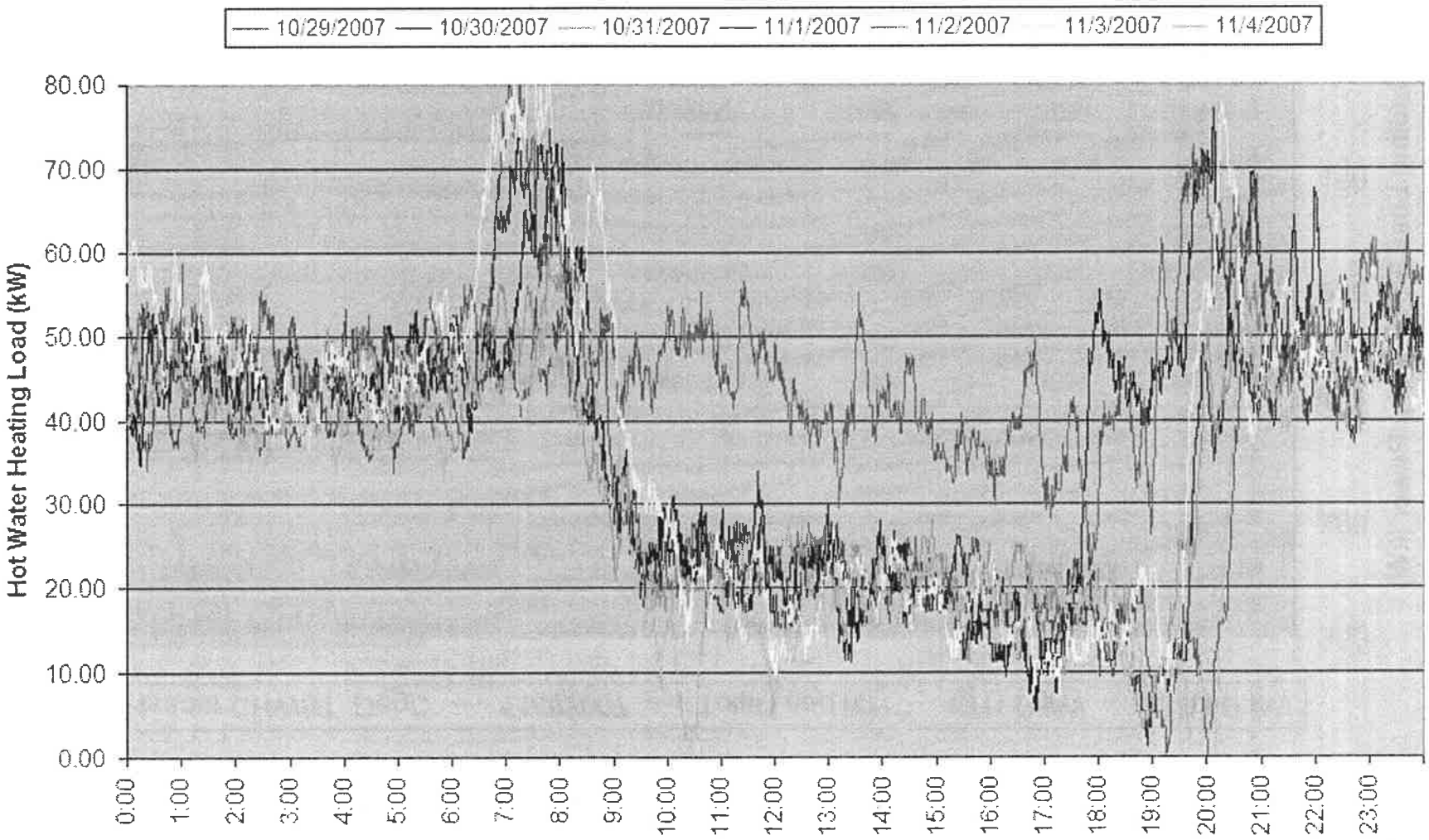
Conditions Of Operations

kaer



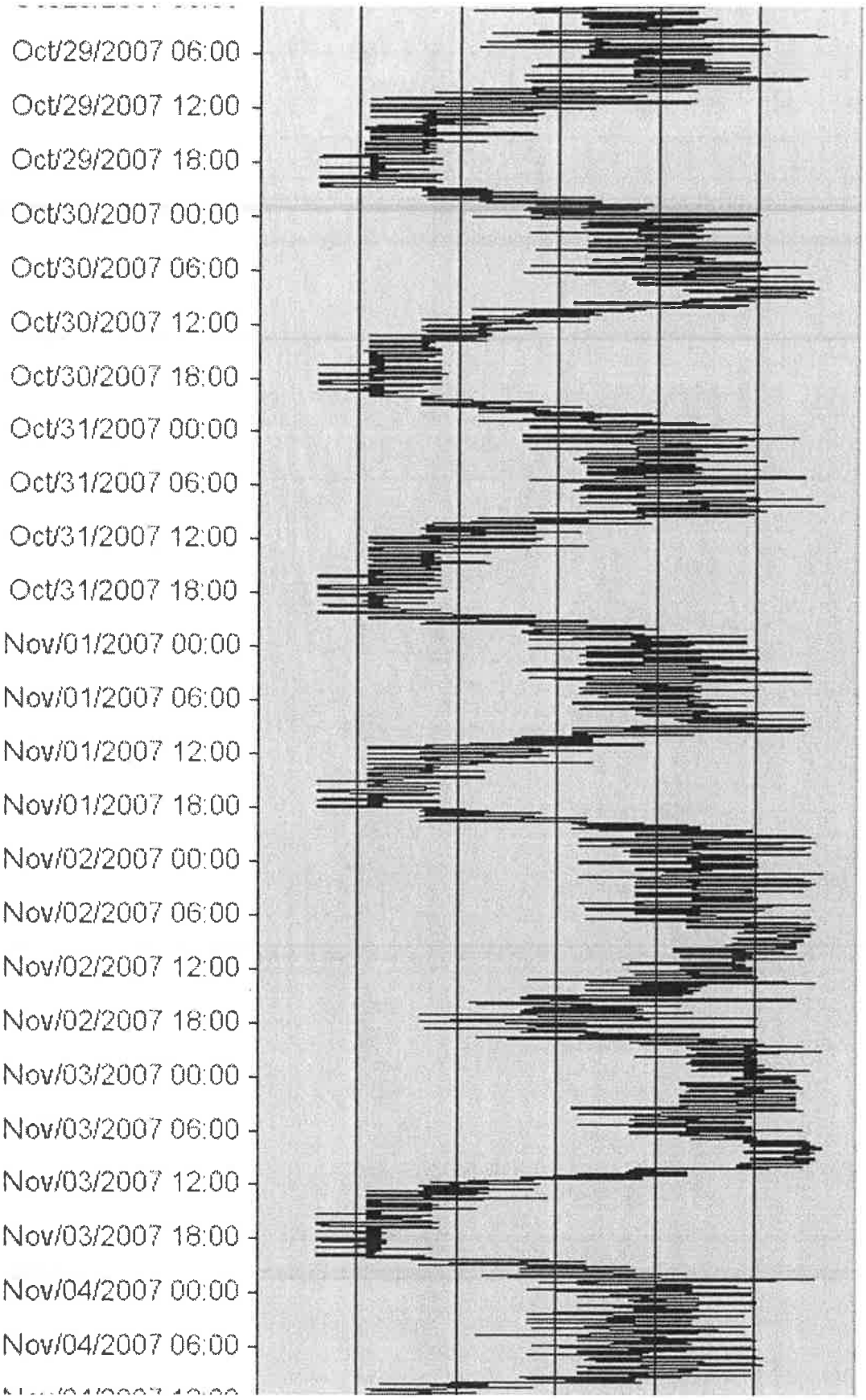
Hot Water System Heat Load

kaer



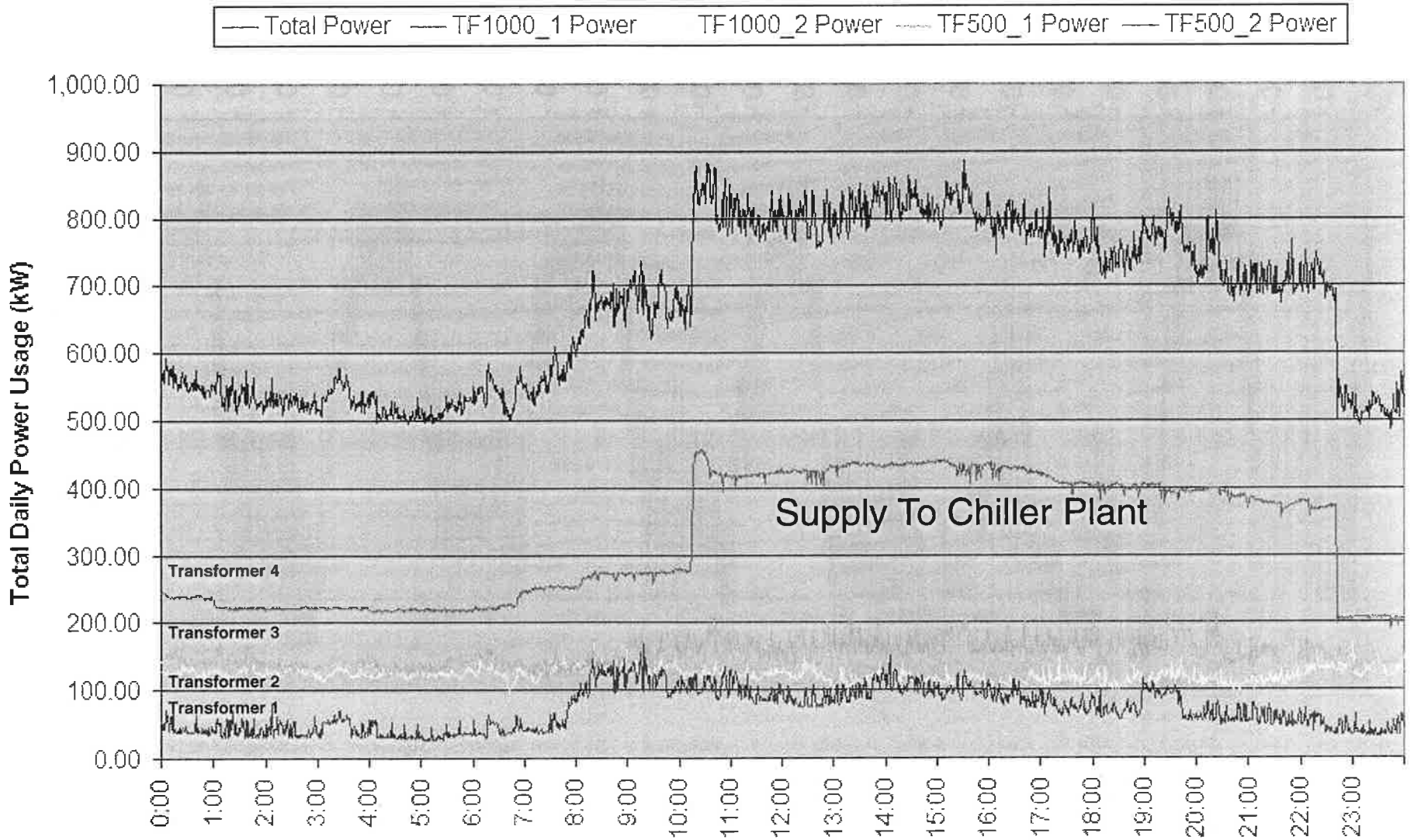
Hot Water System Power Profile

kaer



Maximum Demand Profile

kaer



CHWS Plant Benchmarking

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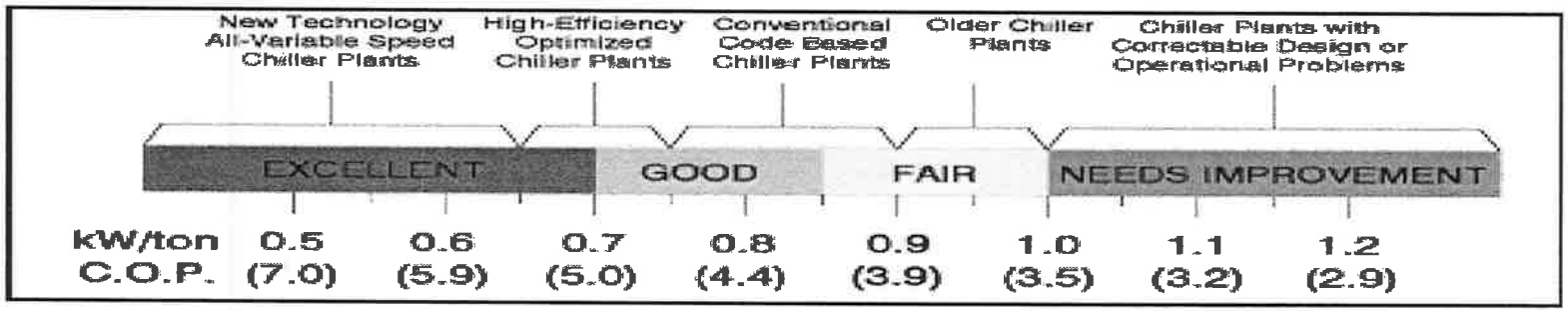
TARGET
< x.xx kW/Ton

Design
x.xxkW/Ton

Current Plant Efficiency x.xx kW/Ton

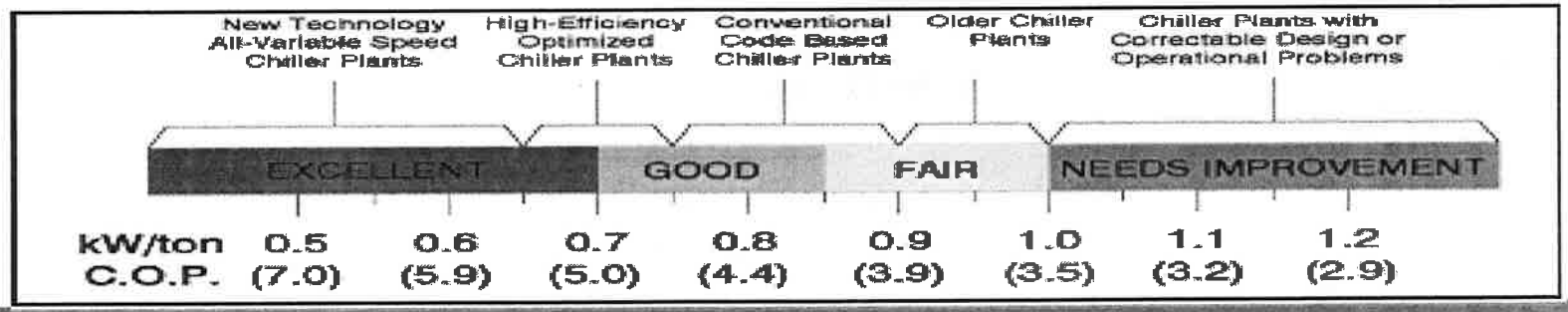


Option 1

Enhancement Of Current System

kaer

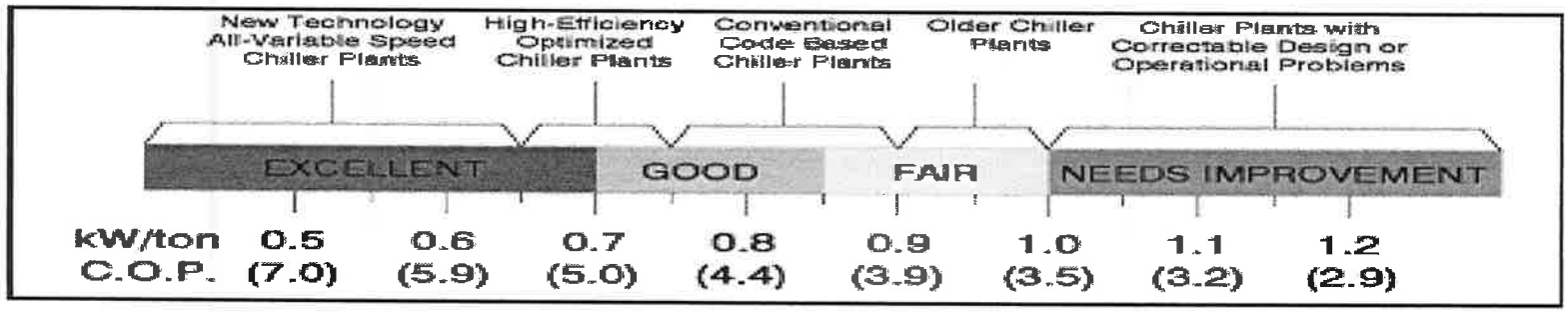
Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback
Enhancement Of The Current System				



Option 2

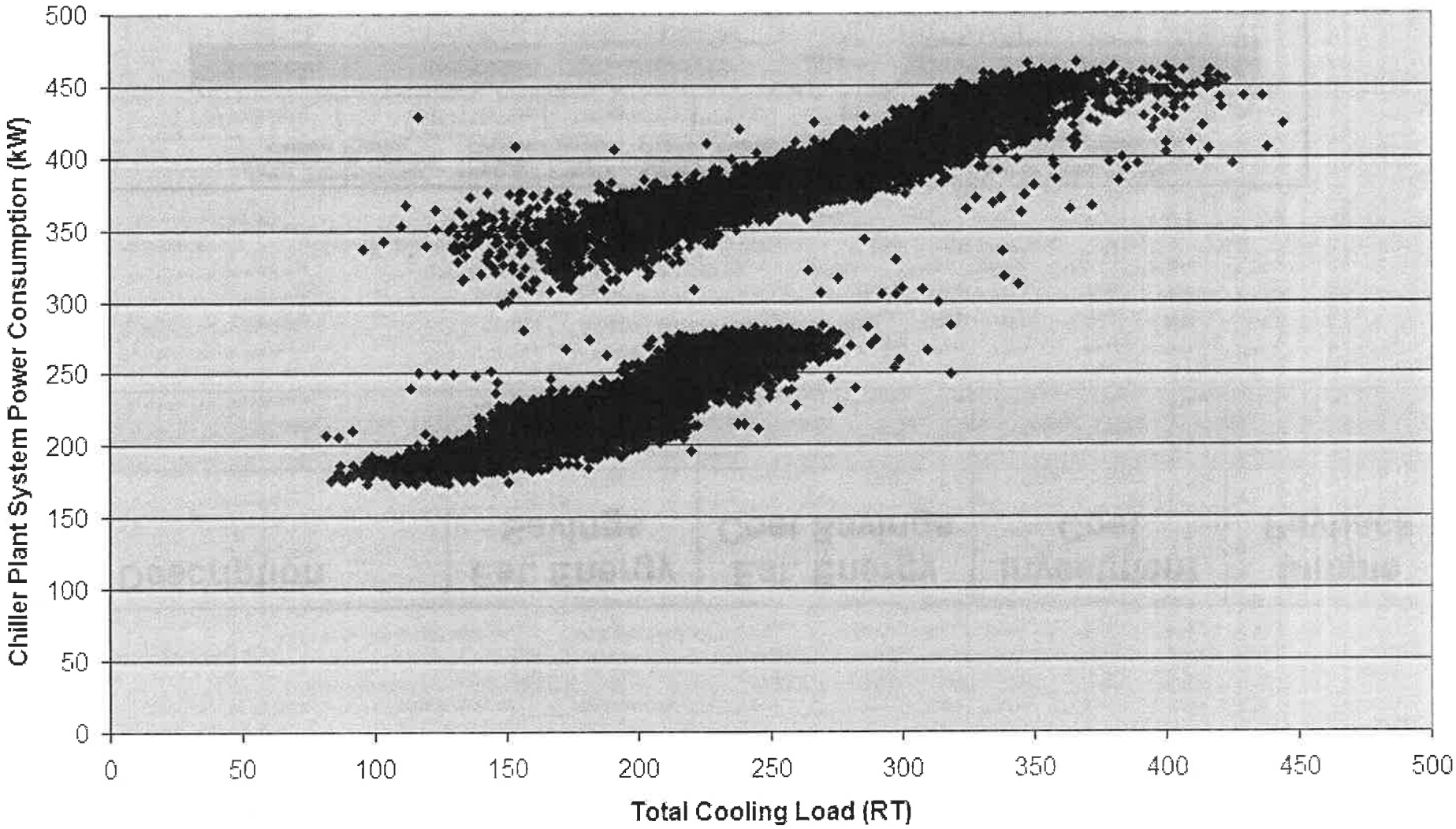
kaer

Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback



Estimated New Baseline Curve

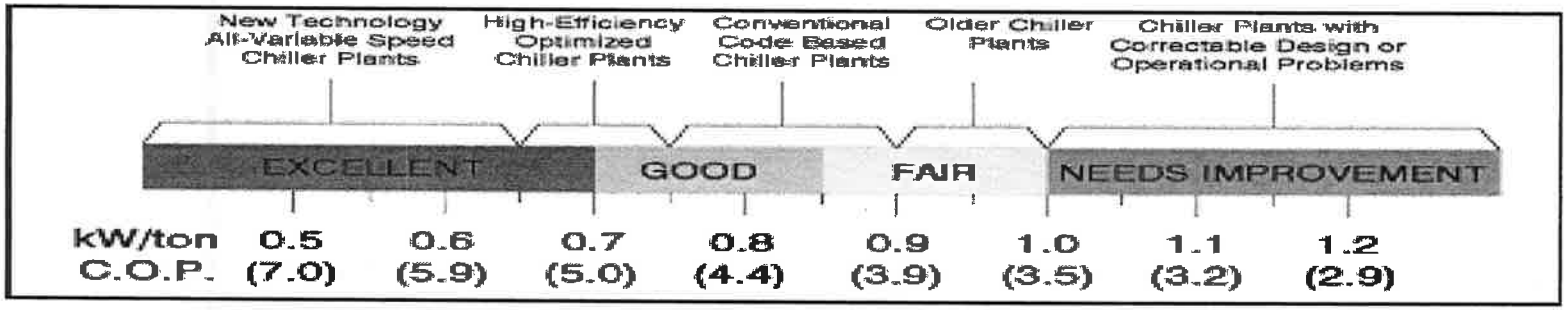
kaer



Option 3

kaer

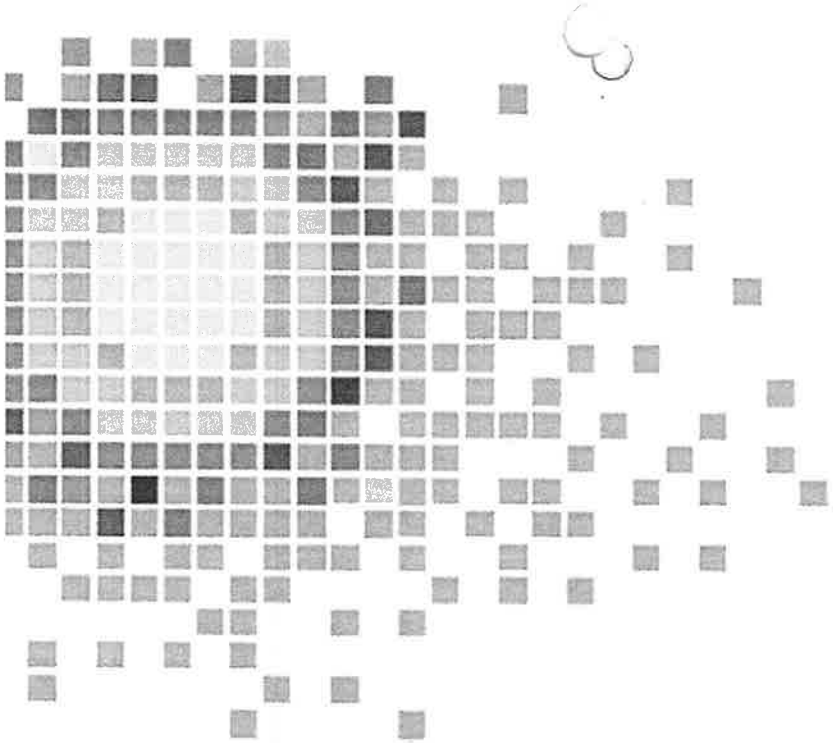
Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback



Way Forward

kaer

1. Aaaaa…
2. Bbbbb…
3. Ccccc…..



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TOMORROW'S BUILDINGS ENGINEERED TODAY

Energy Audit Report – Level 3 Analysis

Day 2, 2pm – 3.30pm

Case Study 3: Retail Mall

Brief Description Of The Facility

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1. GFA : 150,000 m^2 or 1,600,000 ft^2
2. Used For: High End Retail Mall
3. Type Of Plant Available: Chilled water plant system
4. Design Space Condition: 23° C ±1° C RH < 70%
5. Outdoor Ambient Temperature: 32° C RH 75% – 90%
6. Chillers Operating Hours
    - 08:00 – 03:00 ,CH 8 on Monday-Sunday.
    - 09:15 – 22:00 ,CH 1, 4, 6 on Monday – Sunday.
    - 09:45 – 22:00 ,CH 2 on Monday – Sunday.
    - 09:55 – 24:00, CH 3 on Monday – Sunday.
    - 11:00 – 20:00, CH 5 on Monday – Sunday.

Chiller Details

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MODEL	YKHFHBJ35DCF		(MOTOR SELECTED BY USER)	
REFRIGERANT	134A		GEAR CODE	EL(SPEC)
RATED CAPACITY (TR)	1500		SPECIFIED CAPACITY (TR)	1500
INPUT POWER (KW)	934		MAX MOTOR LOAD (KW)	942
VOLTAGE / HZ	3300 / 50			
ORIFICE (VARY)	VALVE:4		OPTISOUND CONTROL	YES
ISOLATION VALVE	NO			
FLA	185		LRA	1135
FULL LOAD (kW/TR)	0.623		NPLV	0.538

STARTER TYPE (0) NONE CHOSEN

	Evaporator	Condenser
FLUID	WATER*	WATER*
% BY WEIGHT	0.0*	0.0*
TUBE MTI NO.	271*	260*
PASSES	2*	2*
FOUL FACTOR	0.00010*	0.00025*
FLUID ENT TEMP (°F)	60.18	85.00*
FLUID LEV TEMP (°F)	44.00*	96.26
FLUID FLOW (gpm)	2222.0*	3750.0*
FLUID PRDROP (ft)	21.5	20.6

(*) Designates Specified Input

PART LOAD PERFORMANCE:

Pct Load	CAP (TR)	Pct Power	Inp Pwr (KW)	EEFT (°F)	ELFT (°F)	CEFT (°F)	CLFT (°F)	Sys Perf (KW/TR)
100.0	1500.0	100.1	935	60.19	44.00	85.00	96.26	0.623
90.0	1350.0	87.7	819	58.57	44.00	85.00	95.10	0.607
80.0	1200.0	76.9	718	56.95	44.00	85.00	93.96	0.598
70.0	1050.0	67.3	629	55.33	44.00	85.00	92.84	0.599
60.0	900.0	58.9	550	53.71	44.00	85.00	91.73	0.611
50.0	750.0	51.0	476	52.09	44.00	85.00	90.63	0.635
40.0	600.0	43.3	404	50.47	44.00	85.00	89.54	0.673
30.0	450.0	35.4	331	48.85	44.00	85.00	88.45	0.736
20.0	300.0	27.4	256	47.24	44.00	85.00	87.35	0.853
15.0	225.6	23.6	220	46.43	44.00	85.00	86.81	0.975

CHW & CW Pumps Details

kaer

Pump	PCHWP 1-6	PCHWP 7-8
Flowrate (Usgpm)	2,222	741
Head (m)	20	20
Motor kW	45	15

Pump	SCHWP 1A-1B	SCHWP 1C-1D	SCHWP 2A-2C	SCHWP 3A-3C	SCHWP 4A-4C	SCHWP 5A-5C
Flowrate (Usgpm)	1,500	300	2,100	1,400	1,500	2,000
Head (m)	40	40	40	30	30	40
Motor kW	45	15	75	37	45	75

Pump	CWP 1-6	CWP 7-8
Flowrate (Usgpm)	3,750	1,250
Head (m)	40	40
Motor kW	132	45

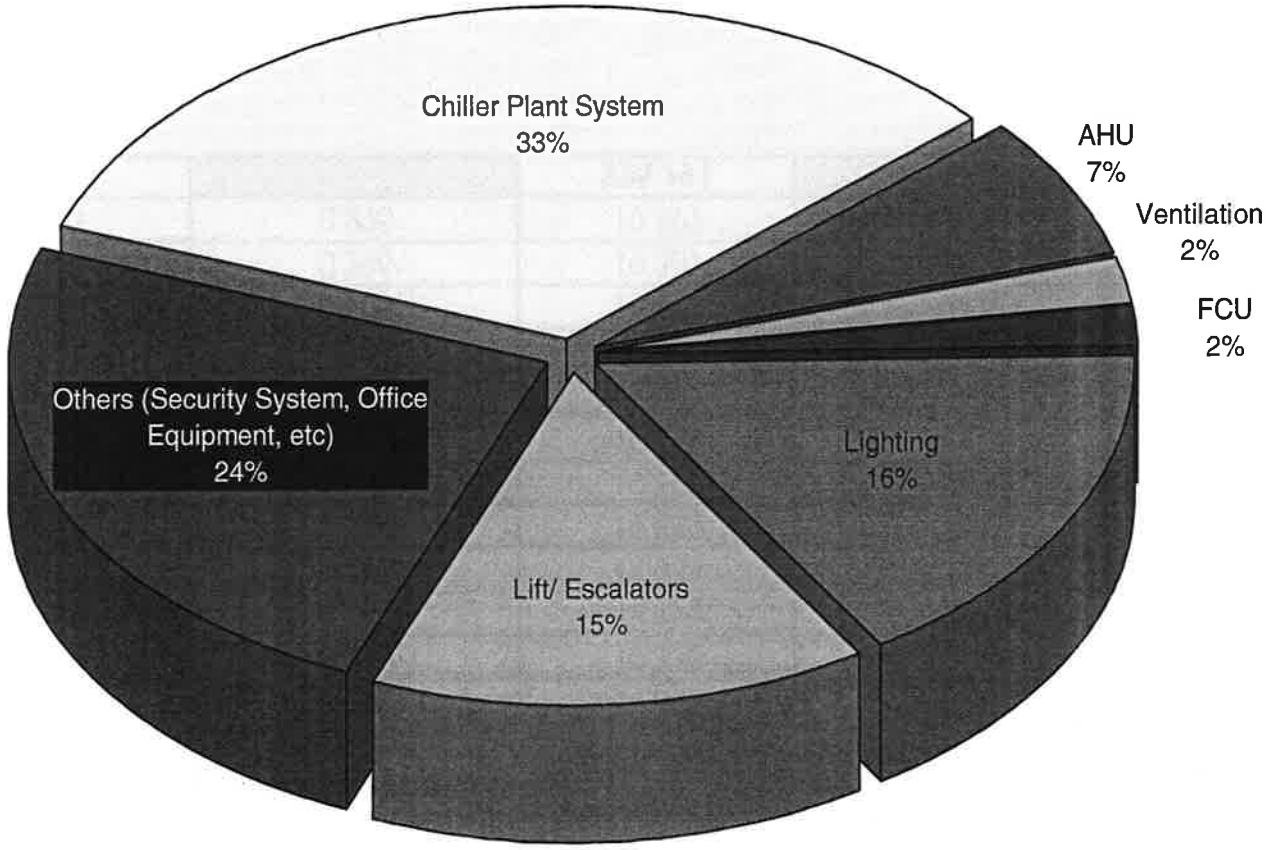
Current Energy Usage

kaer

Month	kWh Consumption	kWh tariff (MYR/kWh)	Max demand (kW)	Max demand rate (MYR/kW)	Total amount (MYR)
Jun-09	8,102,553	0.288	19,622	23.93	2,803,088.77
May-09	8,321,499	0.288	19,138	23.93	2,854,558.07
Apr-09	7,997,008	0.288	14,124	23.93	2,641,125.45
Mar-09	8,172,455	0.288	18,953	23.93	2,807,203.00
Feb-09	7,553,353	0.296	19,359	24.60	2,712,023.89
Jan-09	8,310,797	0.296	19,192	24.60	2,932,119.11
Dec-08	8,417,212	0.296	19,649	24.60	2,974,860.15
Nov-08	8,056,754	0.296	19,082	24.60	2,854,216.38
Oct-08	8,162,258	0.296	19,061	24.60	2,884,928.97
Sep-08	7,930,758	0.296	18,913	24.60	2,812,764.17
Aug-08	8,432,324	0.296	19,307	24.60	2,970,920.10
Jul-08	8,439,463	0.296	19,392	24.60	2,975,124.25
Total	**97,896,434**		**225,791**		**34,222,932.31**

Current Energy Usage

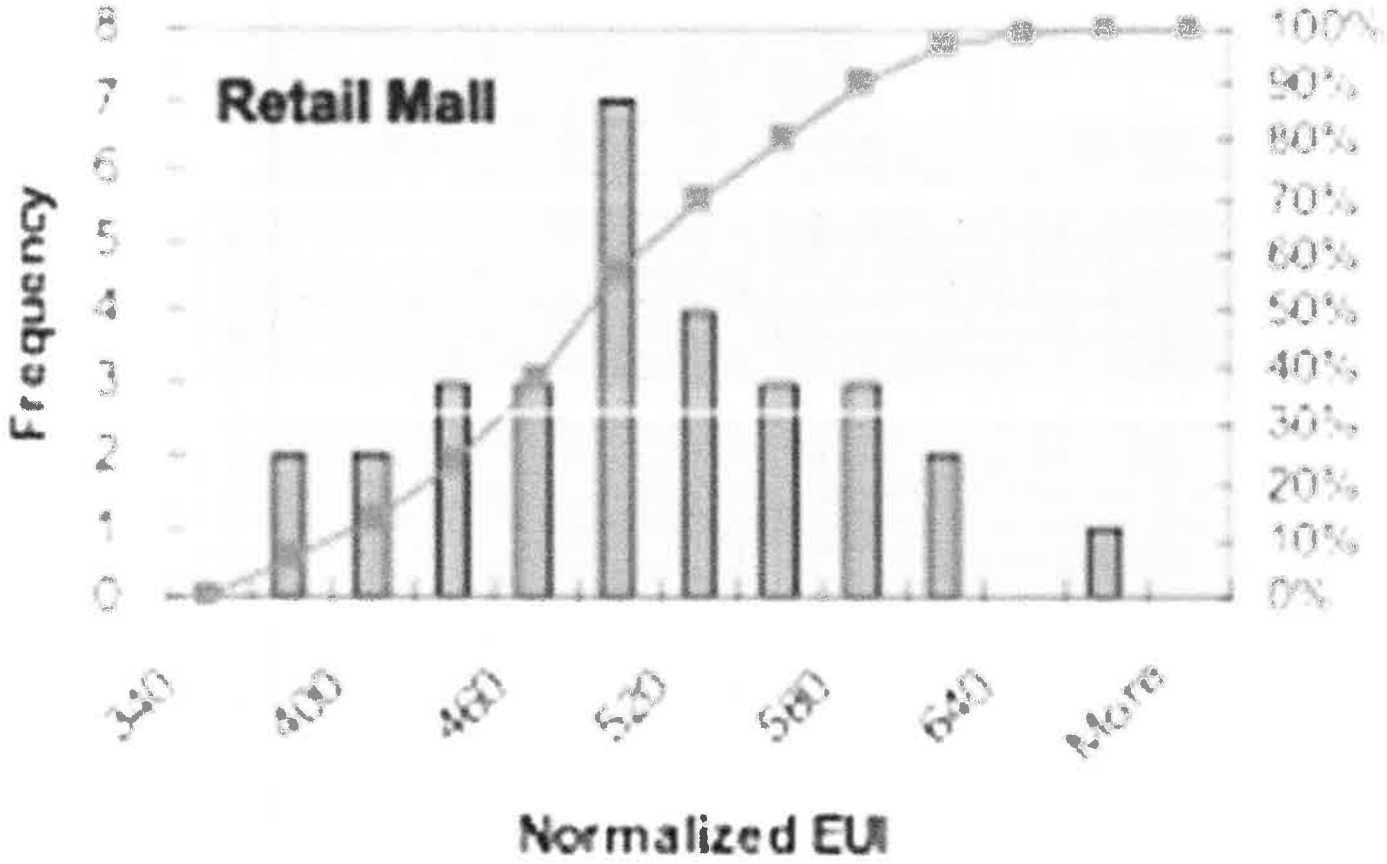
kaer



Energy Usage Benchmarking

kaer

Actual Building	: xxx ft²/ RT
Actual Cooling Load	: xxx RT



CHW Plant System Design

kaer

81 nos. AHUs – Installed AHU Tonnage 7,917 RT

Design Tonnage = 202 ft^2/RT

Fresh Air Intake = 540,000 CMH

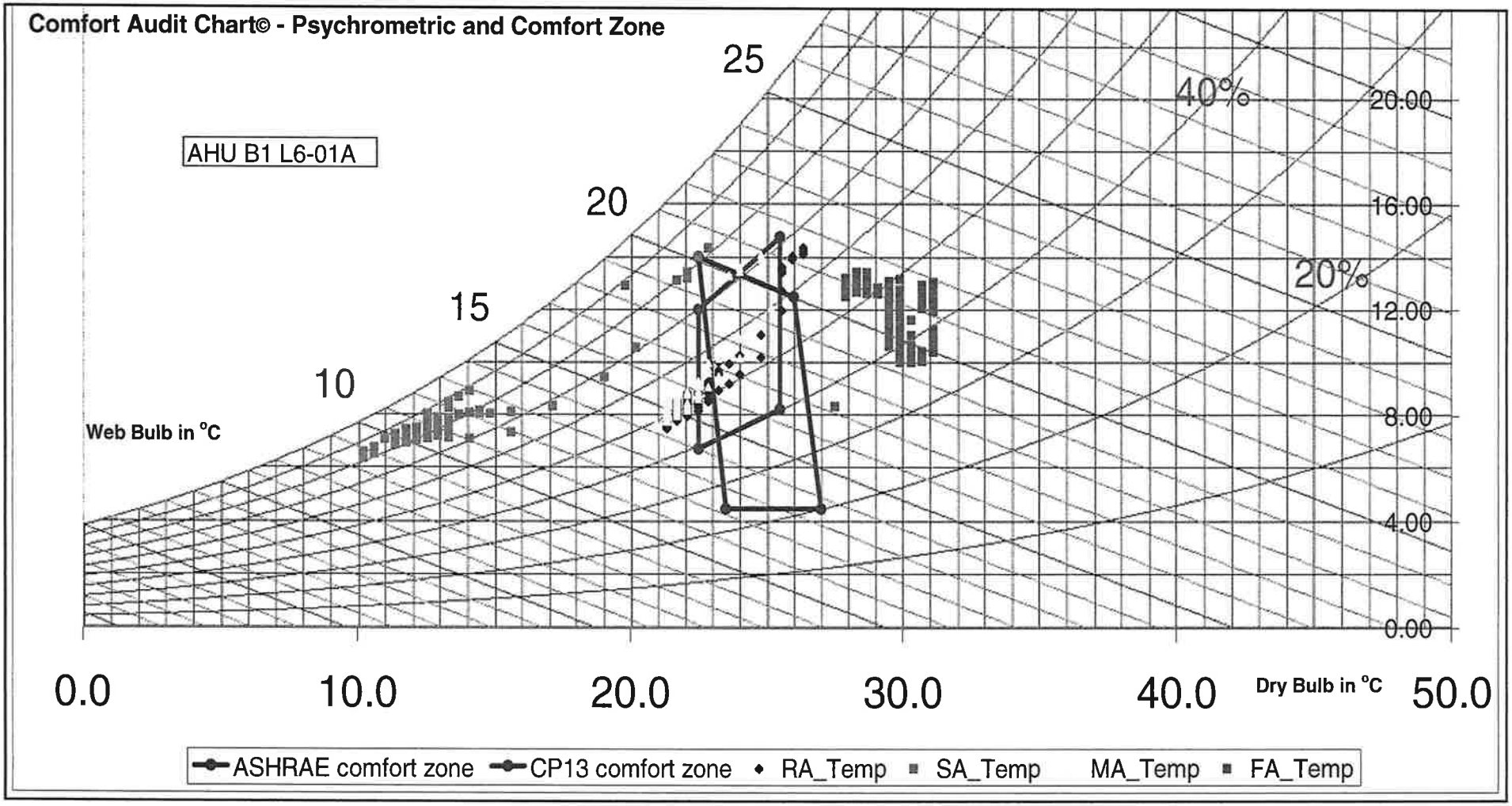
Design Space Condition : 22.5 – 25.5 Deg C

Relative Humidity : ≤ 70 %

	Design	Design
Chiller	1-6	7/8
Capacity (RT)	1,500	500
Efficiency (kW/RT)	0.62	0.59
CHWST (°C)	6.00	6.00
CHWRT (°C)	15.00	15.00
CHW flow (USgpm)	2,222	741
CWST (°C)	29.40	29.40
CWRT (°C)	35.70	35.60

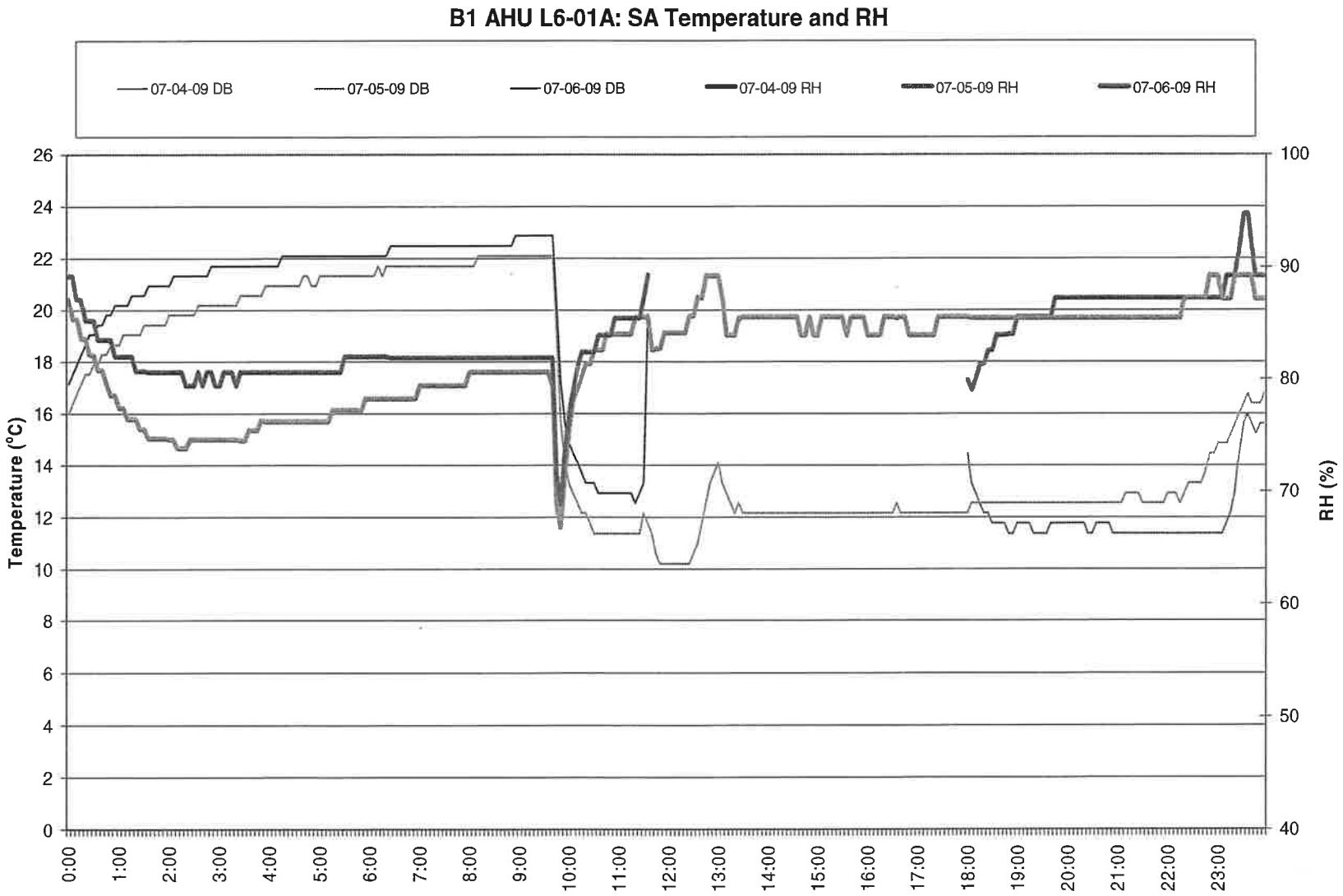
AHU L6-01 A - Condition

kaer



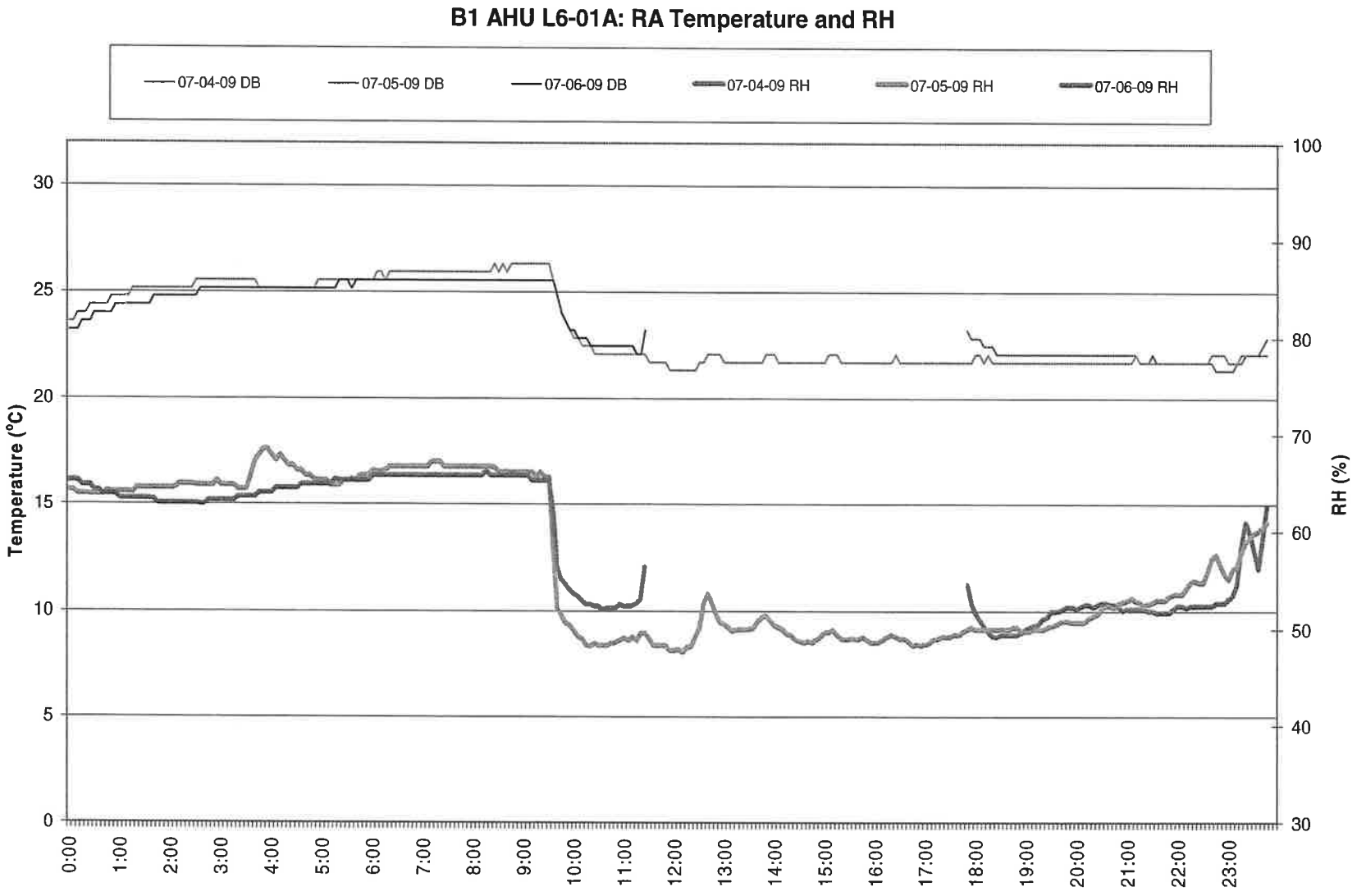
AHU L6-01 A - Condition

kaer



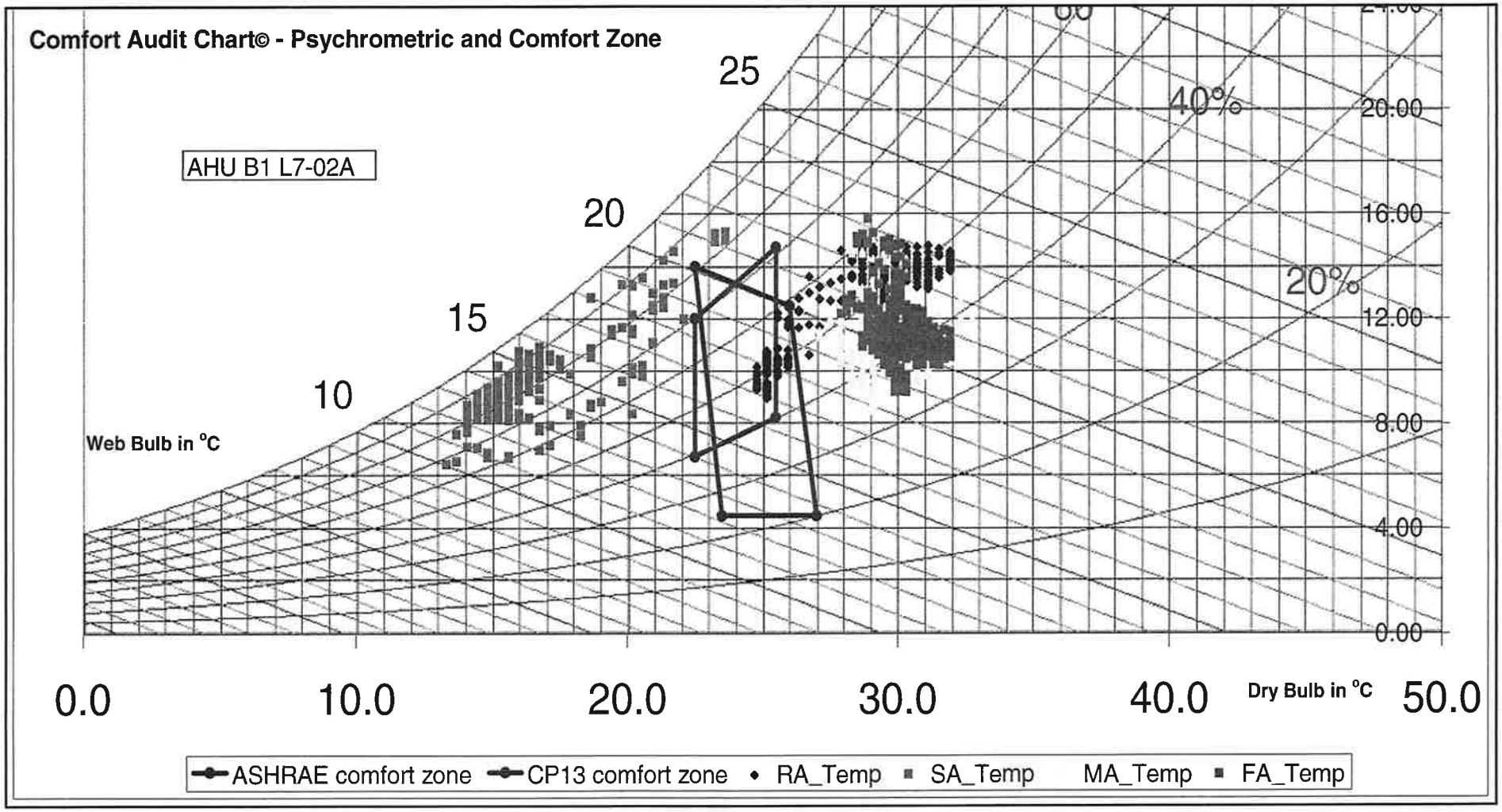
AHU L6-01 A - Condition

kaer



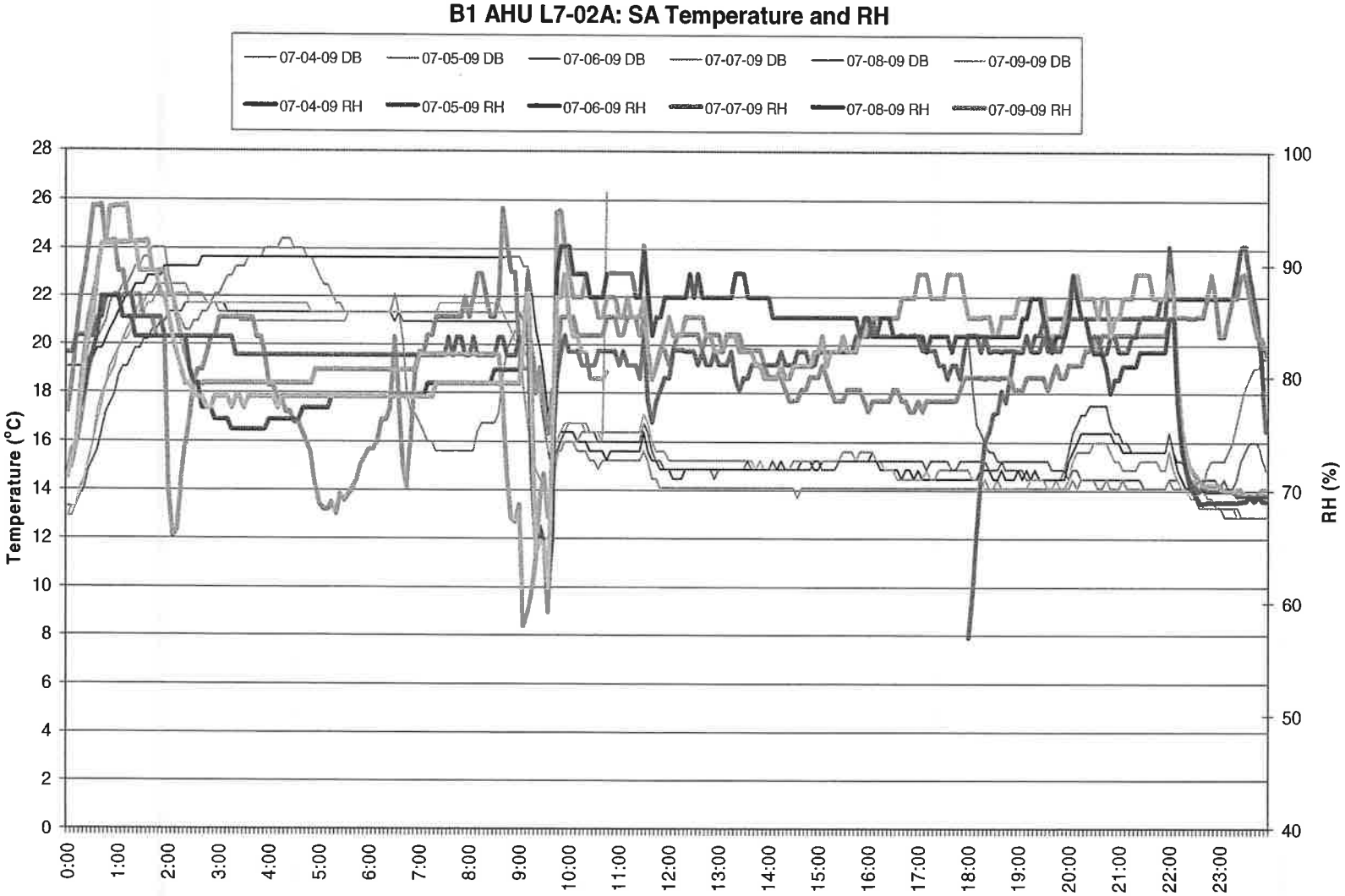
B1 AHU L7-02 A

kaer



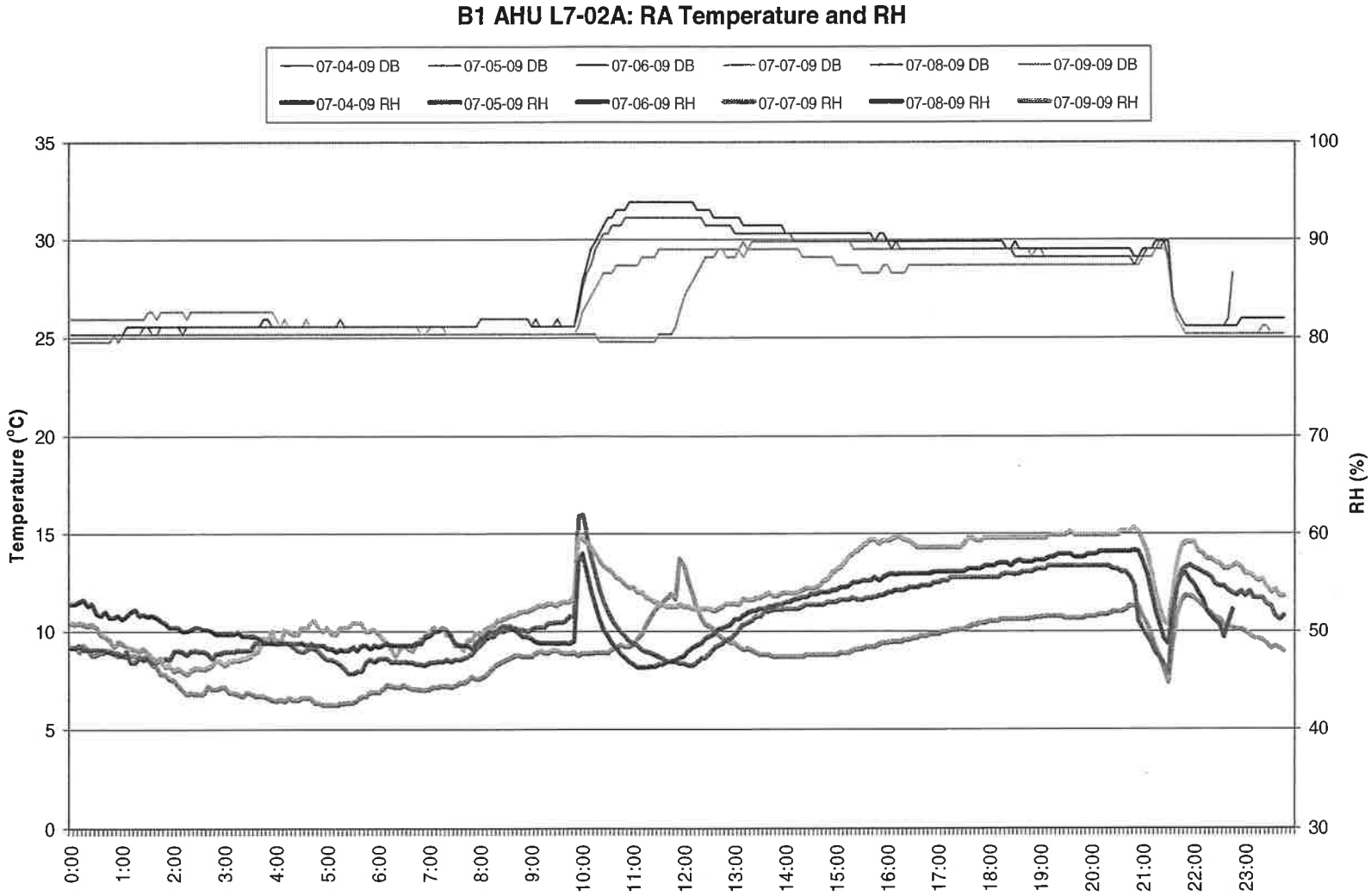
AHU L7-02 A - Condition

kaer



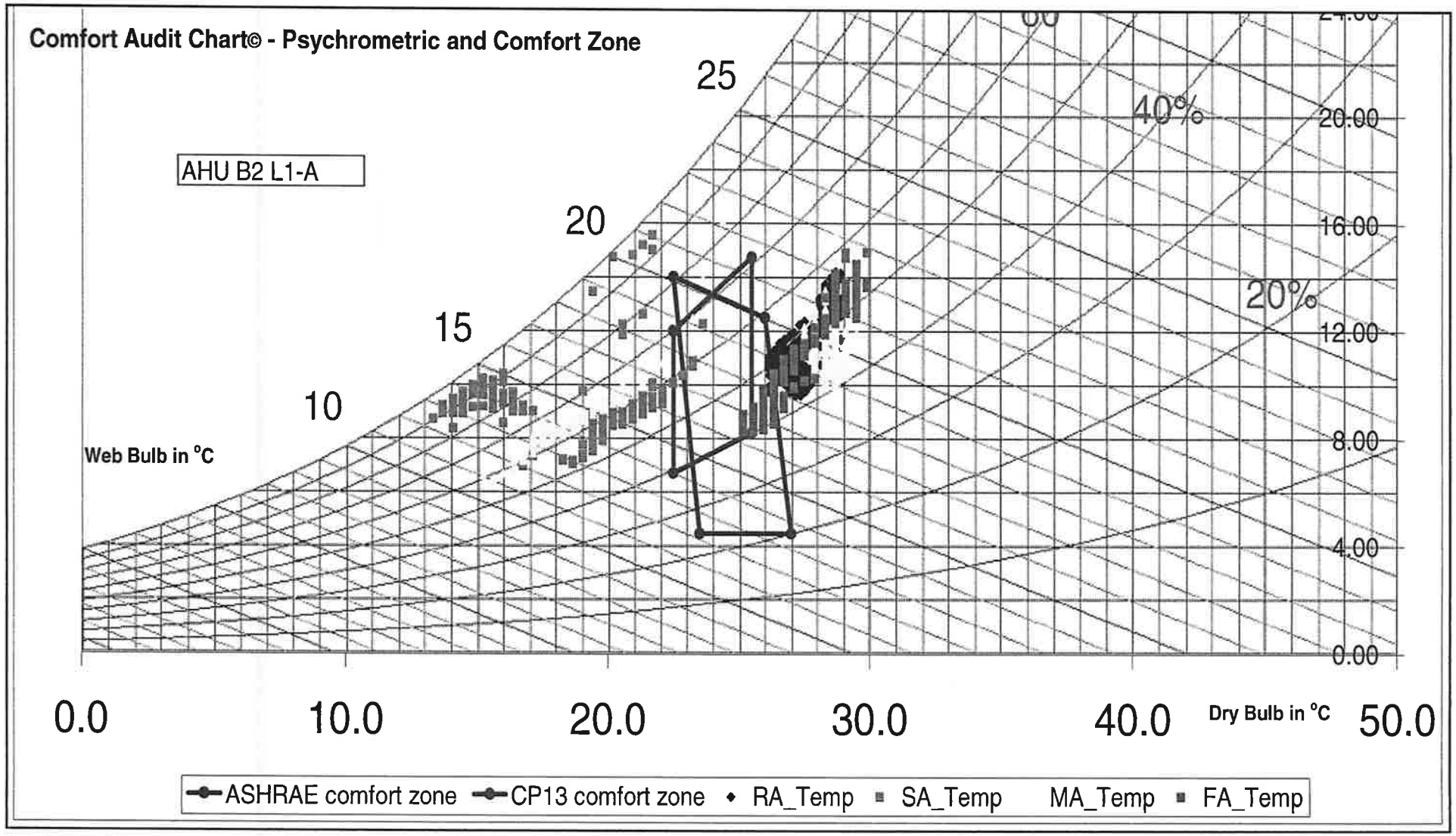
AHU L7-02 A - Condition

kaer



AHU L1-A - Condition

kaer



AHU L1-A - Condition

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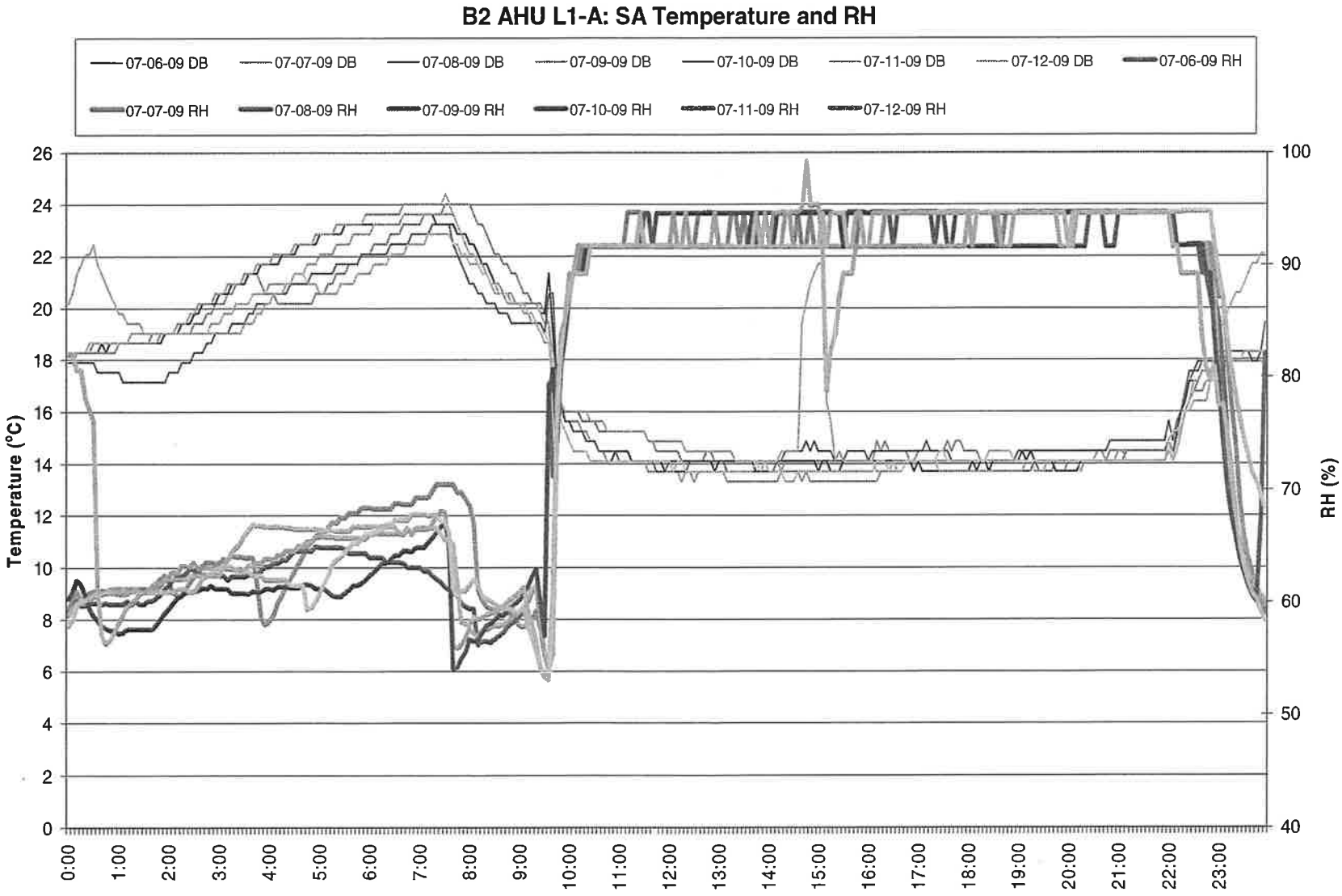

AHU L1-A - Condition

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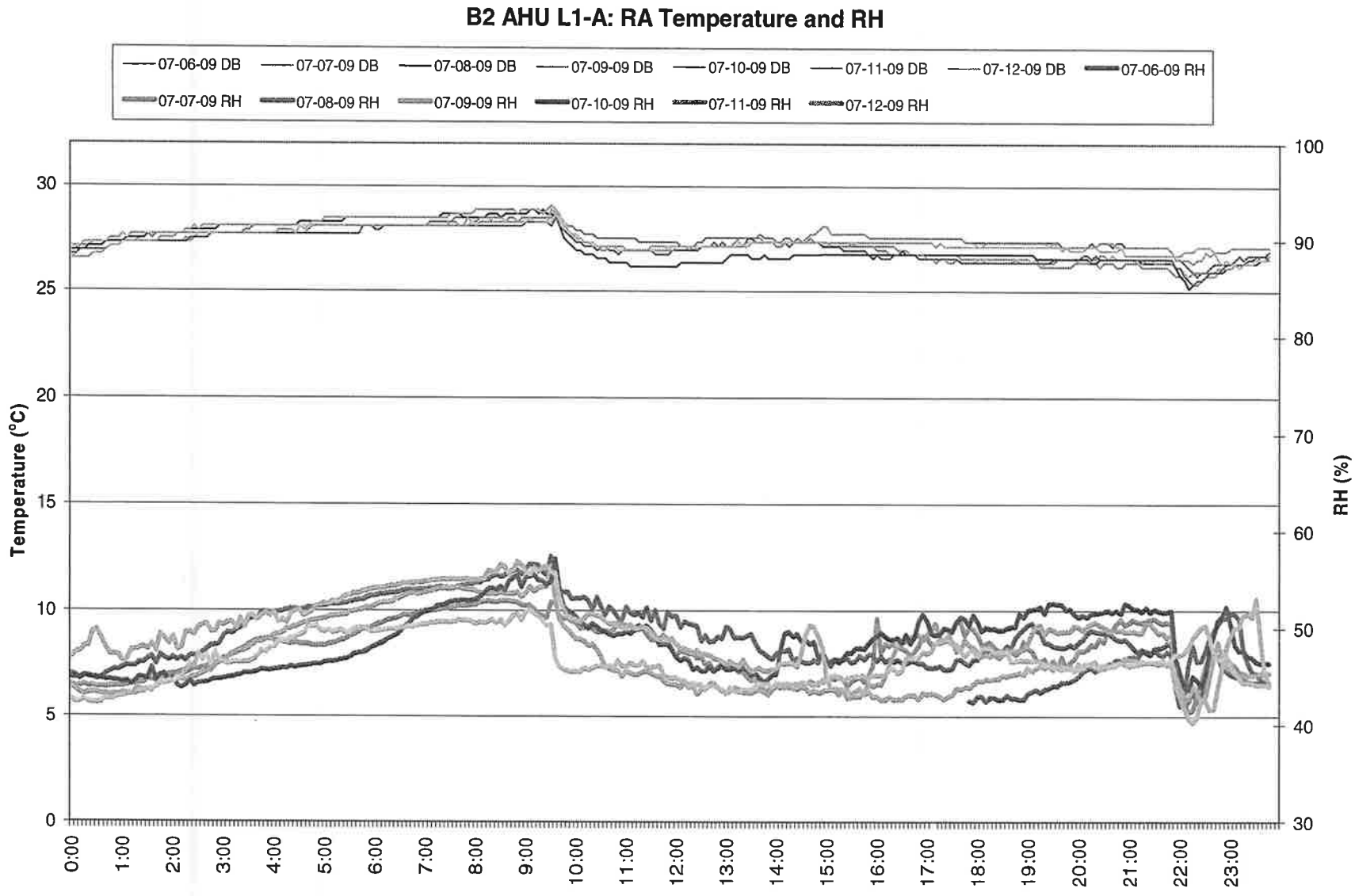
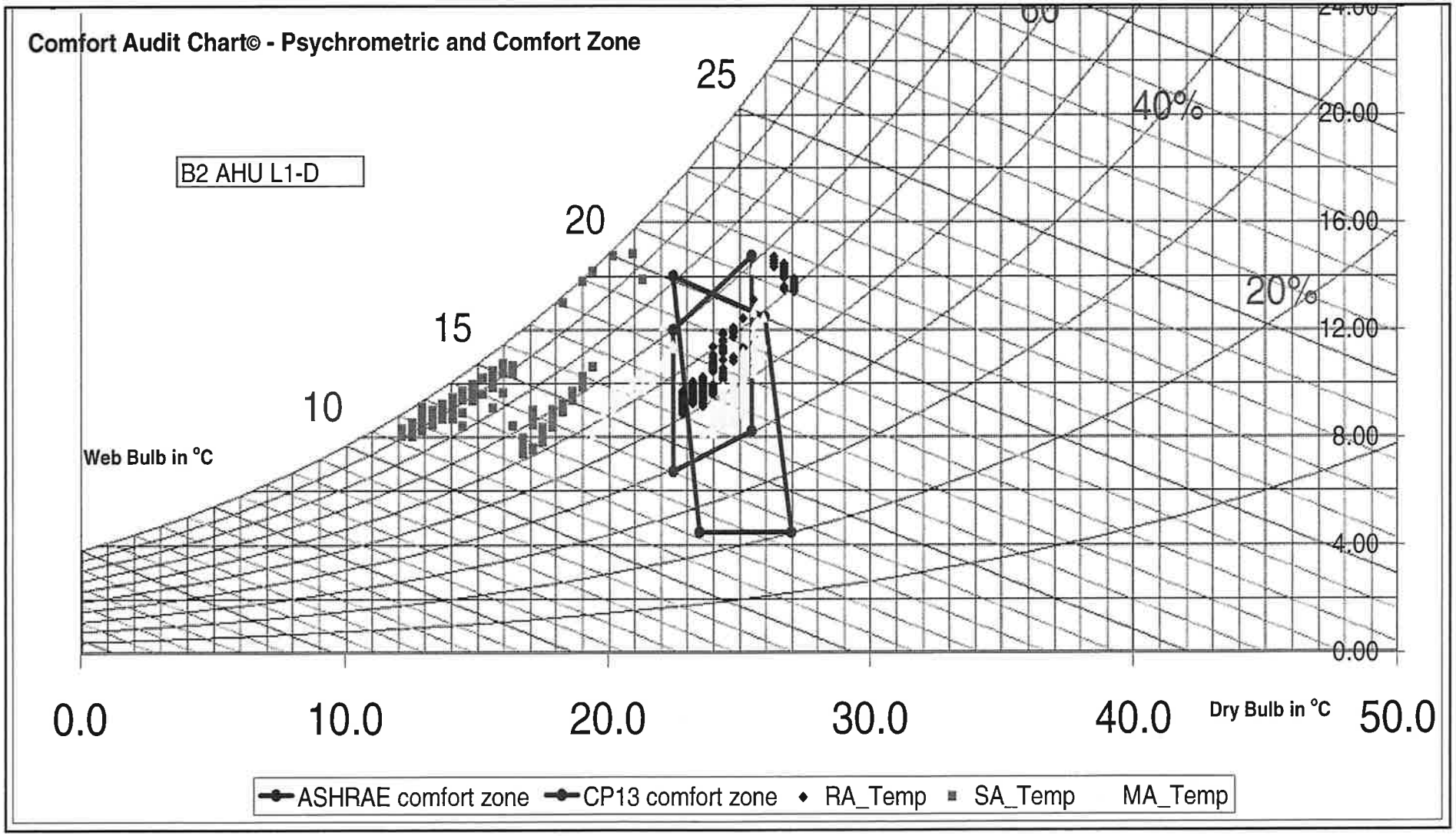


AHU L1-D - Condition

kaer



AHU L1-D - Condition

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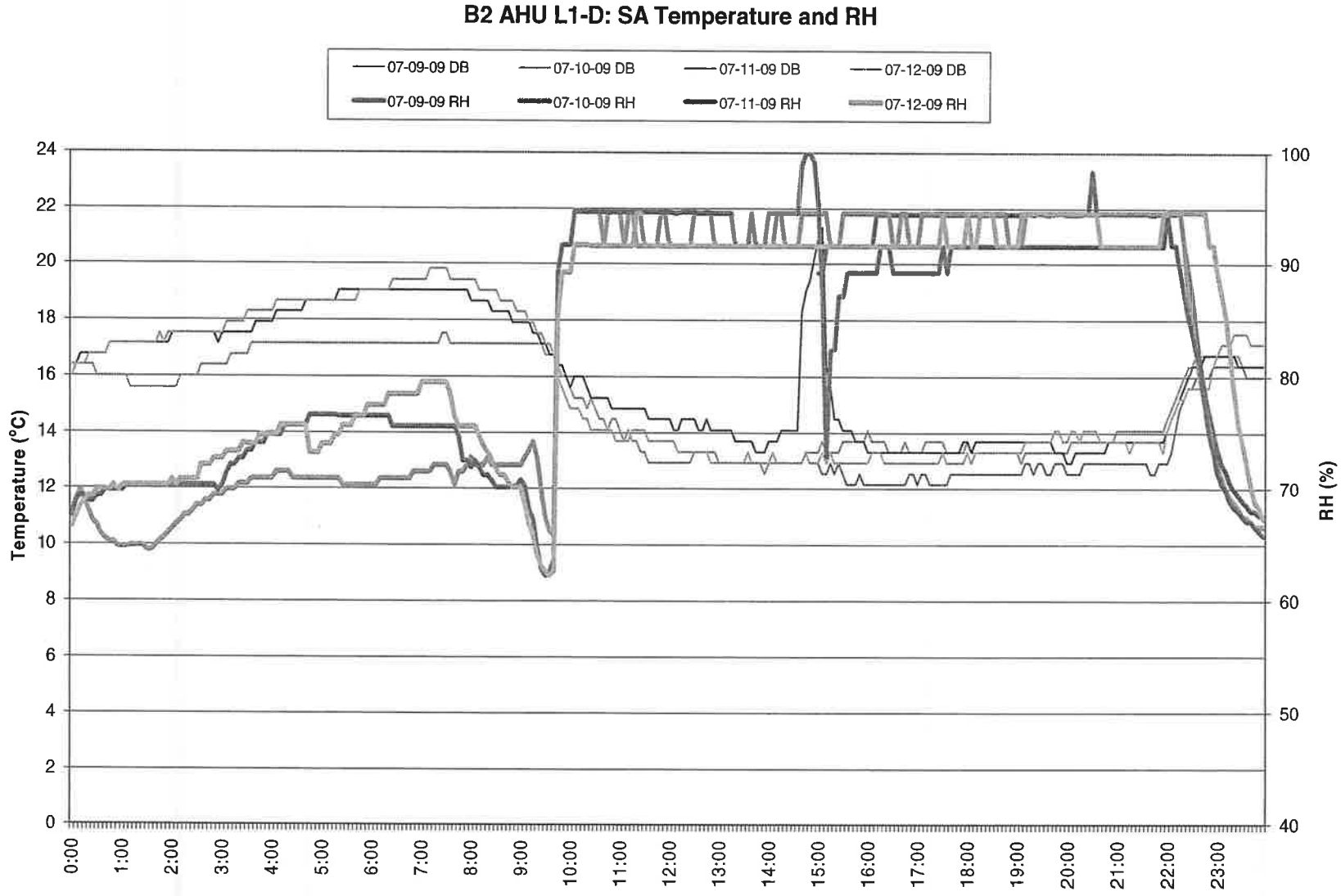

AHU L1-D - Condition

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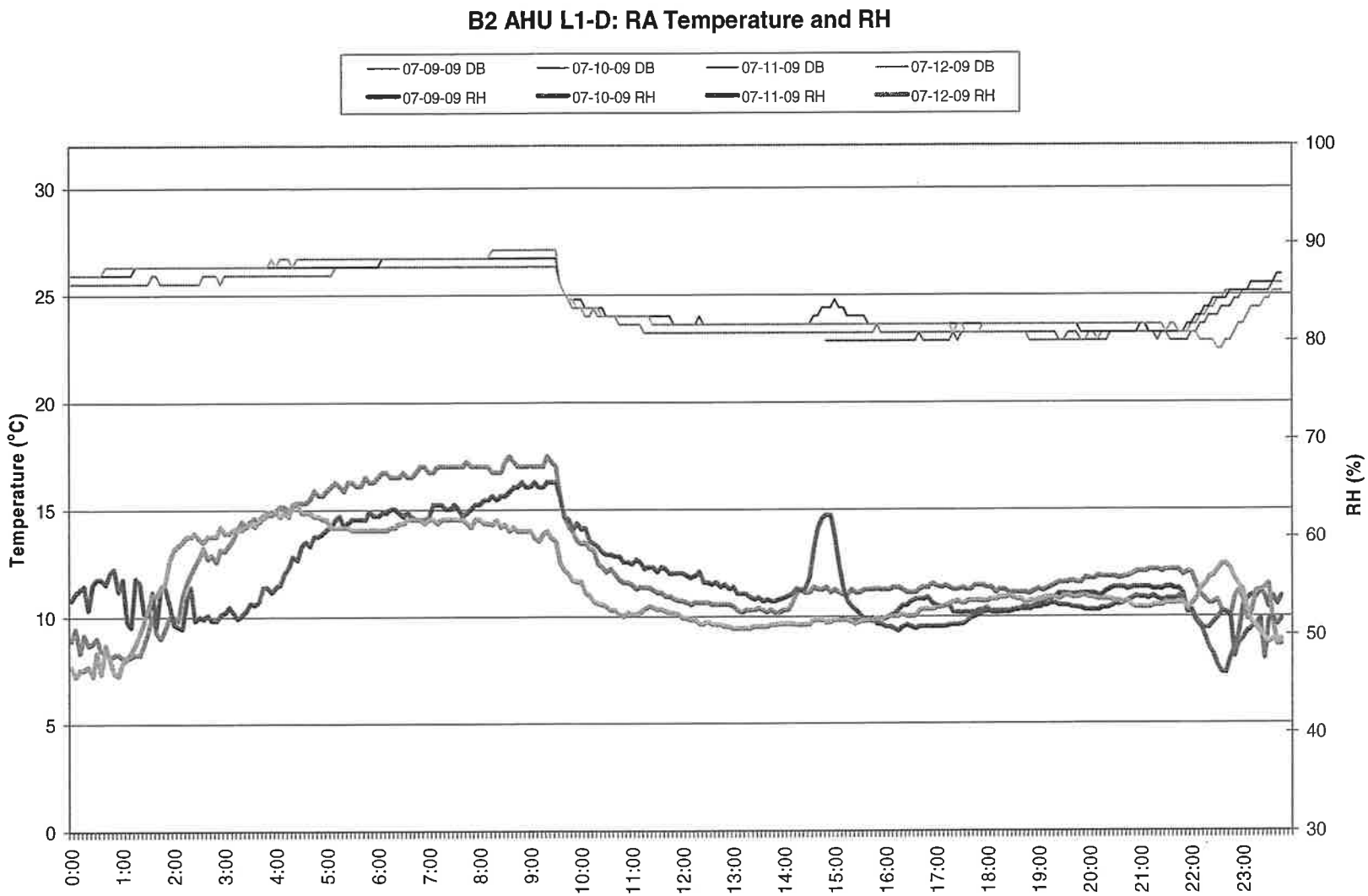
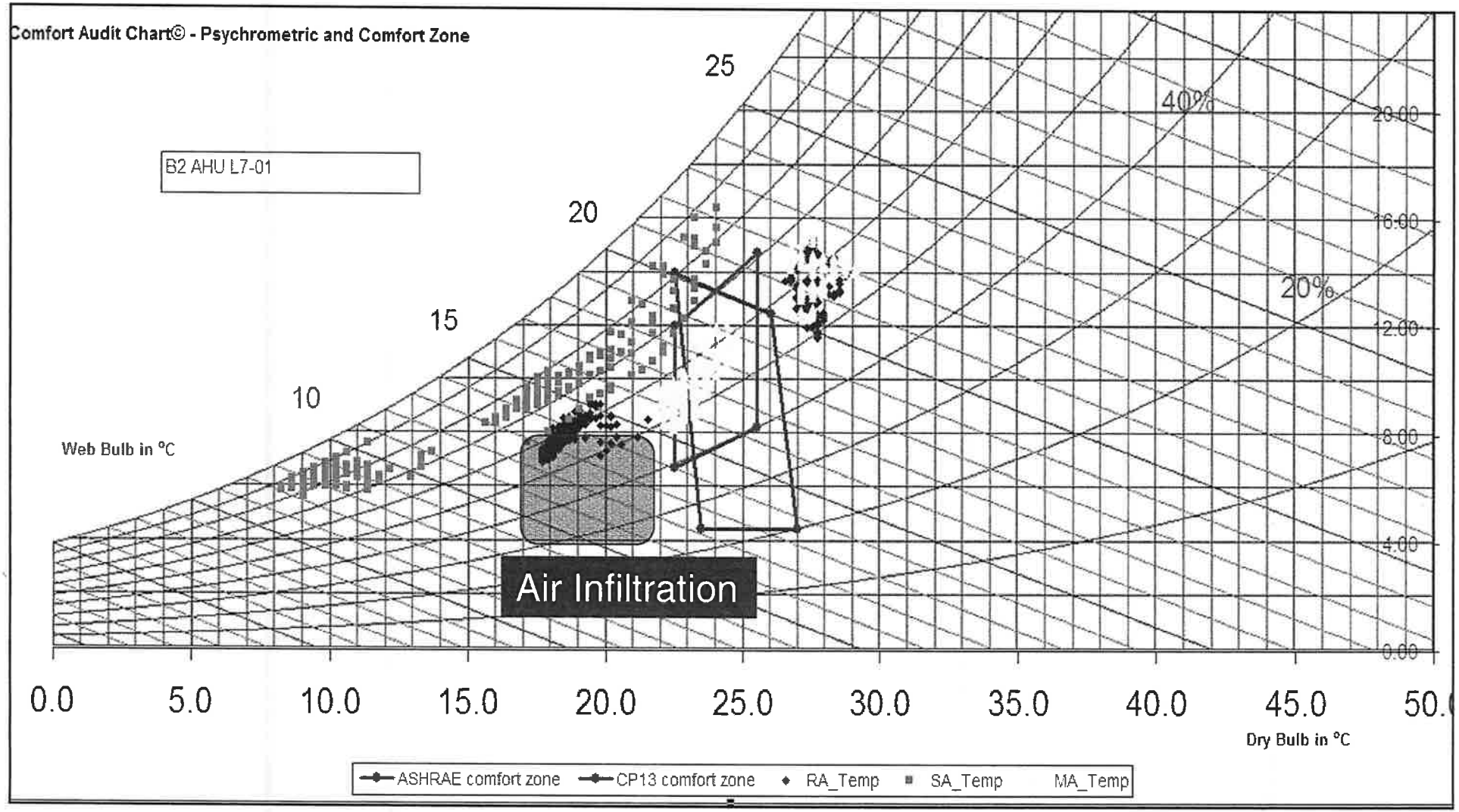


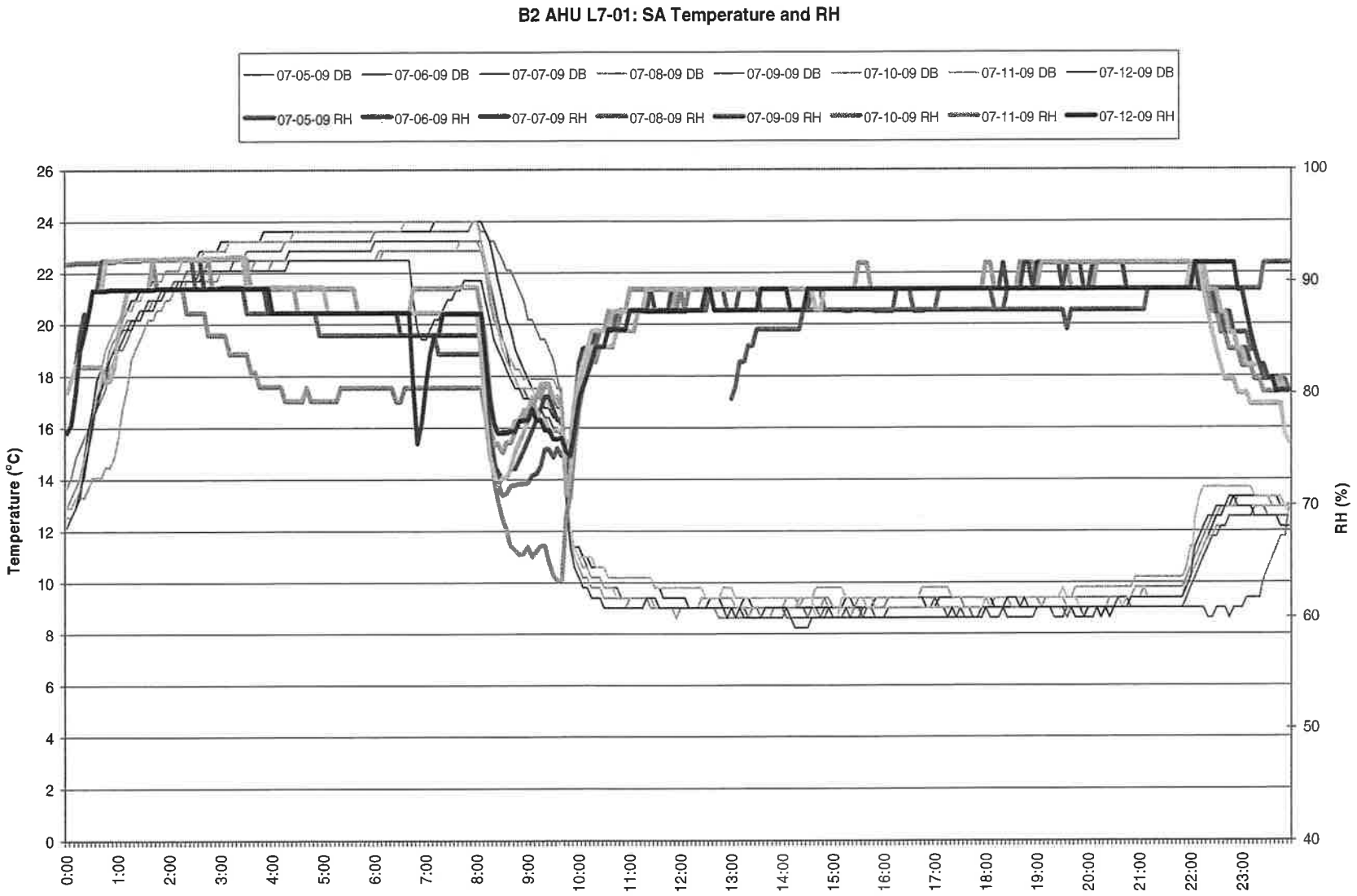
B2 AHU L7-01

kaer



AHU L7-01 - Condition

kaer



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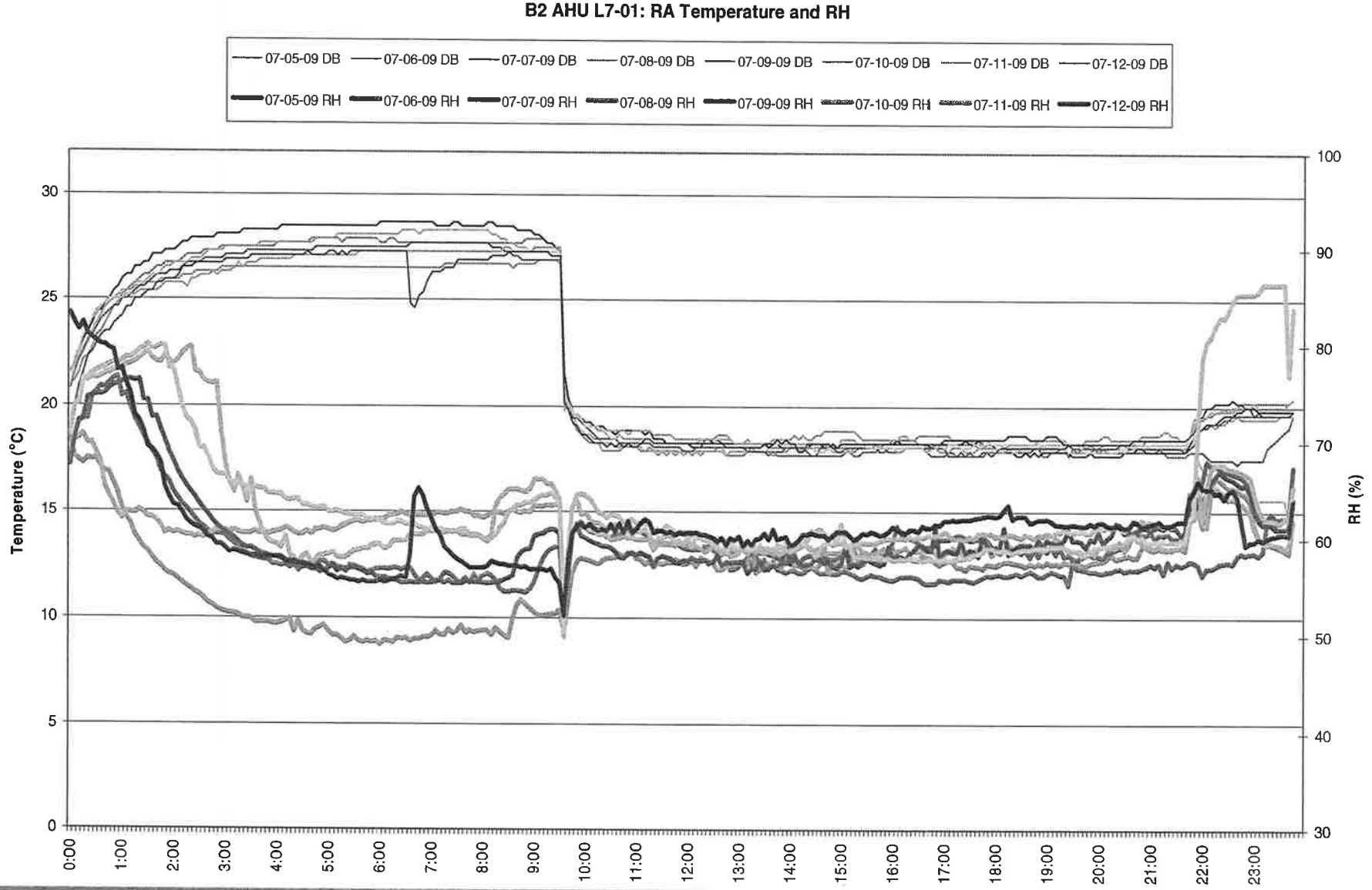
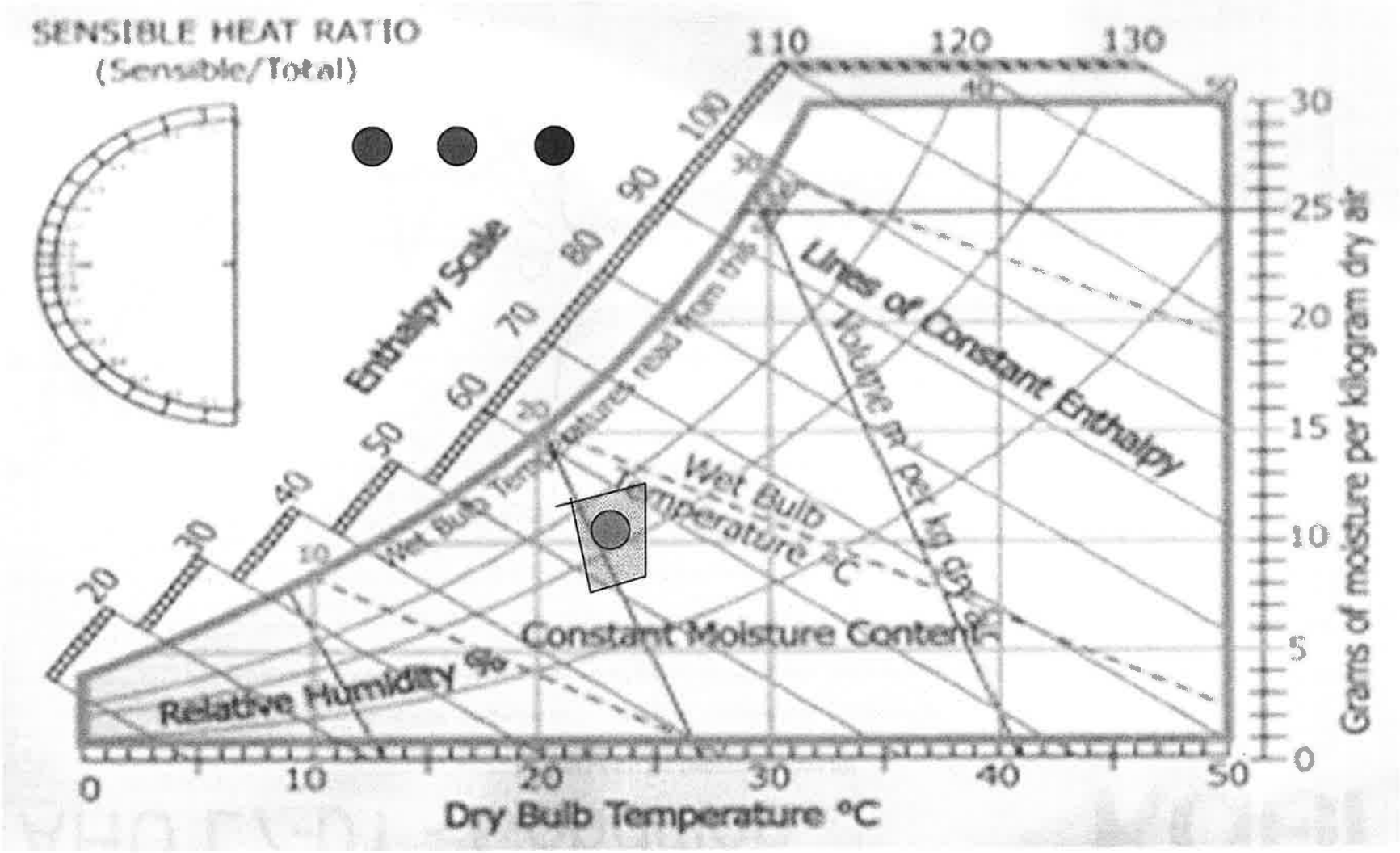


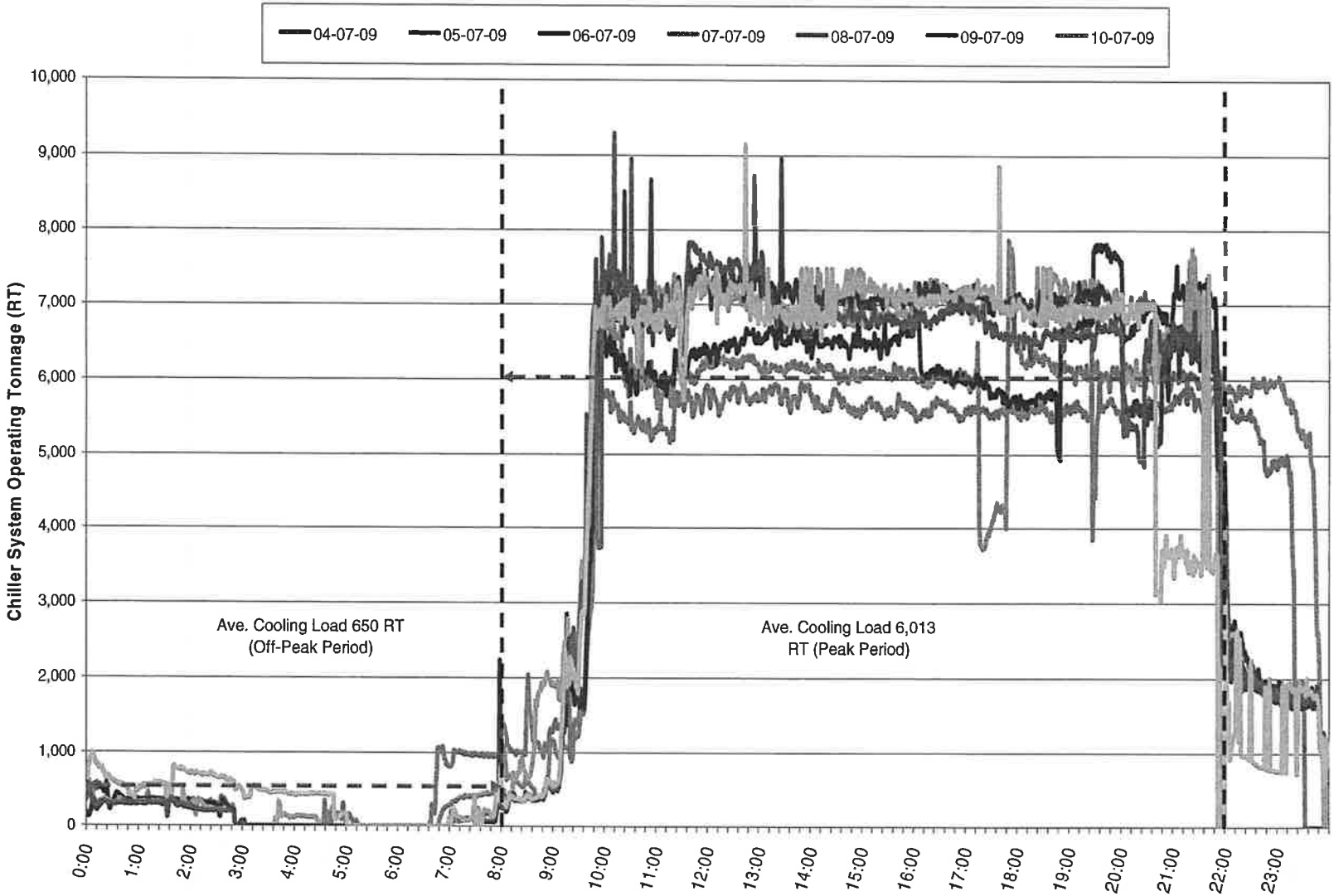
Controls – Show Current Condition

kaer



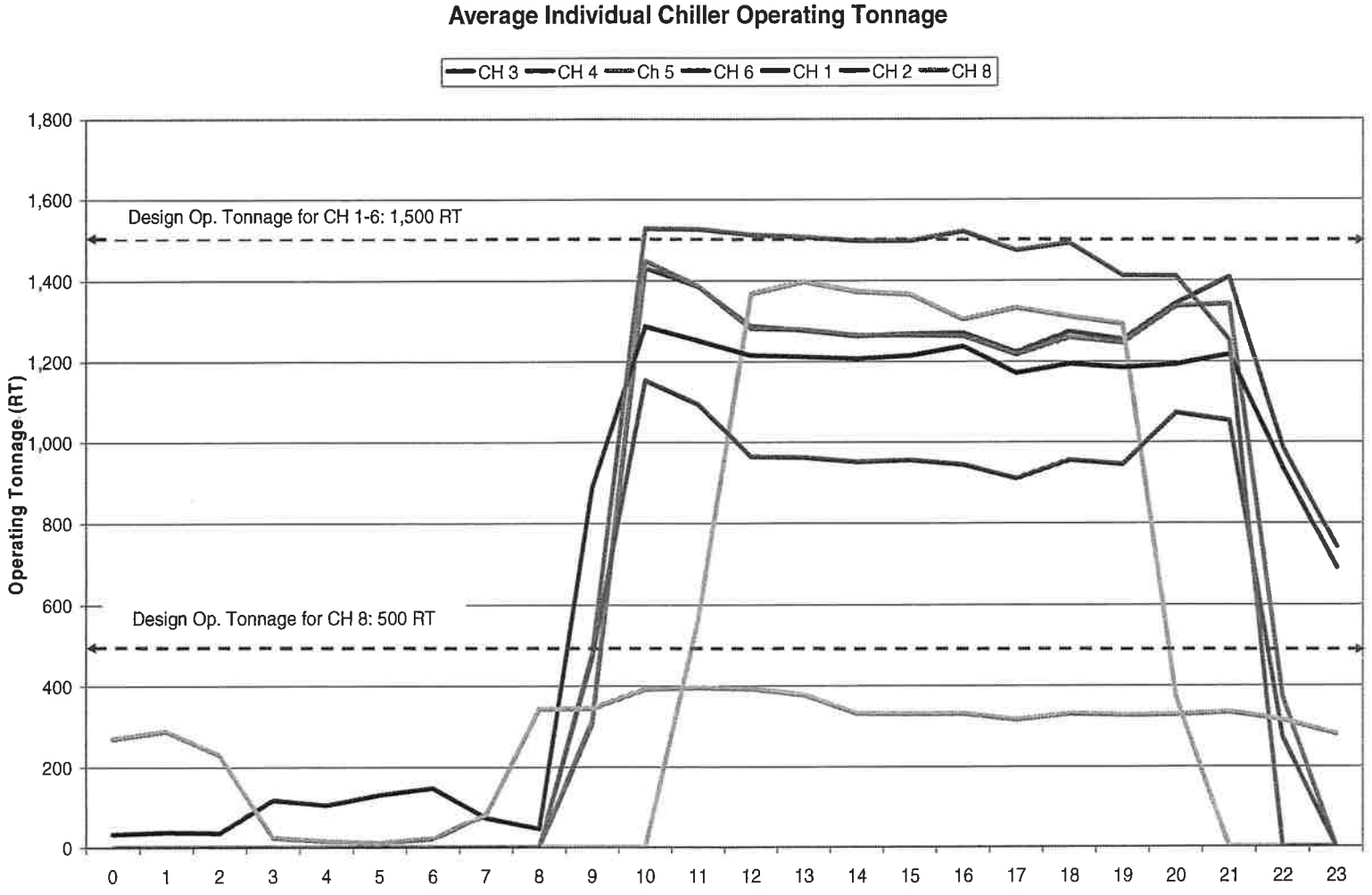
System Cooling Tonnage

kaer



Chiller Operating Tonnage

kaer



Chiller Design & Operating Performance

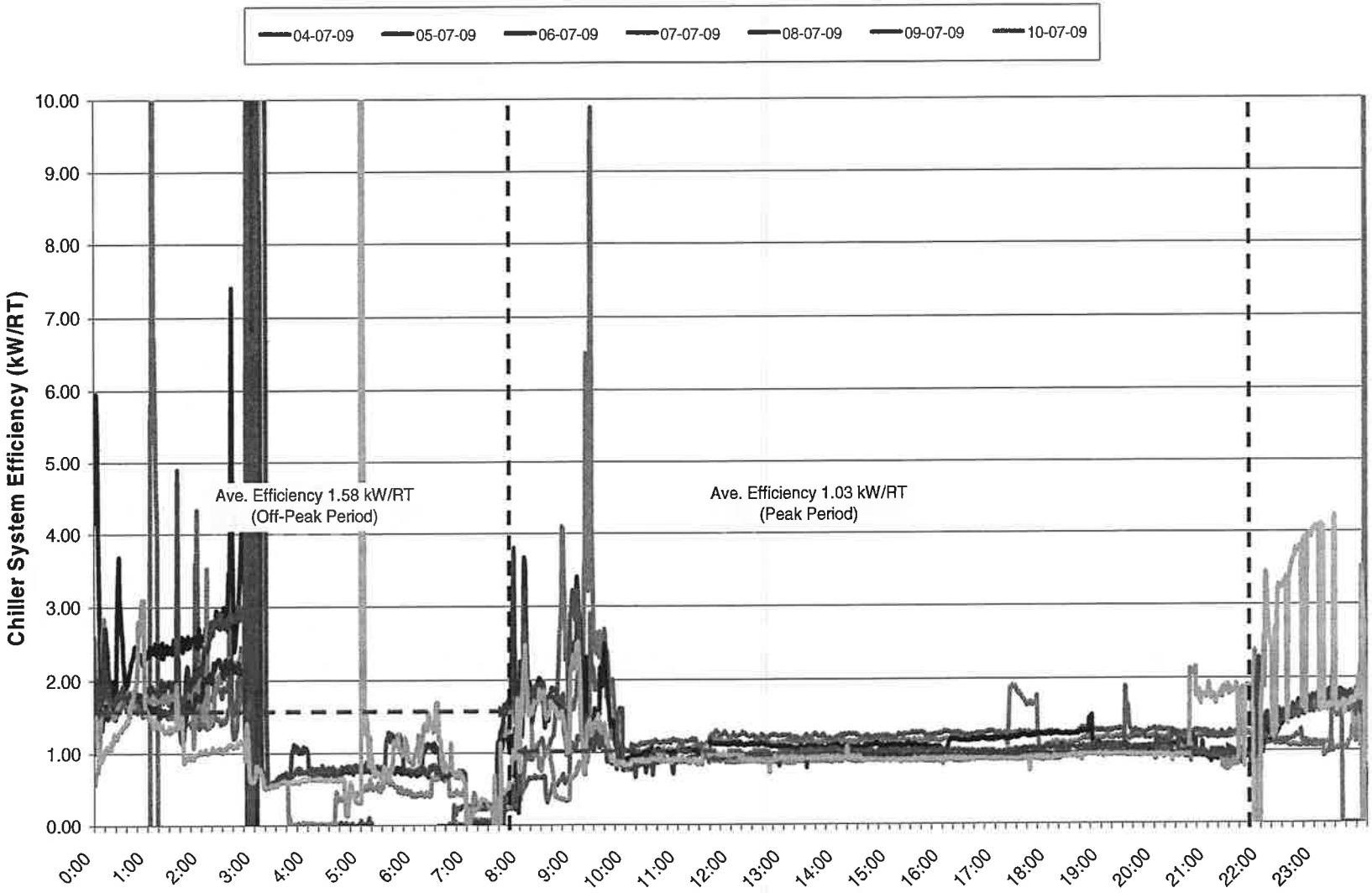
kaer

	Design	Operating					
Chiller	1-6	1	2	3	4	5	6
Capacity (RT)	1,500	1,215	1,499	1,268	1,266	1,366	956
Efficiency (kW/RT)	0.62	0.69	0.56	0.59	0.64	0.59	0.79
CHWST (°C)	6.00	7.00	6.30	6.20	6.20	6.00	6.20
CHWRT (°C)	15.00	14.90	17.70	13.60	13.60	12.30	13.20
CHW flow (USgpm)	2,222	2,200	1,912	2,240	2,240	2,508	1,743
CWST (°C)	29.40	30.30	30.20	29.60	29.50	29.50	29.50
CWRT (°C)	35.70	35.70	35.80	34.30	34.70	34.30	35.00

	Design	Operating
Chiller	7/8	8
Capacity (RT)	500	400
Efficiency (kW/RT)	0.59	0.69
CHWST (°C)	6.00	6.70
CHWRT (°C)	15.00	14.80
CHW flow (USgpm)	741	658
CWST (°C)	29.40	30.20
CWRT (°C)	35.60	35.90

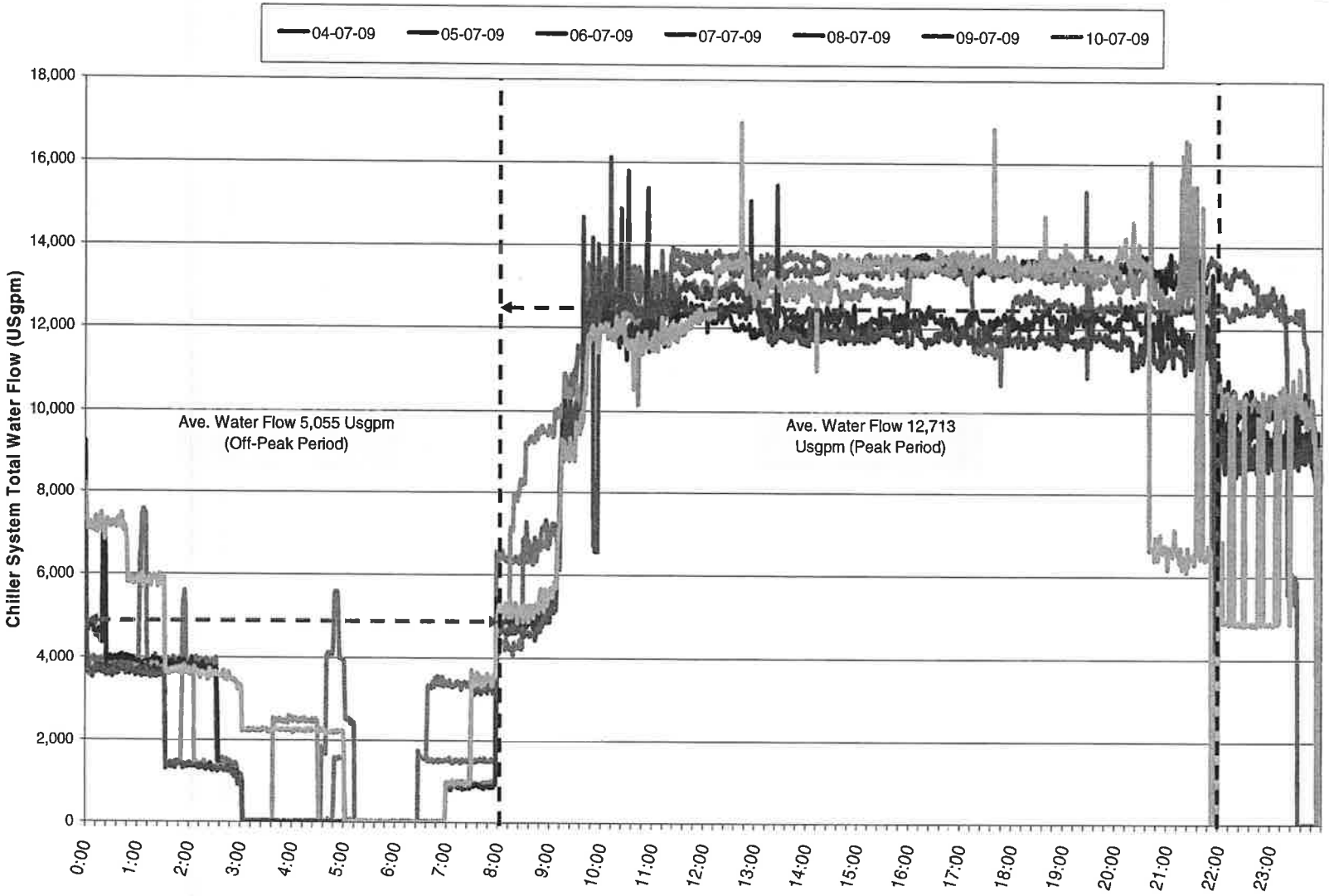
CHW System Efficiency

kaer



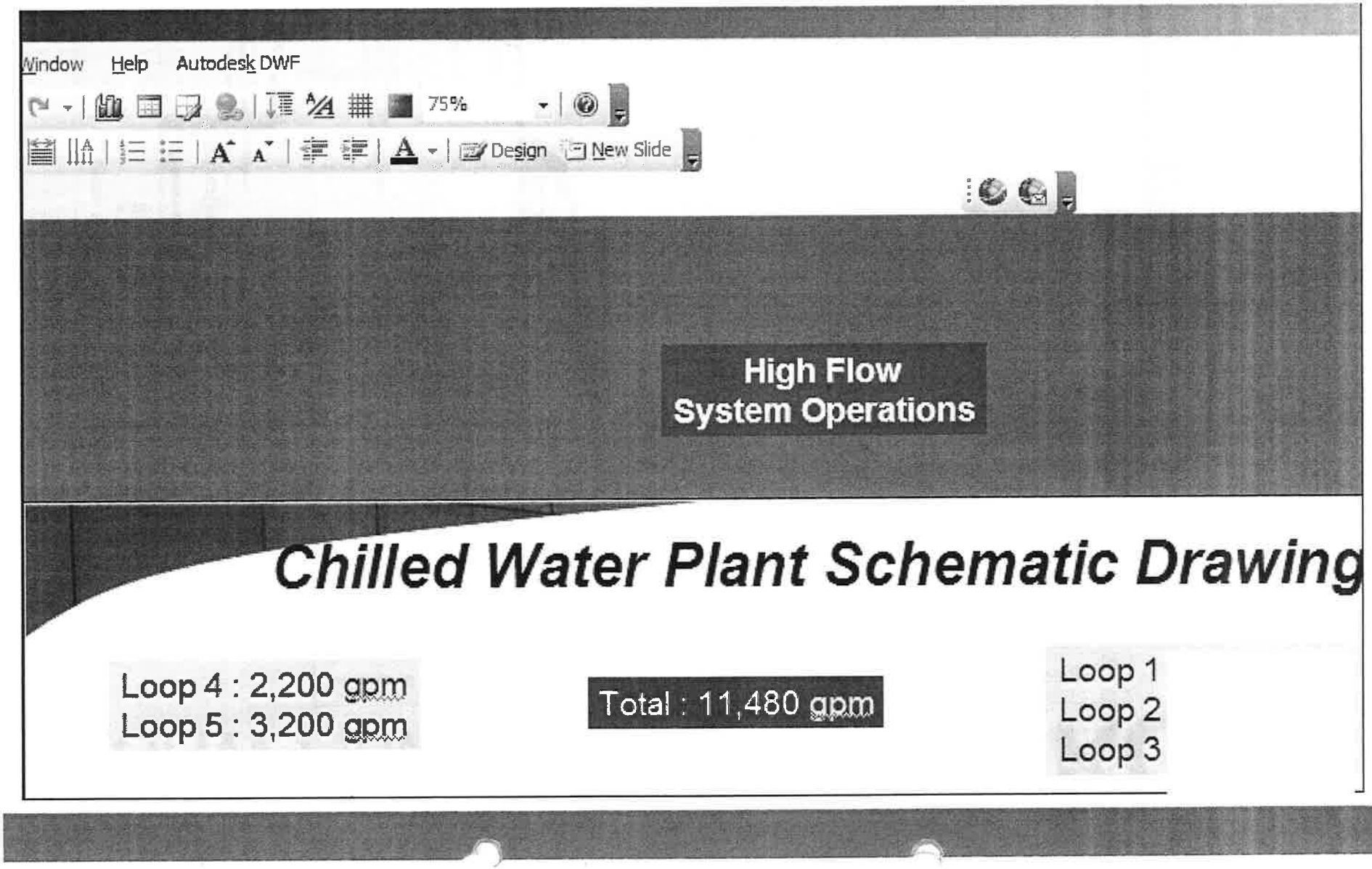
CHW Flow Rate

kaer



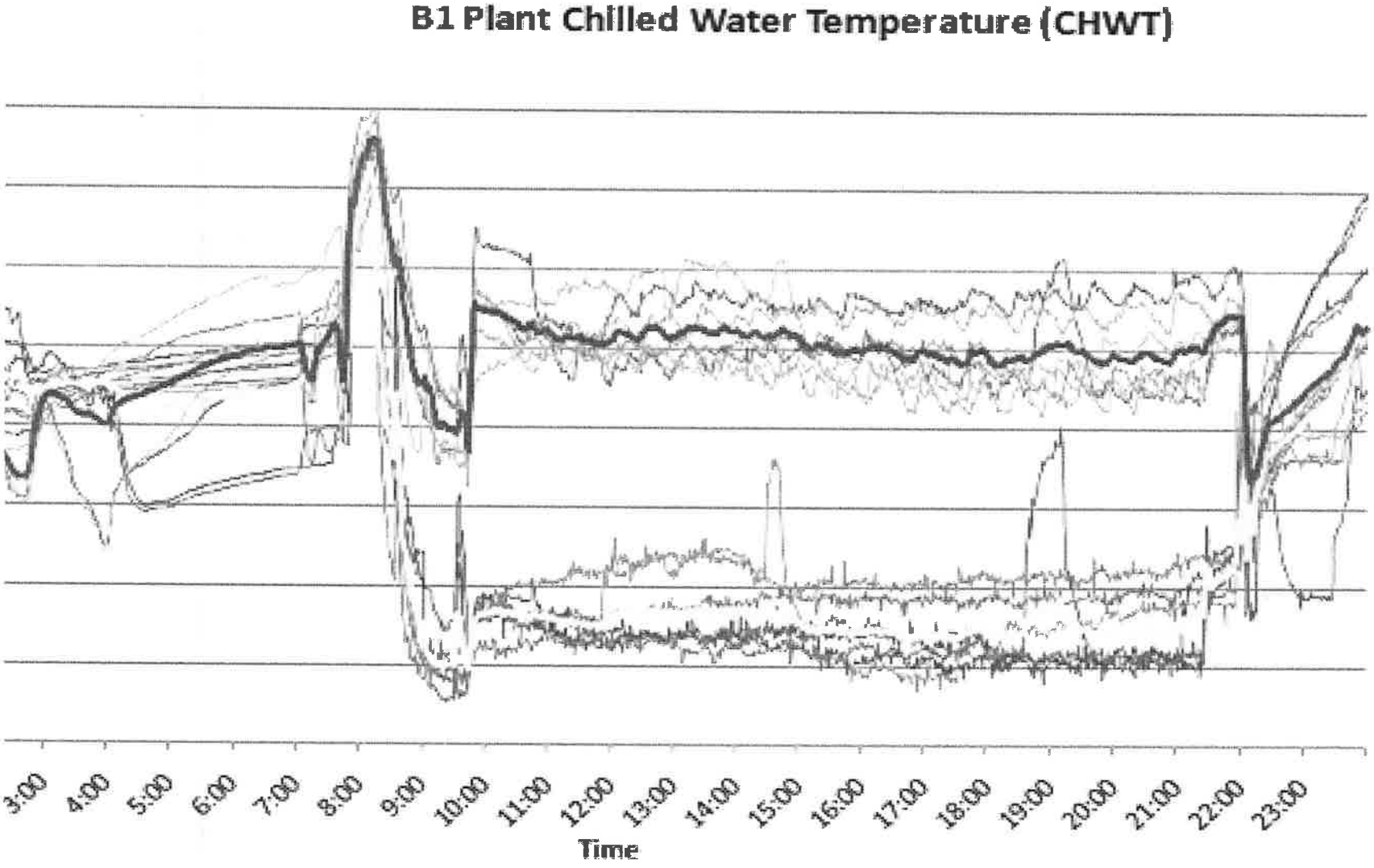
CHW Schematic Drawing

kaer



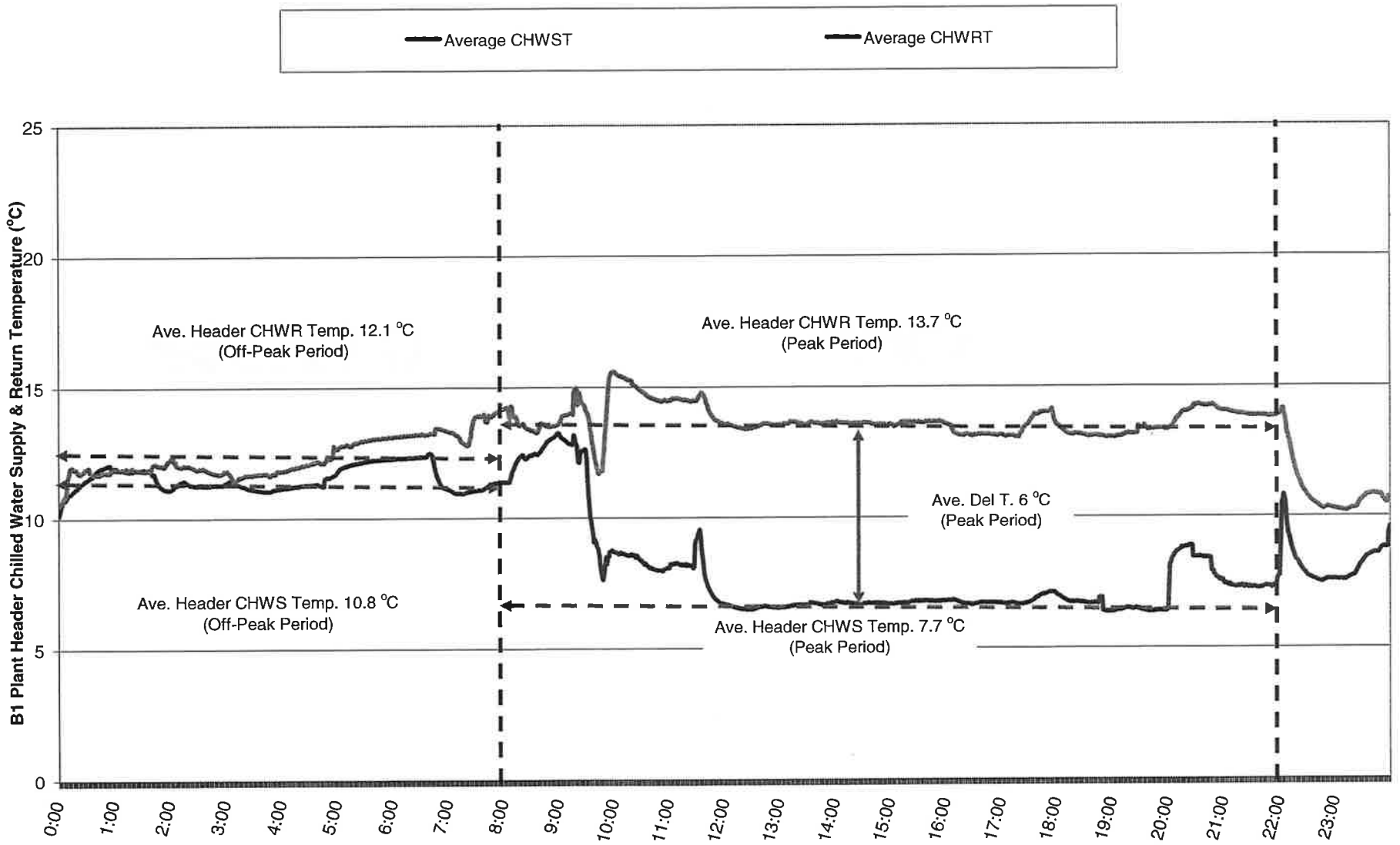
B1 Plant CHW System Temp

kaer



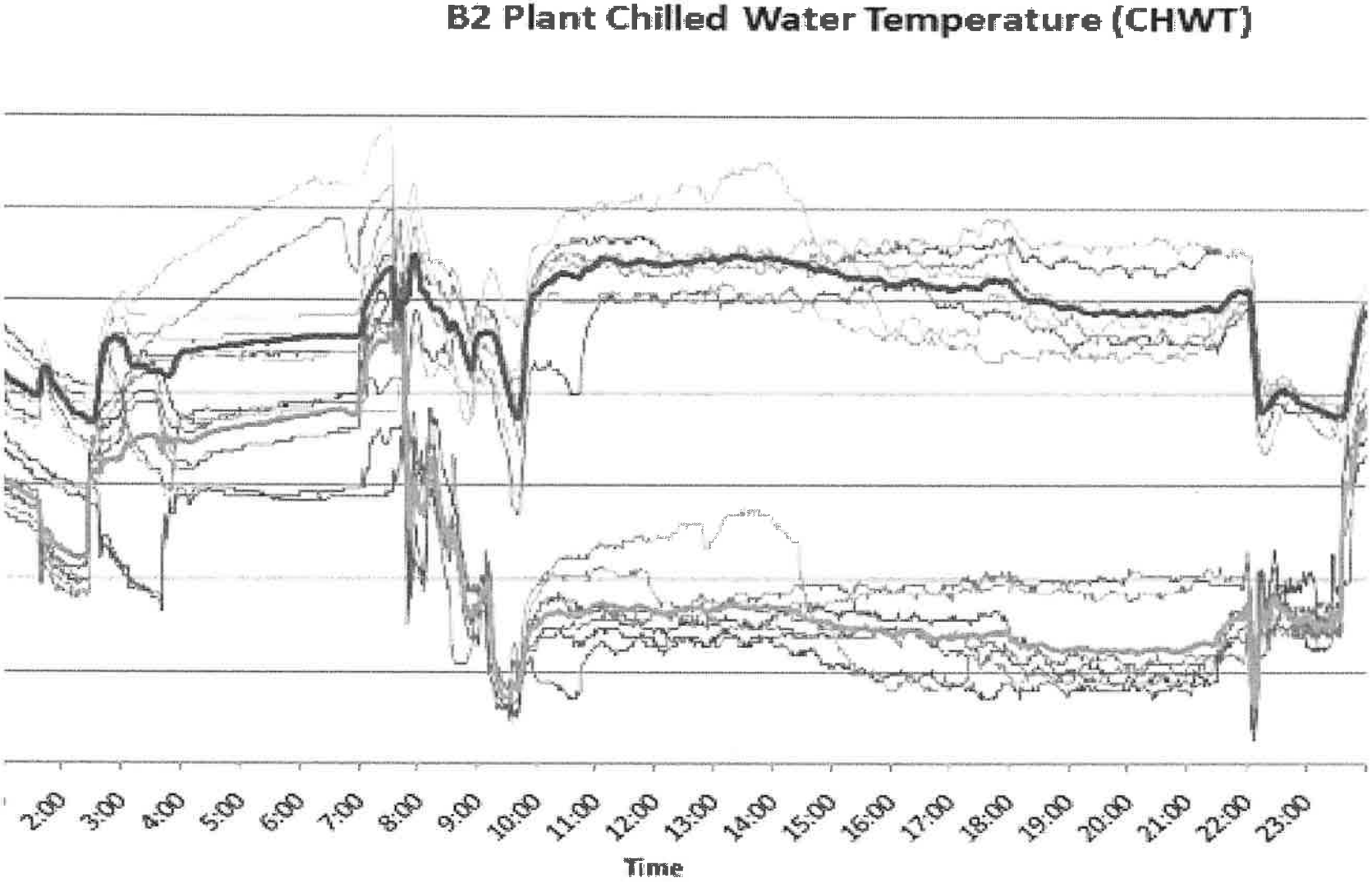
B1 Plant CHW System Del T

kaer



B2 Plant CHW System Temp

kaer



B2 Plant CHW System Del T

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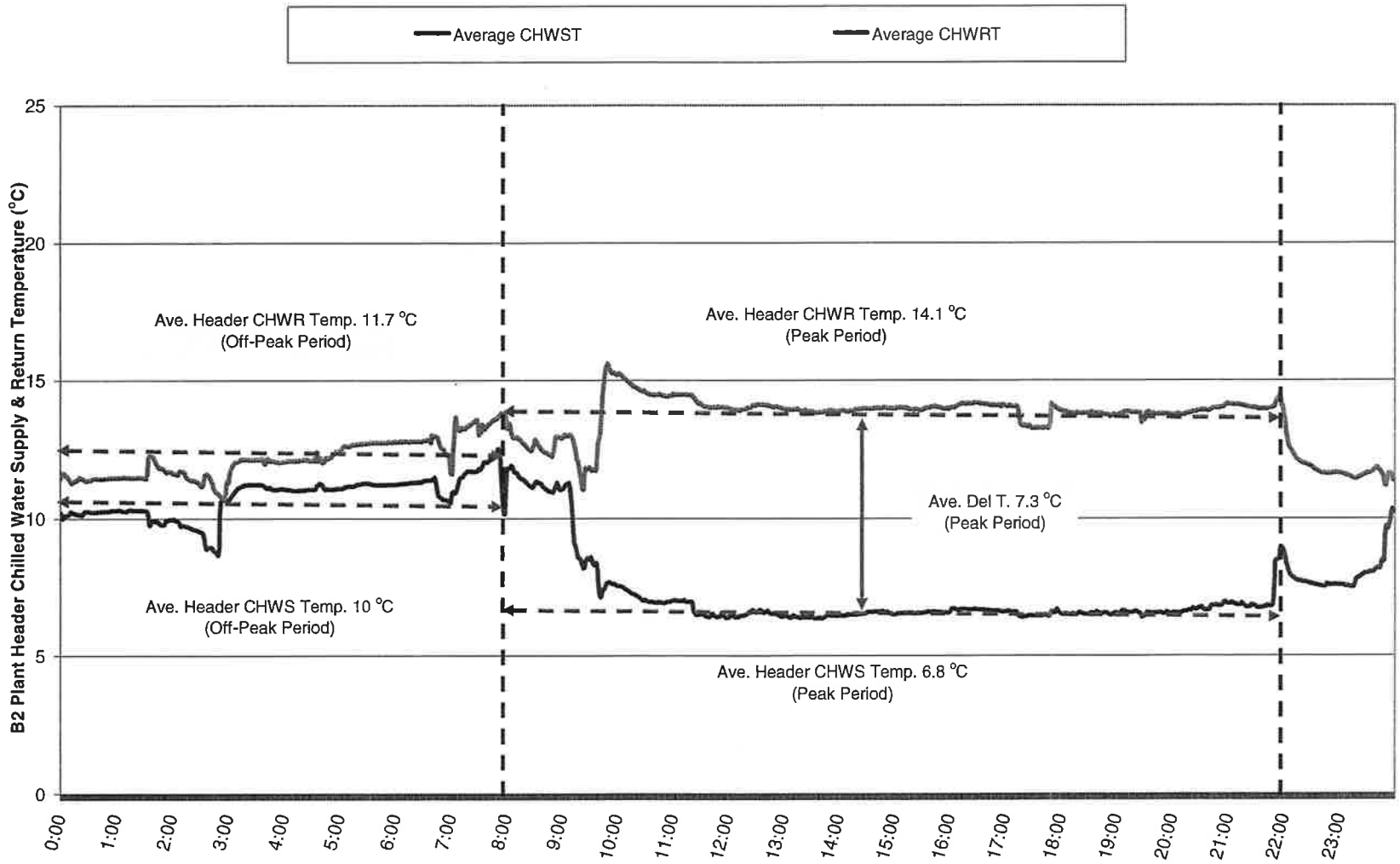
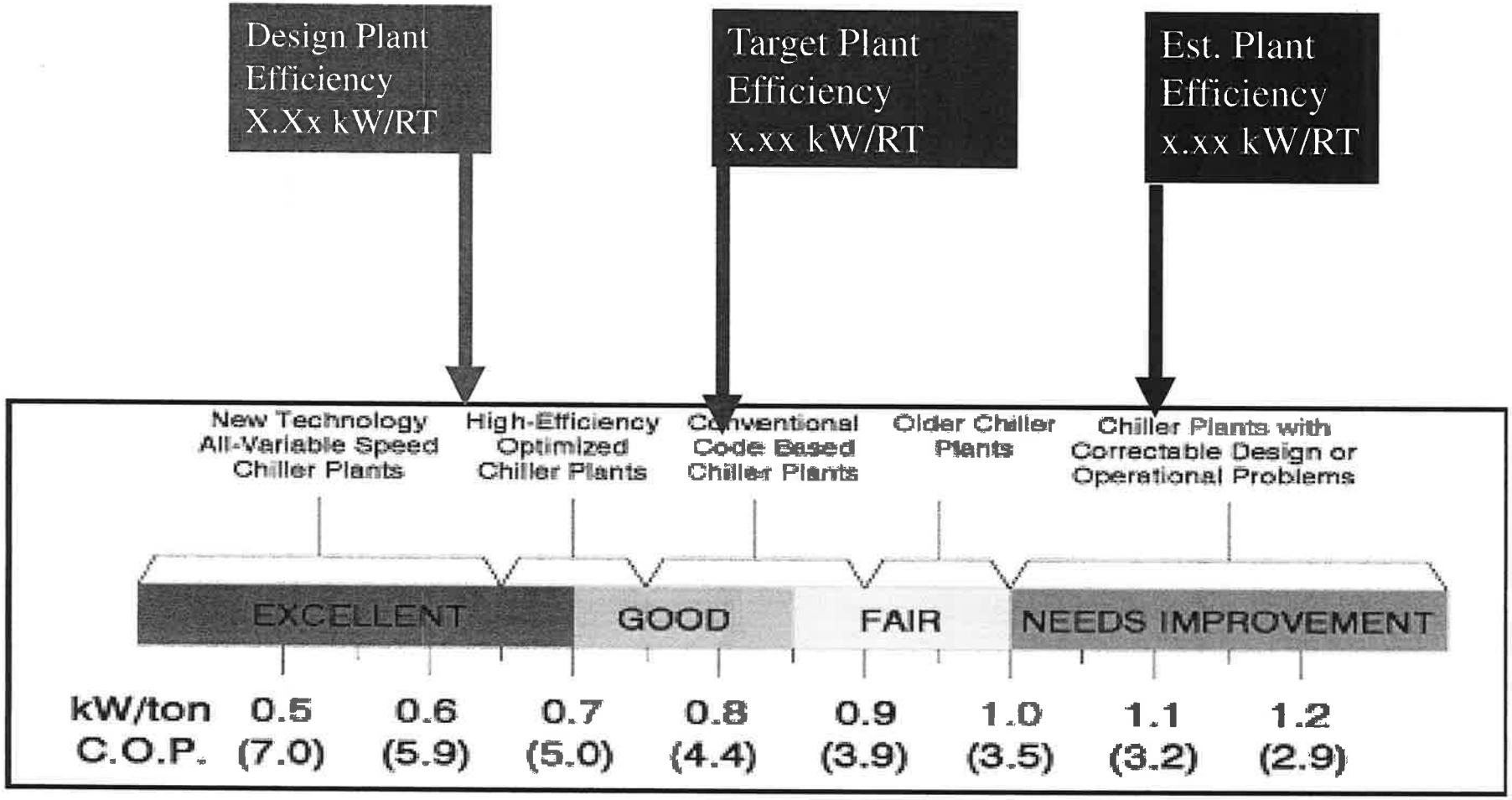


CHW Plant Benchmark

kaer



ASHRAE Benchmark for Chiller Plant System Efficiency

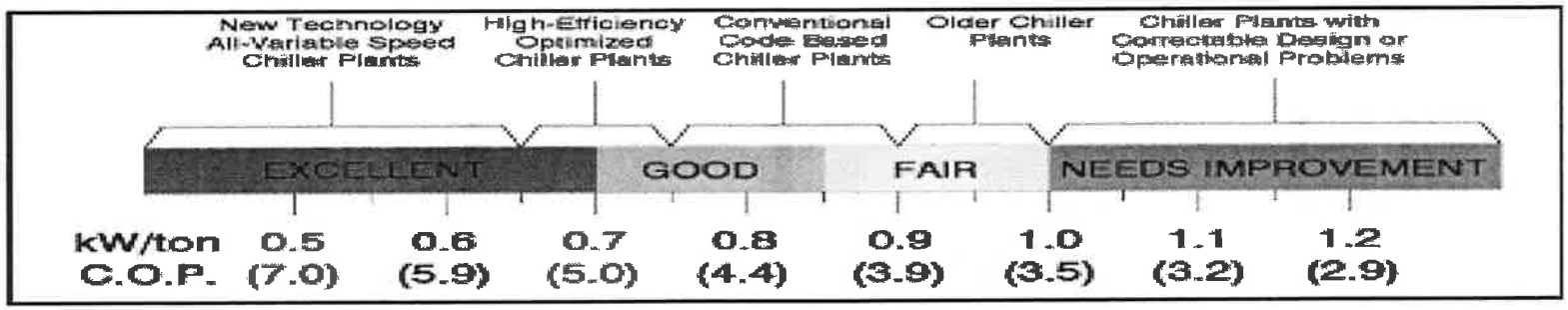
CHWS Plant Benchmarking

kaer

TARGET
< x.xx kW/Ton

Design
x.xxkW/Ton

Current Plant
Efficiency 1.05
kW/Ton

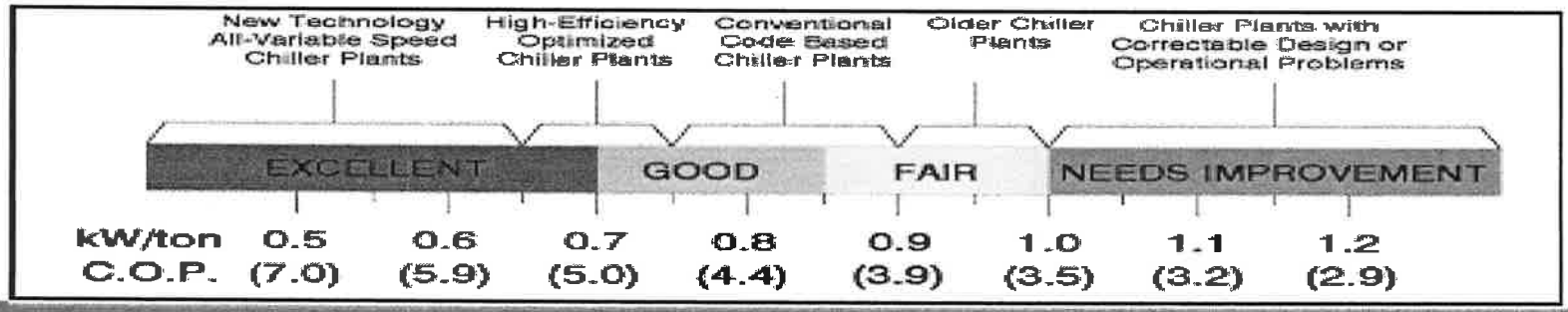


Option 1

Enhancement Of Current System

kaer

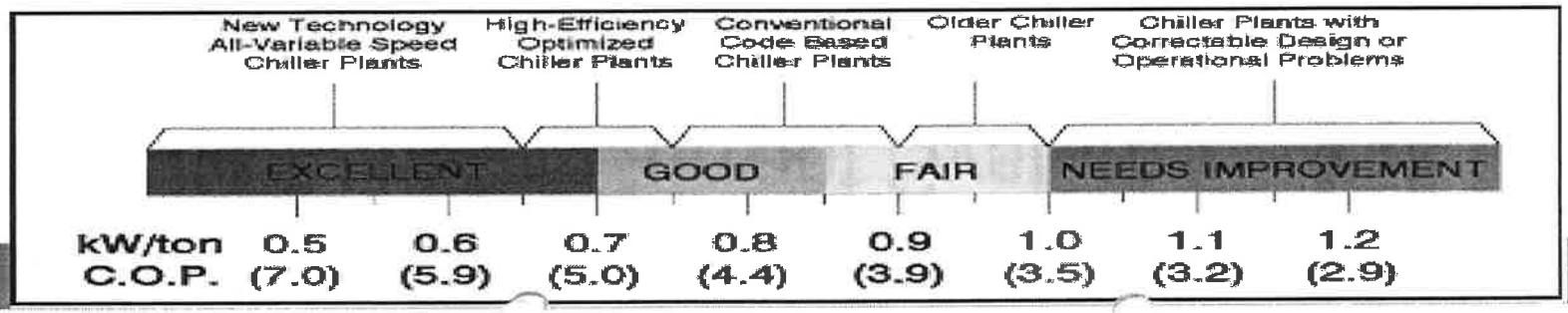
Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback
Enhancement Of The Current System				



Option 2

kaer

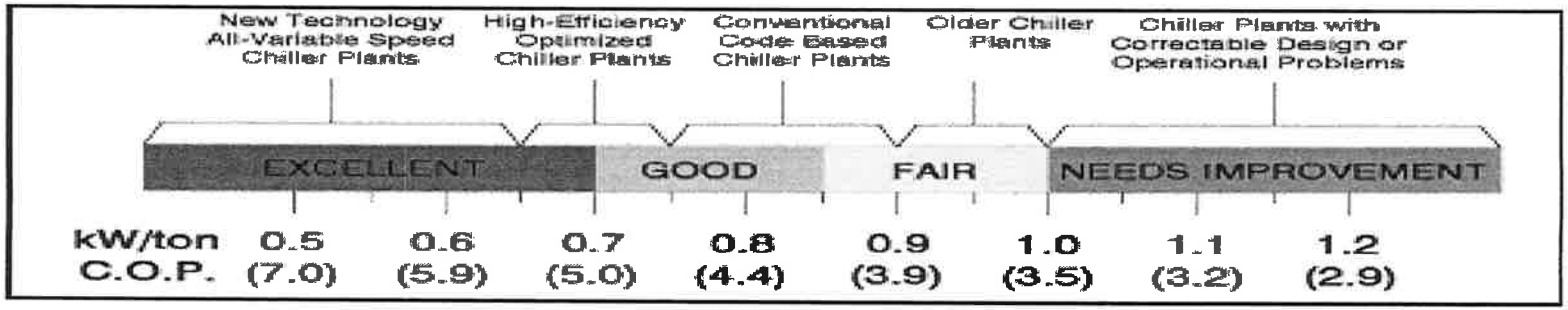
Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback



Option 3

kaer

Description	Est. Energy Savings	Est. Energy Cost Savings	Investment Cost	Simple Payback



Way Forward

kaer

1. Aaaaa…
2. Bbbbb…
3. Ccccc…..