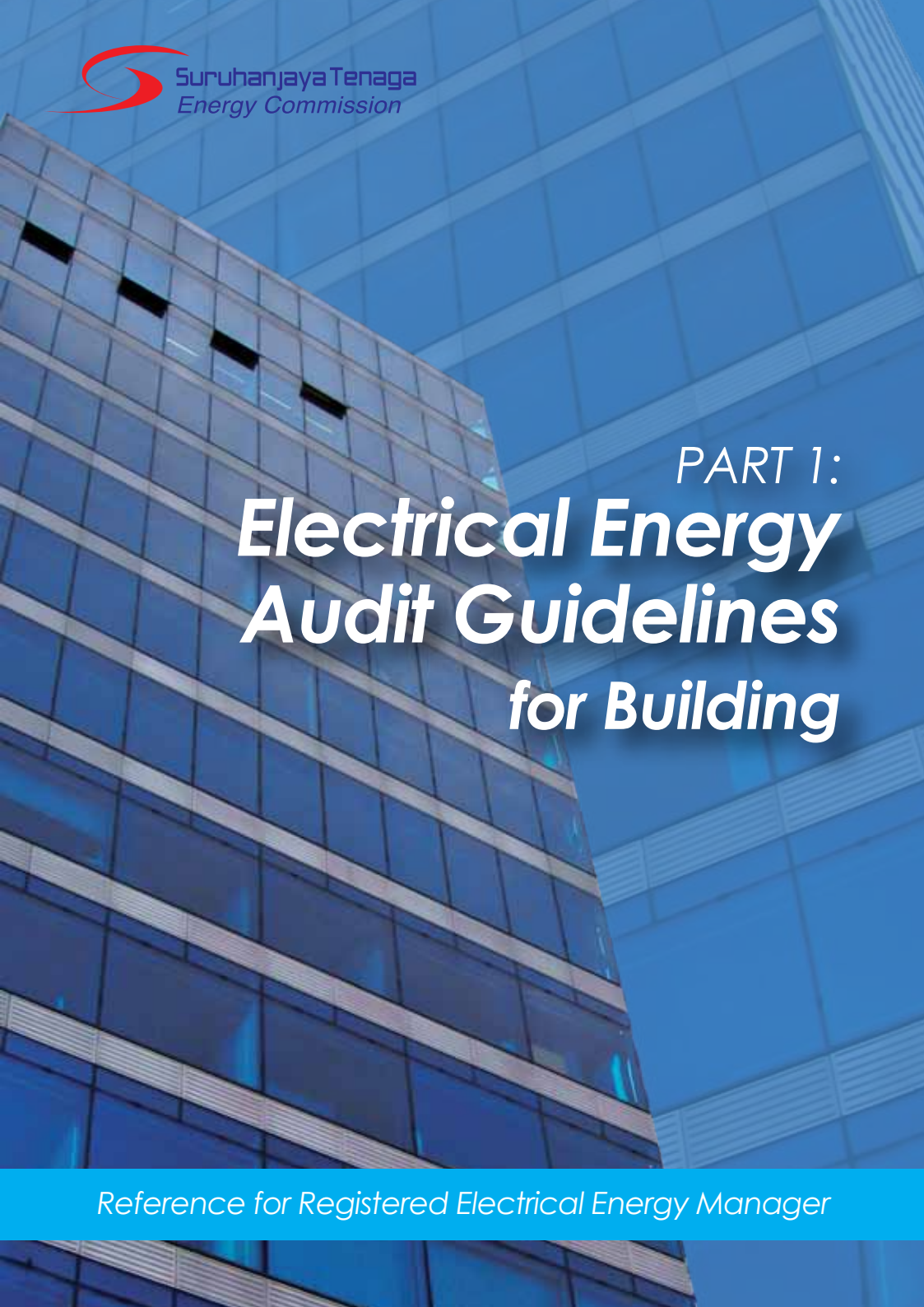
Suruhanjaya Tenaga
Energy Commission



PART 1:

Electrical Energy Audit Guidelines for Building

Reference for Registered Electrical Energy Manager

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Contents

1. Introduction

Energy plays a key role in the development and growth of the economy. The Malaysian government has put special emphasis to ensuring adequate, reliable, secure and cost effective supplies and to utilizing energy resources efficiently while minimizing the negative impacts on the environment. To ensure that there is sustainability of energy in the future, energy audit activities are necessary to determine suitable steps to be undertaken to use energy efficiently. An energy audit is an examination of the energy consumption of the equipment or system to ensure that energy is being used efficiently. This is one of the responsibilities of the Registered Electrical Energy Manager (REEM). This is a guideline for Registered Electrical Energy Manager (REEM) during their energy audit exercise. REEM should not be bound with this guideline but they have to establish their own justification in order to meet the facilities requirement according to the types and purposes such as offices, hotels, shopping complexes, hospital, college/universities and etc.

1.1. Objectives

i) To set minimum standards for undertaking detailed energy audit.

ii) To guide REEM, asset owner and/or operator to identify Energy Conservation Measures (ECMs) in buildings.

2. Energy Audit Definitions

There are several definitions of an energy audit. Some guidebooks define energy audit as a systematic, documented verification process of objectively obtaining and evaluating energy audit evidence, in conformance with energy audit criteria and followed by communication of results to the client[1] (CIPEC 2002). In the Indian Energy Conservation Act 2001[2] (BEE 2008), an energy audit is defined as the verification, monitoring and analysis of the use of energy and submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption. However in Malaysia, it was defined as a process which is very much central for conducting an energy management project or in general an energy audit

1. Canadian Industry Program for Energy Conservation (CIPEC), Canada
2. Energy Management and Audit, Bureau of Energy Efficiency (BEE), India
3. Guidelines for conducting Energy Audit Commercial Buildings, Malaysia

is a study conducted to identify where, when and how much energy is being used in the business and how to reduce the cost of energy for the business[3]. Even though there are several definitions, the objective or goal is the same which is to reduce the energy consumption without compromising comfort and quality of the building. This guideline is meant for REEM who have basic understanding on energy audits, for them to conform to the requirements of the Efficient Management of Electrical Energy Regulations 2008 (EMEER 2008).

2.1. Types of Energy Audits

There are basically two types of energy audits. These are:

i) Walk-through/preliminary energy audit

ii) Detailed audit

2.1.1. Walk-through/preliminary Energy Audit

Walk-through audit is a process used to establish an overall picture of the potential of energy savings through visual inspection of the premise including air conditioning system, lighting, metering, building automation, building maintenance and other factors affecting energy consumption of the building. References to the records of equipment ratings, technical catalogues, operation and maintenance (O&M) manuals that are readily available will be very helpful to quickly determine whether equipment or systems are operating efficiently. Calculation, usually simple in nature, should be done to quantify the savings achievable from implementation of the identified ECMs.

The walk-through/preliminary energy audit usually is carried out in one or two days by either REEM alone or with a team, depending on the size, complexity of the building and the scope of audit. Usually, simple instruments such as a clamp amp meter, thermometer, hygrometer (humidity meter) and lux meter will serve the purpose.

2.1.2. Detailed Energy Audit

The detailed energy audit involves in-depth investigations into how the energy is currently being consumed, current performance of the existing systems and identification of various potential ECMs. It also gives the estimated cost and simple payback periods for all recommended ECMs.

The detailed energy audit involves the following four (4) main processes:

i) Data collection

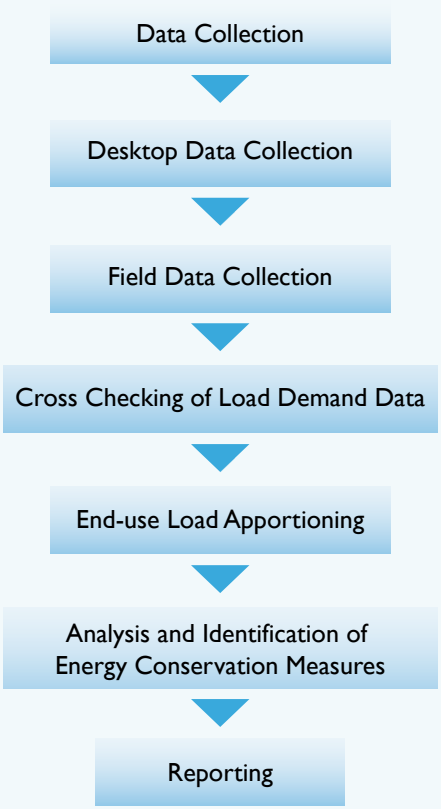
ii) End-use load apportioning

iii) Identification of ECMs

iv) Reporting and presentation

Figure 1.0 shows the process flow of a detailed energy audit.

Figure 1.0: Flow chart of a detailed energy audit process



3. Detail Energy Audit Process

3.1. Data Collection

One of the key tasks in Energy Auditing is the collection of all energy related data required by the REEM to apportion the total facility energy consumption into various energy end-uses. The collected data is then used to build a reliable picture of where and how much energy is being consumed and the cost of energy being used at the building. Data collection is one of the most laborious tasks in Energy Auditing and inability to collect the required data will lead to less reliable Energy Audit results.

One of the difficulties faced by the REEM in order to establish the building's major end-use demands (air-conditioning, lighting and general equipment) is the limited or lack of building metering equipment. To be able to estimate reliably the major building's end-use demand, it is recommended that the REEM uses the following three steps to identify the building end-use demand:

i) Desktop data collection

ii) Field data collection

iii) Cross checking of load demand data

The process of carrying out these three steps of data collection is explained in the following paragraphs:

3.1.1. Desktop Data Collection

The purpose of desktop data collection is to minimize the field energy related data collection by using all available facility data. It would be advisable during the initial process to collect preliminary building energy related data using a Building Detailed Audit form shown in Appendix 2. This form allows the REEM to understand the nature of the audited building and areas to focus on during the auditing. The data collection through the form can be used to estimate the time and manpower required for the field data collection activity later.

To minimize the time and manpower for the field data collection, the REEM should try to gather energy related data as much as possible using available resources such as:

i) Architectural drawings (as built drawing)

ii) M&E drawings

- Lighting circuit drawings (as built drawing)
- Air conditioning system drawing and design manual (as built drawing)
- Single line power supply schematic drawings (as built drawing)

iii) Electrical energy bill historical data (for at least one year)

iv) Load control systems such as timers, building automation system if any and others (as built drawing)

The REEM will use all desktop available energy related data to estimate the current building major energy end-uses. Appendix 2 shows a number of forms which can be used to identify various energy use data including lighting, air conditioning, general equipment and area function which has effect on the building energy consumption.

The desktop data gathering should be considered as a first step of data collection, which will be complemented and verified during the Field Data Collection process.

3.1.2. Field Data Collection

The field data collection is a critical step for:

i. Complementing the missing data, which the REEM could not find during the Desktop Data Collection process.

ii. Verifying the accuracy of Desktop Data.

iii. Understanding closely the building operations, energy wastages and building maintenance status.

iv. Carrying out the necessary field measurements required to establish main incoming load profile, major energy end-uses such as HVAC, lighting and others. Establishing actual building load apportioning.

v. The field data forms shown in Appendix 2 can be used to facilitate the field data collection.

The field data forms shown in Appendix 2 can be used to facilitate the field data collection.

Table of Measurement Tools

No.	Measurement Tools	Parameters to be Measured
1.	Anemometer	Velocity of air in ducts, windows and other openings for estimating the amount of air supply
2.	Hygrometer (humidity meter)	Outside and inside air humidity
3.	Thermometer	Outdoor and indoor dry air temperature
4.	Lux meter	Light intensity of lit areas
5.	Clamp on amp meter	Amperes of various equipment and supply cables and feeders
6.	kW (and kVA where applicable) data logger	kW, kVAR, PF, time and other data relevant to building and main end-uses power supplies
7.	CO, CO_2 meter	Carbon monoxide, Carbon dioxide concentration (in ppm)

SAFETY PRECAUTIONS

All audit activities have to comply with the Electricity Regulations 1994 of Electricity Act 1990 and other safety related acts and regulations

3.1.3. Cross Checking of Load Demand Data

The accuracy of estimated end-use energy consumption will affect the accuracy of estimated energy savings of various building ECMs. Therefore, for reliable estimate of the building and end-use energy consumption, it is recommended to use the following approach:

i. Use the field data collected to estimate the building's total and end-use energy consumptions. Due to a number of assumptions used in this method, in particular the equipment loading and time usage factors, the accuracy in estimating the building total end-use energy consumption may vary depending on the loads measured. For instance, due to the predictable nature of lighting load, this method allows reliable determination of the building lighting load.

ii. Use appropriate data loggers to record the building and end-use load cycles. For example, it is recommended to record typical daily load profiles of main incoming for seven (7) days, one (1) to seven (7) days for HVAC system and one (1) hour to one (1) day for other equipments. A sample of building load data log is shown in Appendix 3.

The logged data can be used to verify the accuracy of the estimated building total and end-use energy consumption generated by the desktop data collection. If there is a large deviation between the end-use loads estimated by desktop data collection and the end use loads estimated by field data collection, the REEM should alter the assumptions (equipment loading and time usage factors) applied in estimating the building equipment loads used in the desktop data collection to reduce these deviations to an acceptable range. REEM should take into account other factors such as seasonal variations and occupancy changes during the year that may impact on overall energy consumption.

TIPS

The REEM should use the building monthly billing historical data to verify the accuracy of the logged typical daily energy consumption and in estimating the building monthly total and end-use energy consumptions.

In addition, if the building has tenants supplied and metered separately, and not covered in the energy audit, than the REEM must ensure that the tenant energy consumption are taken into account when the building total and end-use energy consumption are calculated.

"Calculating is Better Than Estimating But Measuring is Better Than Calculating"

3.2. End-use Load Apportioning

The REEM can use the above suggested three steps in energy audit data collections to apportion the total building load into its major end-use loads. The chart in Appendix 3 shows a sample of load apportioning of a building.

3.3. Analysis and Identification of Energy Conservation Measures (ECMs)

The effectiveness of an energy audit is related to the understanding in depth of the nature and operations of the audited building by the REEM. Knowing the acceptable level of comfort and tolerance for lighting, temperature and humidity level by employees are essential to come up with effective and acceptable ECMs.

The ECMs can be classified into the following categories:

Categories	Description
No/low cost measures	Involves practically no/low cost investment and without any disruption to building operations, normally involving general housekeeping measures
Medium cost measures	Involves medium cost investments with some minor disruption to building operation
High cost measures	Involves relatively high capital cost investments with much disruption to building operation

Typical sample of ECMs activities that REEM can start with are listed out in Appendix 4. However REEM should not be bound with this sample only but have to expand the ECMs according to the findings during the energy audit activity to suit with the building requirement.

TERMS USED

ECMs are also known as Energy Management Opportunities (EMO) / Energy Saving Measures (ESMs) / Energy Conservation Opportunities (ECO)

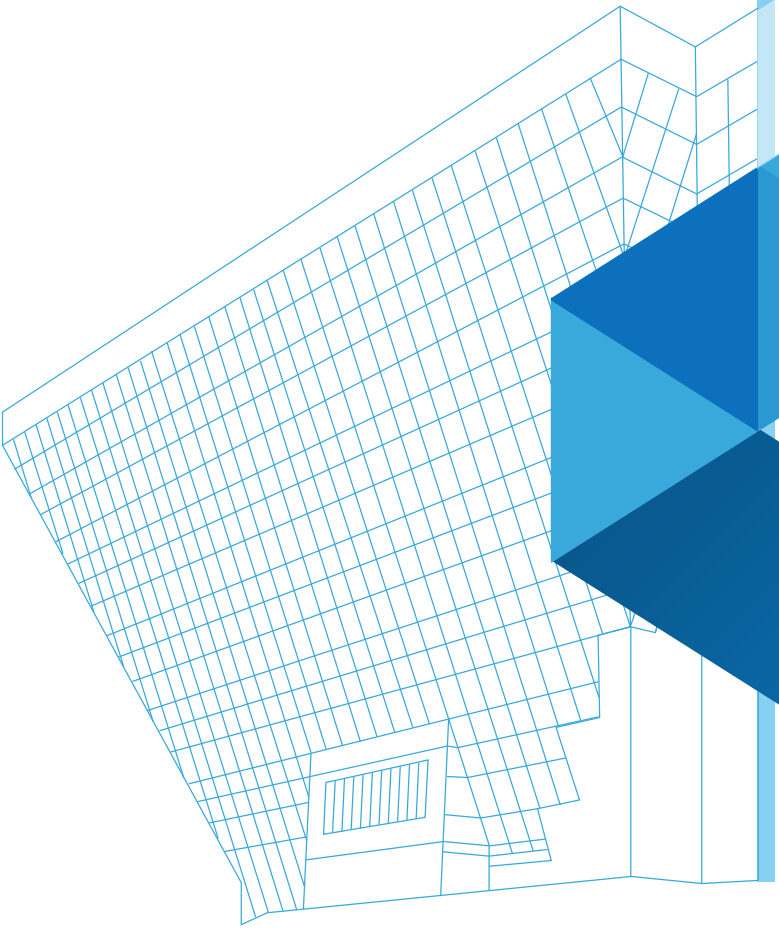
3.4. Reporting

REPORT ON
DETAILED ELECTRICAL ENERGY AUDIT

1. EXECUTIVE SUMMARY
2. INTRODUCTION
   - 2.1. Audited Building Details
   - 2.2. Objective of the Audit
   - 2.3. Study Scope of the Audit
   - 2.4. Energy Audit Measurement Tools
   - 2.5. Brief Description on Electricity Distribution and Background
3. DESCRIPTION OF THE EQUIPMENT / SYSTEM AUDIT
   - 3.1. Main Incoming Description
   - 3.2. Lighting System Description
   - 3.3. Air Conditioning System Description
   - 3.4. Other Electrical Equipment Description
4. OBSERVATION & FINDINGS
   - 4.1. Load Apportioning
   - 4.2. Main Incoming
   - 4.3. Lighting System
   - 4.4. Air Conditioning System
   - 4.5. Other Building Electrical Equipment
5. ANALYSIS AND IDENTIFICATION OF ENERGY CONSERVATION MEASURES (ECMS)
   - 5.1. ECMs at Main Incoming
   - 5.2. ECMs at Lighting System
   - 5.3. ECMs at Air Conditioning System
   - 5.4. ECMs at Other Electrical Equipment
   - 5.5. ECMs Categories
     - 5.5.1. No Cost
     - 5.5.2. Low Cost
     - 5.5.3. High Cost
6. CONCLUSSION

Please refer to Appendix I for the details of the reporting.

APPENDICES



Appendix 1 - Reporting Descriptions

Reporting

The Electrical Energy Audit Report should be based on the desktop data collection and field data collection. Any recommendations proposed in the Electrical Energy Audit Report should be supported by reliable technical calculations.

The Electrical Energy Audit Report must present the full description of the audited building, historical and current energy consumption status, observations, findings and ECMs identified. The Electrical Energy Audit Report prepared by REEM should consist of the following main topics; however REEM should not be bound with the sample framework mentioned in the following details:

1. Executive Summary

This part is to highlight the methodology used, observation and findings such as the energy consumption and building energy indices (BEI) (kWh/m^2/yr). The total energy saving potential, cost and simple payback period for implementing the recommended ECMs could be presented in tabular format according to its ECMs categories.

2. Introduction

This part should address the following points:

2.1. Audited Building Details

- Background about the building audited (size, block, location/address, occupancy, year built/age, building type/function, owner of the building, operating hours and others)

2.2. Objective of the Audit

- Purpose of the Electrical Energy Audit project and roles of the REEM in the project

2.3. Study Scope of the Audit

- To describe the area covered in the Electrical Energy Audit activity such as main incoming, lighting system, air conditioning system and other electrical equipments

2.4. Energy Audit Measurement Tools

- List the measuring tools used in collecting field data and their accuracies

2.5. Brief Description on Electricity Distribution and Background

- To provide sufficient information about the electrical distribution system in the building (e.g. voltage level, rating and no of transformer installed) energy tariff used, historical annual electrical energy consumption, cost and BEI

3. Description of the Equipment / System Audit

3.1. Main Incoming Description

3.2. Plot of Main Incoming Load Profile Over At Least 1 Week (kW)

3.3. Lighting System Description

- Information of lighting system
- Plot of lighting load profile (kW)

3.4. Air Conditioning System Description

- Information of Air Conditioning system
  i. Chiller:- mass flow rate of chilled water (kg/hr), Chilled water temperature at evaporator inlet and outlet (°C), Logging kW
  ii. CHWP:- Logging kW
  iii. CWP:- Logging kW
  iv. Cooling Tower Fan:- Logging kW, RPM
  v. AHU Blower Fan:- Logging kW, RPM, Air Flow
- Plot of load profile (kW)

3.5. Other Electrical Equipment Description

- Information of other electrical equipment load
- Plot of electrical equipment load (if necessary)

4. Observation & Findings

4.1. Load Apportioning

- Using the building load data collected through desktop and field data collection methods, the REEM will be able to show how the total energy use is distributed between the major energy end-uses i.e. air conditioning, light and general office equipment energy end-uses.
- The REEM should observe on the type of tariff and power factor value.

4.2. Main Incoming

- The REEM should focus on the pattern of load profile, load factor and maximum demand.

4.3. Lighting System

- The REEM should focus on the lux level, operation hours, lighting control system, maintenance and lighting application and human behavior

4.4. Air Conditioning System

- The REEM should focus on the temperature setting, operation hours, control system, schedule arrangement, maintenance, indoor air quality and human behavior

4.5. Other Electrical Equipment

- The REEM should focus on the operation hours, control system, maintenance, efficiency of equipment used and human behavior

5. Analysis and Identification of Energy Conservation Measures (ECMs)

In this part of the report, the energy auditor should highlight:

- The assumptions used in estimating the energy savings
- The methods used in estimating the savings
- The conditions to achieve the savings
- The estimated budget cost for implementing the recommended Energy Conservation Measures
- Simple payback periods of the proposed ECMs

The reliability of estimated savings and implementation costs of the identified ECMs are critical in energy auditing. The REEM should use reliable and accurate methods for estimating the energy savings of the recommended ECMs. However, due to the numbers of assumptions made by the REEM during estimation of end-use loads and energy savings, it is recommended to be conservative, logical and practical in estimating the energy savings. This would guarantee that achieved savings after the implementation are at least equal if not higher than the study estimations. In addition, the REEM should state all assumptions, conditions and cost used in estimating the savings.

The REEM should also indicate that the actual implementation cost and savings could vary within certain margin depending on final contractor's quotation, design and installation of the implemented ECMs. It is recommended that the ECMs analysis to be summarized in tabular format showing the assumption used in calculation, estimated consumption before and after implementing ECMs, estimated saving in kWh and RM, estimated implementation costs, simple payback periods and some remarks on the recommended measures. It is also recommended that the indentified ECMs to be summarized according to its categories: no/low, medium and high cost.

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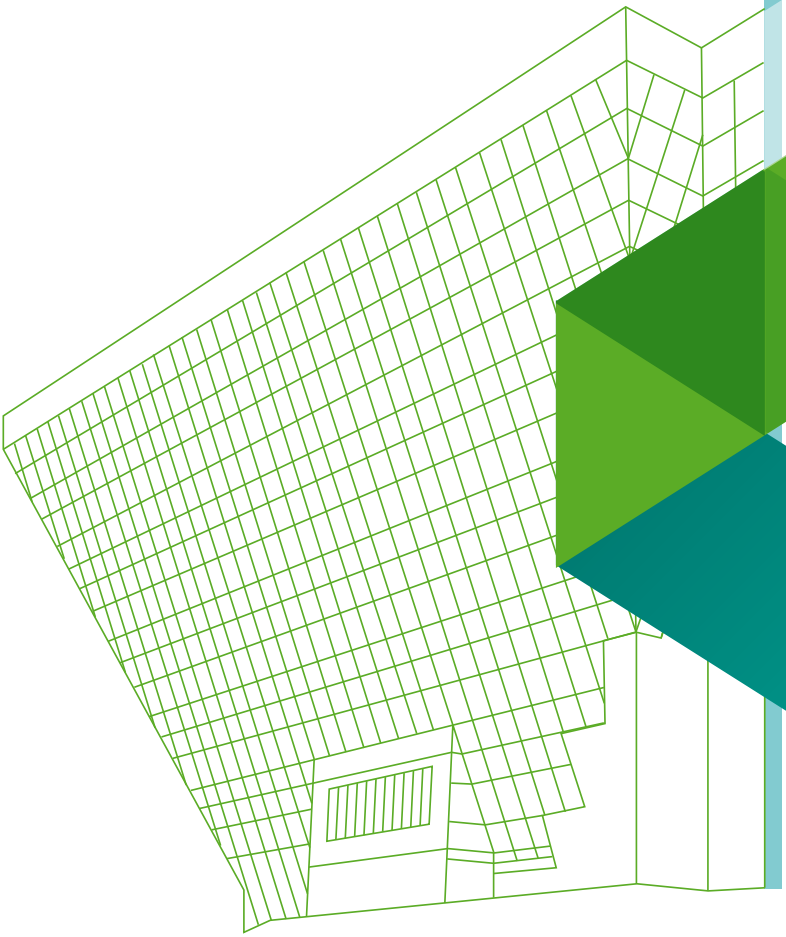

Appendix 2 - Sample Forms & Tables

Building Detailed Audited Form

Company Name and Address	
Name, designation, telephone, fax no & email of company's person in-charge	
Name, telephone, fax no & email of registered electrical energy manager	
No. of staff	
Operating hours (day, week, month)	
Electricity tariff category	
Building age	
Building function	
No. of blocks	
Gross floor area (m^2)	
Percent of gross floor area that is air conditioned (%)	
Server area (%)	
Parking area that is enclosed (%)	
Designed occupant load (please specify unit)	
Actual occupant load (%)	

Building Historical Annual Electrical Energy Consumption Form

(Mth/yr)	Maximum Demand	Electricity Consumption (kWh)			Total
	(kW)	Peak	Off Peak	Total	(RM)
Total					
Average					

Lighting Data Form

Desktop Data Collection

	Type of light:_____						
Level	Operation hours (hr/day)	Rated power kW (lamp + ballast)	Total no installed (nos)	Place of use	Control system (manual/auto)	Remark	Please expand the table for other type of lighting(s)

Field Data Collection (If any changes/absence of information during desktop data collection)

	Type of light*:_____							
Level	Operation hours (hr/day)	Power measured kW (Lamp + ballast)	Loading factor (%)	Place of use	Control system (manual/ auto	Average lux level	Remark	Please expand the table for other type of lighting(s)

* T8/T5 fluorescent light, CFL, incandescent light, LED, etc

Other Electrical Equipment Data Form

Desktop Data Collection

	Type of building electrical equipment*:_____				Please expand the table for other type of building electrical equipment (s)
Level	Operation hours (hr/day)	Rated power kW	Quantity (nos)	Remark	

* *E.g. photocopying machine, fax machine, computer, printer, water dispenser, vending machine, lift, escalator etc*

Field Data Collection (If any changes/absence of information during desktop data collection)

	Type of building electrical equipment*:_____					Please expand the table for other type of building electrical equipment (s)
Level	Operation hours (hr/day)	Power measures (kW)	Loading Factor (%)	Quantity (nos)	Remark	

* *E.g. photocopying machine, fax machine, computer, printer, water dispenser, vending machine, lift, escalator etc*

Air Conditioning Data Form

Desktop Data Collection
Centralized Air Conditioning System

A/C Components	Rated power (kW)	Operating hours (hr/day)	Loading factor (%)	Time usage factor (%)	Control (manual/ auto)	Year installed	Refrigerant type (R134/R22/ HFC/etc)	Chiller type (centrifugal/ screw/etc)	COP chiller design (kWr/kWe)	Setting temperature	
										Supply temp (°C)	Return temp (°C)
Chiller 1											
Chiller 2											
Chiller 3											
AHU 1											
AHU 2											
AHU 3											
Cooling tower 1											
Cooling tower 2											
Cooling tower 3											
Total chilled water pumps											
Total condenser water pumps											

Air Conditioning Data Form

Split Unit Air Conditioning System

Split Unit No.	Level	Room No/Description	Rated Power (kW)	Operating Hours (hr/day)	Control (manual/auto)	Remarks
Split Unit 1						
Split Unit 2						

Field Data Collection (If any changes/absence of information during desktop data collection chiller)

Chiller No.	Loading factor (%)	Time usage factor (%)	Flow rate (l/s)	Operating hours (hr/day)	Chileld water temperature measured		Total power measured*			
					Supply temp (°C)	Return temp (°C)	Chiller (kW)	Chilled water pump (kW)	Condenser water pumps (kW)	Cooling tower (kW)
Chiller 1										
Chiller 2										
Chiller 3										

Air Handling Unit (AHU)

AHU No.	Level	Outside air intake				Return air				AHU air intake				Control (manual/ auto)	Measured Power (kW)	Loading Factor (%)	Operating Hours (hr/day)	Remarks
		Temp (°C)	RH (%)	Vel (m/s)	Area (m²)	Temp (°C)	RH (%)	Vel (m/s)	Area (m²)	Temp (°C)	RH (%)	Vel (m/s)	Area (m²)					
AHU 1																		
AHU 2																		
AHU 3																		

Split Unit No.	Level	Room No/Description	Measured Power (kW)	Loading Factor (%)	Operating Hours (hr/day)	Control (manual/auto)	Remarks
Split Unit 1							
Split Unit 2							

Field Data Collection
Indoor Air Quality

	Indoor Air Quality					
Level	Place of use	Temperature (°C)	Humidity (%)	CO_2 (PPM)	CO (PPM)	Remarks

Note:
RH - Relative Humidity (%)
Vel - Velocity (m/s)
Temp - Temperature (°C)

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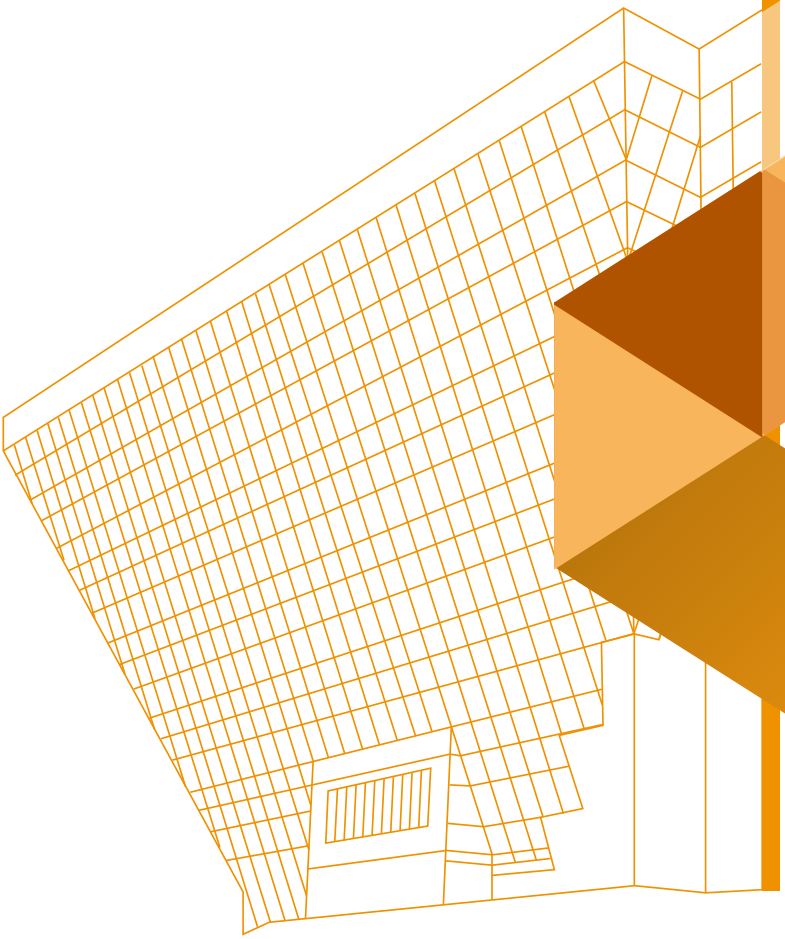
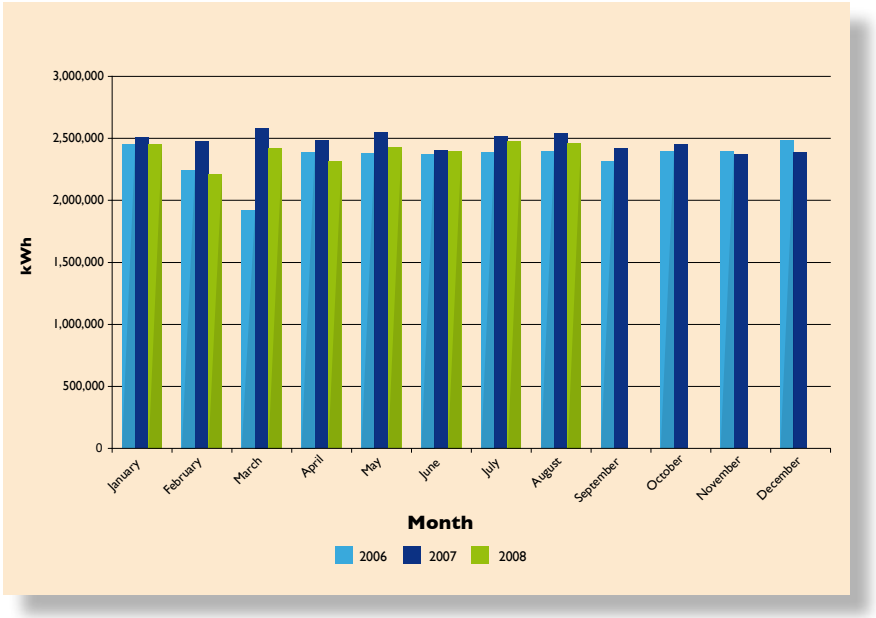
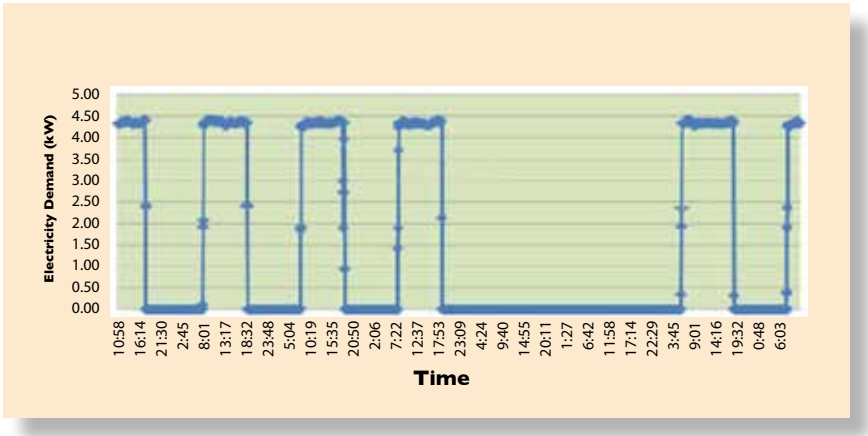


Appendix 3 - Sample Chart & Graph

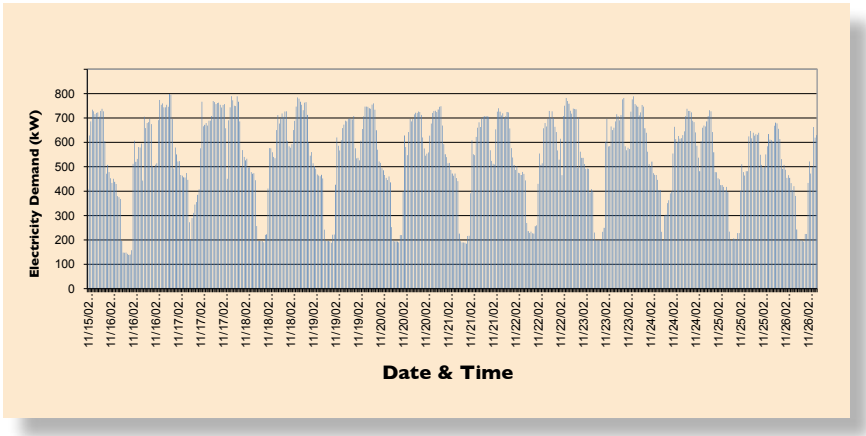
Electricity Consumption



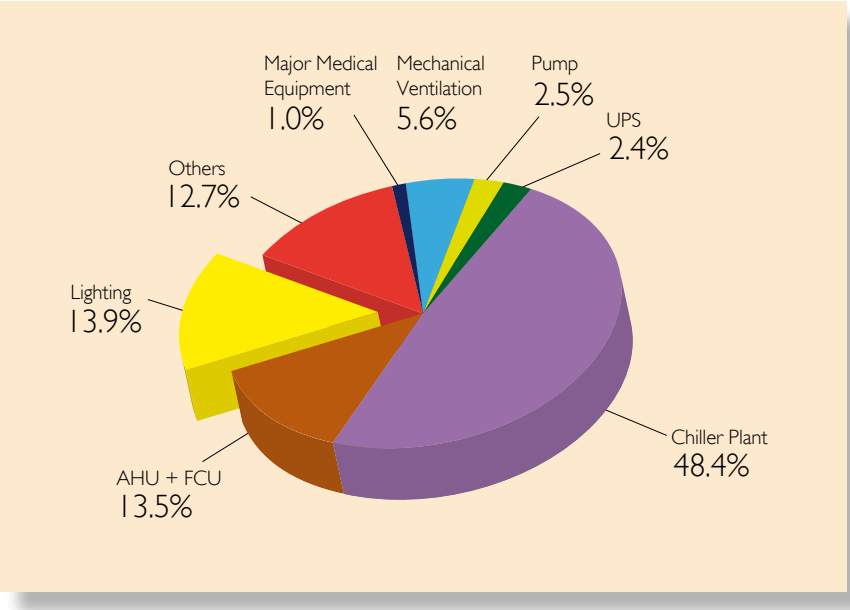
Chiller Load Profile (kW)



Main Incoming Load Profile (kW)



Annual Electricity Consumption (kWh)



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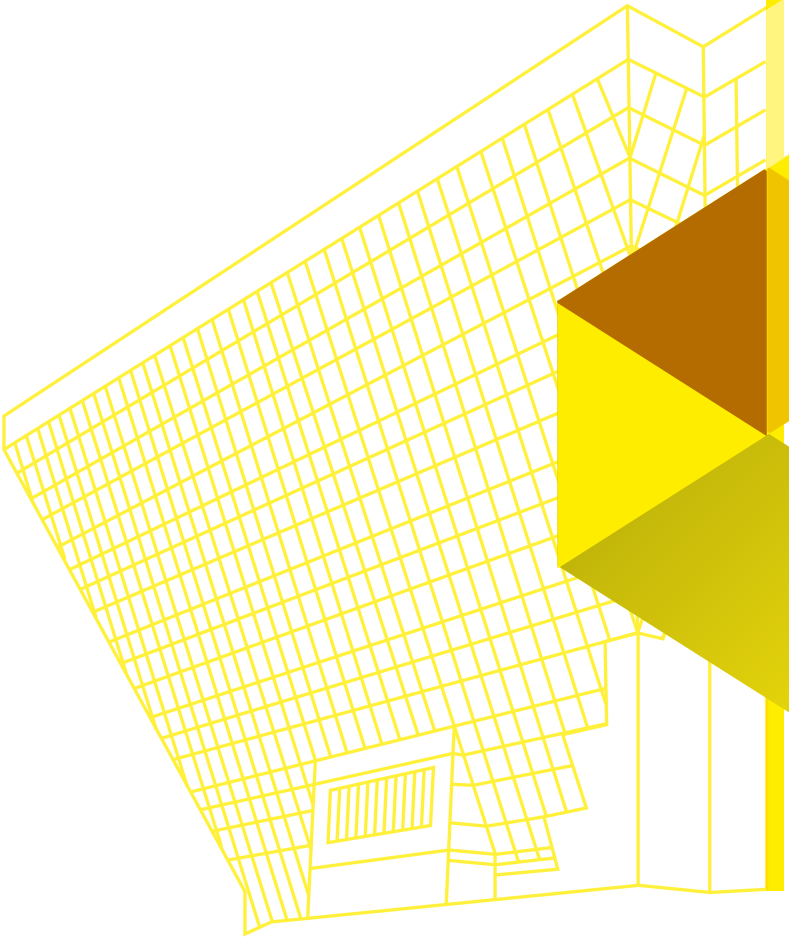

Appendix 4 - Example of ECMs

There are several guidelines and handbooks that details out the ECMs. Among the available sources which can be referred to are as follows:

1. Guidelines of Efficient Management of Electrical Energy Regulations 2008, Energy Commission of Malaysia

2. Energy Efficiency and Conservation Guidelines for Malaysian Industries Part 1, Malaysia Energy Center

3. MS 1525: 2007 Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings, Department of Standard Malaysia

4. Guidelines for Conducting Energy Audits in Commercial Buildings, Malaysia Energy Center

The following are list of typical ECMs:

Example of ECMs for Main Incoming

- Ensure appropriate electricity tariff
- Power factor improvement
- Maximum demand control

Example of ECMs for Air Conditioning System

- Equipment tuning
- Manual/automatic equipment control
- Equipment replacement
- Equipment maintenance
- Use of the most suitable air distribution system (eg. Variable air volume (VAV), induction system, etc)
- Use of heat exchangers to pre-cool outside air used by Air handling Units (AHU) using spill air
- Limit outside air intake to minimum requirements or use air quality sensors (e.g CO_2 sensors) to control outdoor air intake according to occupancy level
- Use of ice storage for peak load reduction
- Improve piping insulation

Example of ECMs for Lighting System

- Manual/automatic control equipment
- Equipment maintenance (periodical cleaning, ballast replacement with more efficient alternatives)
- Delamping in over-lit areas
- Use of daylight in conjunction with lighting control
- Equipment replacement (e.g. Efficient luminaires, low loss ballast, tri-phosphor lamps, etc)
- Automatic control equipment (e.g. Dimmers, occupancy sensors, Photo/Daylight sensors cells, time clock, etc)

Example of ECMs for Other Electrical Equipment

- On - off system
- Maintain ventilation at optimum requirements
- High efficiency motors
- Use of variable speed drive to reduce fan and pump loads
- Use of equipment control for equipment start and stop

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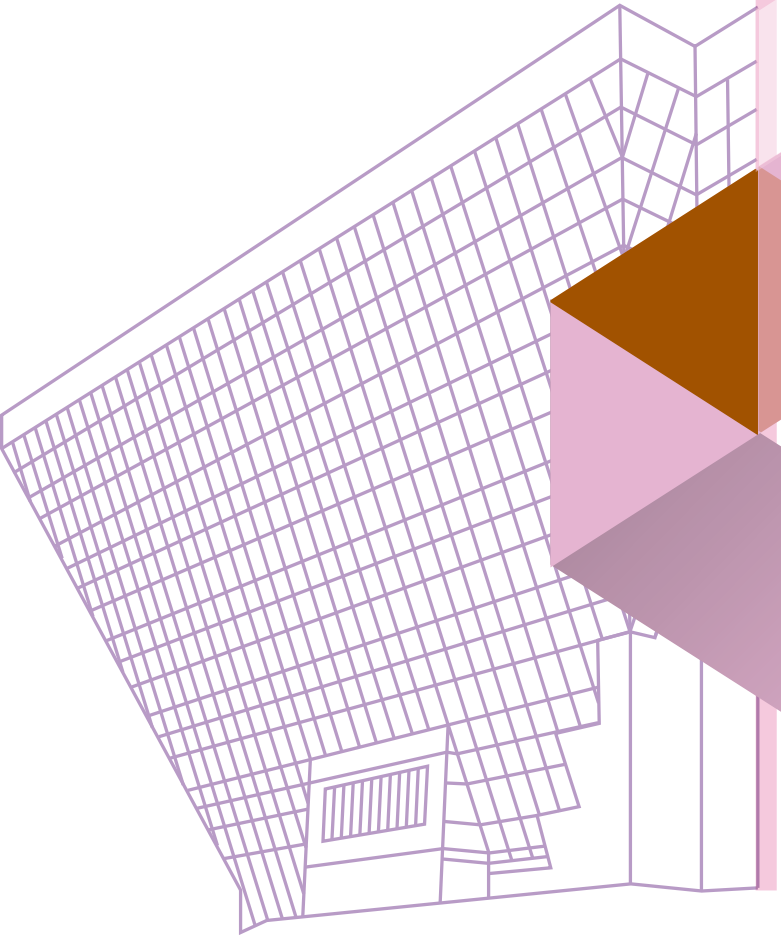

Appendix 5 - Recommended Guidelines

Lighting

Recommended average illuminance levels:

Task	Illuminance (lux)	Example of Applications
Lighting for infrequently used area	20	Minimum service illuminance
	100	Interior walkway and car-park
	100	Hotel bedroom
	100	Lift interior
	100	Corridor, passageways, stairs
	150	Escalator, travellor
	100	Entrance and exit
	100	Staff changing room, locker and cleaner room, cloak room, lavatories, stores.
	100	Entrance hall, lobbies, waiting room
	300	Inquiry desk
	200	Gate house
Lighting for working interiors	200	Infrequent reading and writing
	300 - 400	General offices, shops and stores, reading and writing
	300 - 400	Drawing office
	150	Restroom
	200	Restaurant, Canteen, Cafeteria
	150 - 300	Kitchen
	150	Lounge
	150	Bathroom
	100	Toilet
	100	Bedroom
	300 - 500	Class room, Library
	200 - 750	Shop / Supermarket / Department store
	300	Museum and gallery
Localised lighting for exacting task	500	Proof reading
	1000	Exacting drawing
	2000	Detailed and precise work

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