Energy Efficiency EMSD

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Guidelines on
Energy Audit

Electrical & Mechanical Services Department
The Government of the Hong Kong Special Administrative Region

EMSD

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2007

FOREWORD

Guidelines on Energy Audit set out the requirements on energy audit for commercial buildings. The Guidelines should be read in conjunction with a set of comprehensive *Building Energy Codes* that addresses energy efficiency requirements on building services installations. The Guidelines also supersede the *"Guidelines on Energy Audit"* issued by the Energy Efficiency Advisory Committee (now the Energy Advisory Committee) in 1993. Other than giving an overview of *"What is Energy Audit and what are its Benefits to Energy Conservation"*, the Guidelines provide end-users/building owners/building management/ operation and maintenance personnel comprehensive information on how to conduct energy audits, propose energy management opportunities and write up audit reports as well as cover a wide range of issues including the audit procedures, the report format and the required audit skills.

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TABLE OF CONTENT

LIST OF APPENDICES

ABBREVIATIONS USED IN THESE GUIDELINES

Abbreviations

ASHRAE	-	American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.
A/C	-	Air-Conditioning
AHU	-	Air Handling Unit
BEP	-	Building Energy Performance
BS	-	Building Services
CAV	-	Constant Air Volume
CCMS	-	Central Control and Monitoring System
CIBSE	-	The Chartered Institution of Building Services Engineers
COP	-	Code of Practice
DDC	-	Direct Digital Control
EMO	-	Energy Management Opportunity
EMP	-	Energy Management Programme
EPD	-	Environmental Protection Department
EUI	-	Energy Utilisation Index
FCU	-	Fan Coil Unit
GFA	-	Gross Floor Area
HVAC	-	Heating, Ventilation and Air-Conditioning
LTHW	-	Low Temperature Hot Water
M&V	-	Measurement and Verification
O&M	-	Operation and Maintenance
T&C	-	Testing and Commissioning
THD	-	Total Harmonics Distortion
VAV	-	Variable Air Volume
VRV	-	Variable Refrigerant Volume
VSD	-	Variable Speed Drive
VVVF	-	Variable Voltage Variable Frequency

1 INTRODUCTION

1.1 Background

An Energy Audit is an examination of an energy consuming equipment/system to ensure that energy is being used efficiently. In many ways, this is similar to financial accounting. Building manager examines the energy account of an energy consuming equipment/system, checks the way energy is used in its various components, checks for areas of inefficiency or that less energy can be used and identifies the means for improvement.

Energy audit is a top-down initiative. Its effectiveness relies largely on the resources that should be allocated to energy audit by the building management:-

a) Commitment on energy conservation and environmental protection;
b) Anticipation on the energy savings achievable; and
c) Aspiration of the improvement to corporate image by promoting energy efficiency and conservation.

It is important that the building management should be provided with the right perception of the benefits of the energy audit.

These Guidelines are targeted at commercial buildings, the energy consuming equipment/systems in particular. For other type of buildings, these Guidelines can be used as a reference for end-users/building owners/building managers/operation and maintenance personnel, as the concepts and approaches to energy audit are similar in nature.

1.2 Intended Users

These Guidelines are written primarily for end-users, building owners who have installed their own equipment/systems and building managers. The building owners who have legal control of building facilities retain primary responsibility for energy audit. The duties of the building owner may, however, be modified by contractual agreements such as lease agreements made with end-users. The building manager is usually the legal representative of the building owner.

1.3 Objectives

Energy Audit is an effective energy management tool. By identifying and implementing the means to achieve energy efficiency and conservation, not only can energy savings be achieved, but also equipment/system services life can be extended. All these mean savings in money.

Based on the principle of "The less energy is consumed, the less fossil fuels will be burnt", the power supply companies will generate relatively less pollutants and by-products. Therefore, all parties concerned contribute to conserve the environment and to enhance sustainable development.

Energy Audit = Savings in Money $ + Environmental Protection + Sustainable Development

ENERGY MANAGEMENT OPPORTUNITY

2

In Energy Audit, the means to achieve energy efficiency and conservation is technically more appropriate to be called Energy Management Opportunity (EMO), which will be used in the remainder of these Guidelines. According to the cost and the complexity for implementation, EMOs are classified as follows:-

Category of EMO	Capital Cost
Cat I	Involves practically no cost investment and without any disruption to building operation, normally involving general house keeping measures e.g. turning off A/C or lights when not in use, revising A/C temperature set-points, etc.
Cat II	Involves low cost investment with some minor disruption to building operation, e.g. installing timers to turn off equipment, replacing T8 fluorescent tubes with T5 fluorescent tubes, etc.
Cat III	Involves relatively high capital cost investment with much disruption to building operation, e.g. adding variable speed drives, installing power factor correction equipment, replacing chillers, etc.

3 HOW TO CONDUCT ENERGY AUDIT

3.1 General

The Energy Audit should be carried out by a competent person having adequate technical knowledge on Building Services (BS) installations, particularly Heating, Ventilation and Air-Conditioning (HVAC) Installation, Lighting Installation and any other BS Installations. This competent person is referred to as the "auditor" and a team of auditors forms the "audit team". The number of auditors and time required for an audit depends on the audit scope and objectives. During the audit process, the auditor needs assistance and cooperation from the auditees, such as end-users, operation and maintenance (O&M) personnel, etc.

To gain a better knowledge of the building and its energy consuming equipment/systems, the audit team must collect information on the building operation characteristics and the technical characteristics of its various energy consuming equipment/systems. Its performances have to be identified through checking O&M records, conducting site surveys and reading metering records. The audit team will then identify areas that can be improved and write up an energy audit report on the findings for record purposes and for subsequent EMO implementation and follow-up actions. The flow chart on conducting energy audit is shown in **Figure 1** for reference.

3.2 Defining Scope of Energy Audit

The scopes of works and the available resources for conducting the energy audit should be determined. The available resources mean staff, time and budget. Recognising the extent of support from the building management, the audit team should then determine the scope of the energy audit such as the areas to be audited, the level of sophistication of the audit, the savings anticipated, any EMOs to be implemented, the audit result to be used as reference for improvement on O&M, the need for any follow up training or promotion of results achievable, etc. The plan for conducting the energy audit should then proceed.

3.3 Forming an Energy Audit Team

An audit team should be formed by:-

a) Determining the members of the audit team and their duties.
b) Involving the O&M personnel to provide input.
c) Facilitating meetings for sharing of information and familiarising among different parties.

Should in-house expertise or resources be regarded as not adequate, energy audit consultants should be employed. Many of the local BS consultants and tertiary academic institutions have the expertise on energy audit.

3.4 Estimating Time Frame & Budget

Based on the available resources, the time frame and the budget can be fixed. The budget is mainly built-up on cost of auditor-hours from collection of information to completion of the audit report. The audit team should check whether they have adequate testing instruments as shown in **Appendix A**. In addition, the cost for employing BS consultants and/or tertiary academic institutions may be included, if so required.

3.5 Collecting Building Information

The audit team should then proceed to collect information on the building. The information should include:-

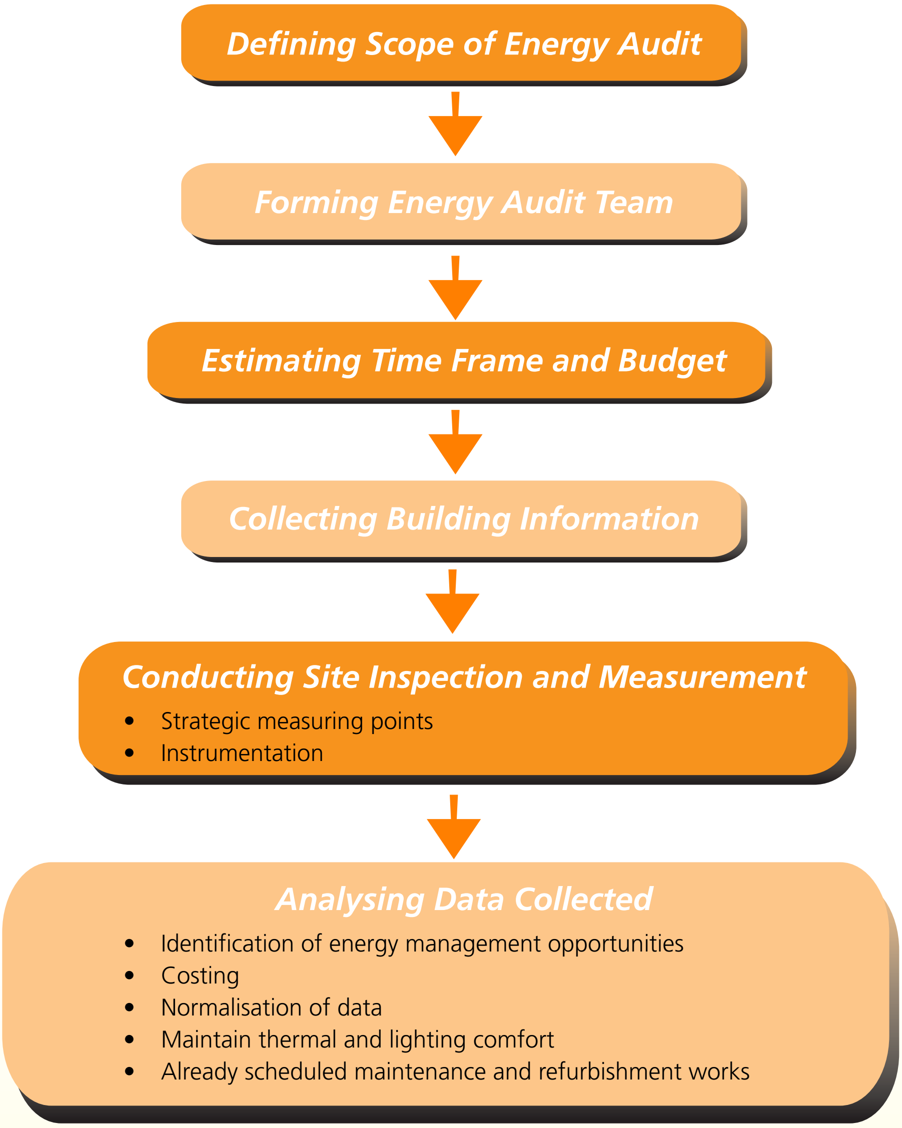
a) General building characteristics such as floor areas, numbers of end-users, construction details, building orientation, building facade, etc.;
b) Technical characteristics of energy consuming equipment/systems, design conditions and parameters;
c) Building services design report with system schematic diagrams and layout drawings showing system characteristics;
d) Equipment/system operation records, including data logs of metered parameters on temperature, pressure, current, operational hours, etc.;
e) Record of EMOs already implemented or to be implemented;
f) Record of maximum demand readings;
g) O&M manuals and testing and commissioning (T&C) reports; and
h) Energy consumption bills in previous three years.

3

In general, it should be assumed that the building manager would have information on general building characteristics and the O&M personnel would keep the equipment/system technical and operation records. **Appendix B** shows some samples of log sheets. The audit team should determine the appropriate parties to be approached for information collection, the need to discuss with these parties for familiarisation of the building, the equipment/systems to be investigated and data verification and the need to discuss with selected end-users.

The audit team should consider issuing questionnaires to end-users to collect information on thermal comfort, lighting comfort, operational hours of individual floors/offices, electrical equipment and appliances, etc. A sample questionnaire is given in **Appendix C**.

Figure 1: Flow Chart on Conducting Energy Audit



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After having collected all or the majority of the above information, the audit team will have better understanding of the building context and its energy consuming equipment/systems. With this information, the audit team can better plan subsequent audit activities and detect any missing important datum and arrange to obtain them.

At this stage of the audit, the auditor should be able to tell the characteristics of the energy consuming equipment/systems such as:-

a) Type of chillers, their capacities and operational characteristics (refrigeration pressure/temperature, water flow rate/temperature/pressure, etc.);

b) Type of HVAC systems, their components (fans, pumps, pipework, ductwork, etc.) and operating characteristics (flow rate, temperature, pressure, etc.);

c) Occupancies or usage for various equipment/systems;

d) Control mechanisms for various equipment/systems (controller, actuator, sensor, control logic, etc.);

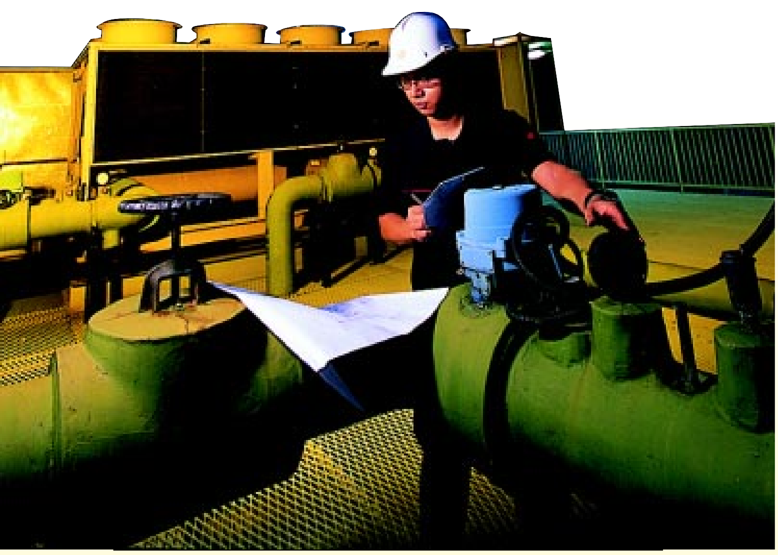
e) Type of luminaires, their characteristics and control mechanisms;

f) Power distribution system characteristics;

g) Operational characteristics of lift and escalator installation (zoning, type of motor drive, control mechanism, etc.);

h) Operational characteristics of other energy consuming equipment/systems; and

i) Characteristics of the building.



The audit team should compare the operational characteristics against design or corresponding general engineering practices. The comparison can reveal if the energy consuming equipment/systems are operating per design or general engineering practice and identify the areas of inefficiencies. The parameters for comparison include the following:-

a) Chiller efficiency (Coefficient of Performance)

b) Motor efficiency (%)

c) Fan system power (kW per L/s of supply air quantity)

d) Fan efficiency (%)

e) Piping system frictional loss (Pa/m)

f) Pump efficiency (%)

g) Lighting power density (W/m^2)

h) Lamp luminous efficacy (Lm/W)

i) Lamp control gear loss (W)

j) Efficiencies of various equipment e.g. boiler, heat pump, etc (%)

The Codes of Practice for Energy Efficiency of Lighting Installation, Air Conditioning Installation, Electrical Installation and Lift & Escalator Installations[1] and the *Guidelines to Performance-based Building Energy Code*[2] and the Executive Summary for study on Private Offices and *Commercial Outlets*[3] provide good reference figures for comparison purpose.

For HVAC Installation, areas of inefficiencies could be identified from data logs of flow rates and corresponding changes in temperatures and pressures. For Electrical Installation, areas of inefficiencies could be identified from data logs of electrical currents and voltages. If relevant data logs are not available, measurements should be taken to obtain the data of possible inefficient equipment/systems. The numbers of measuring points would depend on the resources available.

[1] http://www.emsd.gov.hk/emsd/eng/pee/eersb_pub_cp.shtml
[2] http://www.emsd.gov.hk/emsd/eng/pee/eersb_pub_gng.shtml
[3] http://www.emsd.gov.hk/emsd/e_download/pee/esab.pdf

3.6 Conducting Site Survey and Measurement

More activities should include the following actions:-

a) Proceed to plan the site survey for the areas and the equipment/systems to be investigated.
b) Allocate the work among the audit team members.
c) Assess if separate groups are needed for the areas and the equipment/systems. For example, the first sub-group for low floors, the second sub-group for mid floors, the third sub-group for high floors, so on and so forth. The grouping should also be based on the quantity of measuring instruments available.
d) Develop energy audit forms in **Appendix D** to record the findings.
e) Plan ahead on the site measurement to supplement or verify the information collected. The measurements should focus on equipment/systems that inadequate information is available to determine their efficiency and equipment/systems that appear to be less efficient.

Forms in **Appendix D** could be used in recording the measurements. Some data may have to be logged over a period.

3.6.1 Strategic Measuring Points

During the measurement, the sensors should be located at points that can best reflect the need or function of the controlled parameters. For example, for the office environment, a lux meter should be placed at about 0.8m above floor level (or at level of the working plane) and a thermometer at about 1.1m (seating thermal comfort) above floor level and pressure and flow sensors in ductwork at points according to general engineering practice.

For measurement requiring interfacing with the stream of flow, the system may already have test holes/plugs or gauge cocks. However, many systems may not have such provisions and the audit team may need to install the test holes/plugs or to use the ultrasonic type meter. In fact, it is impractical in most cases to install additional flow meter or gauge cocks in water pipework. Under such circumstances, the audit team may have to make use of the existing ones available, e.g. gauge cocks before and after pump, coil, etc. to measure the pressure of the flow and to calculate the flow rate by referring to pressure/flow curves of pump, valve, pipe section, etc. If the original O&M manuals showing the pressure/flow curves are not available, make reference to those of similar size/rating.

3.6.2 Instrumentation

Whilst much data and characteristics on equipment/systems can be obtained from the O&M personnel, the information may not be adequate to provide a full picture of their operation. To obtain accurate operating conditions and operating performance of equipment/systems, the auditor should have the necessary measuring instruments to take readings of corresponding parameters such as temperature, pressure, flow, lighting lux level, running current, etc. A list of the commonly used instruments is given in **Appendix A**.

3.7 Analysing Data Collected

At this stage of the audit, the audit team has collected a lot of information on:-

a) Equipment/system characteristics obtained from site surveys;
b) Equipment/system performance data obtained from O&M log sheets;
c) Equipment/system performance data obtained from site measurements; and
d) Equipment/system operating conditions of equipment/systems based on design and/or general engineering practices.

Based on the above, the audit team should screen and spot the parameters with values and trends that deviate from what would be anticipated or required respectively. These are the potential EMOs. However, they should take into account the analysis of the irregularities caused by changes in occupancy or other activities.

3

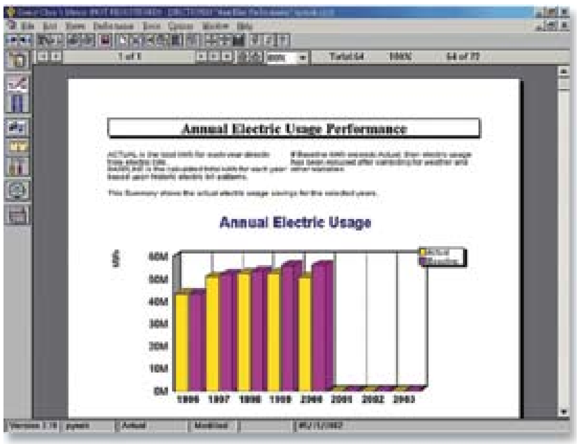
3.7.1 Identification of EMOs

To identify the improvement works for the potential EMOs, calculations should be performed to substantiate the improvement works by quantifying energy savings. Some of the typical findings in an audit, the corresponding EMOs and energy savings have been shown in **Appendix E**.

3.7.2 Costing

In evaluating the effectiveness of an EMO, the auditor has to calculate the payback period, net present worth or rate of return. Most calculations can be done using simple payback approach by dividing the EMO's capital cost by the cost of anticipated annual energy saving to obtain the payback period in years.

However, if there are appreciable deviations between the trends of energy cost and the interest rate or if the capital costs of EMOs are to be injected at different stages with different energy savings achievable at different times, the audit team may have to perform a life cycle cost assessment that can better reflect the cost effectiveness of EMOs. Some common calculations are shown in Appendix F.



3.7.3 Normalisation of Data

In the energy consumption bills, the measurement dates may not fall on the same day of each month. For more accurate comparison, particularly when different fuel types metered on different dates are involved, these data should be preferably normalised as figures on the common dates. **Appendix G** shows how this can be done.

3.7.4 Maintaining Thermal and Lighting Comfort

Energy audits aim to improve efficiency but not to save energy by purely sacrificing the standard of service. An EMO should normally not downgrade the quality of service to that below common design standards. Examples of substandard level of comfort include room cooling temperature and air movement rate respectively higher and lower than the recommendations in *ASHRAE Standard 55-2004*[4], lighting level below the recommendations in *CIBSE Code for Interior Lighting*[5] , excessive noise from equipment/systems causing nuisance, etc.

In the past, energy can be saved by limiting the fresh air supply to an A/C space. With renewed concerns on good indoor air quality, consideration to provide "adequate fresh air supply" in accordance with the requirements of the Environmental Protection Department (EPD) or ASHRAE Standard *62-2001*[6] should be a foremost thought when degrading to reduce fresh air supply.

[4] ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy
[5] CIBSE Code for Interior Lighting
[6] ASHRAE Standard 62-2001: Ventilation for Acceptable Indoor Air Quality

3

3.7.5 *Already Scheduled Maintenance and Refurbishment Works*

When determining EMO, it is necessary to take into account the already scheduled major maintenance and refurbishment works. Therefore, when planning EMO implementation programme, the already scheduled major maintenance and refurbishment works may consider including some of the EMOs.

3.7.6 *Annual Monthly Energy Consumption Profile*

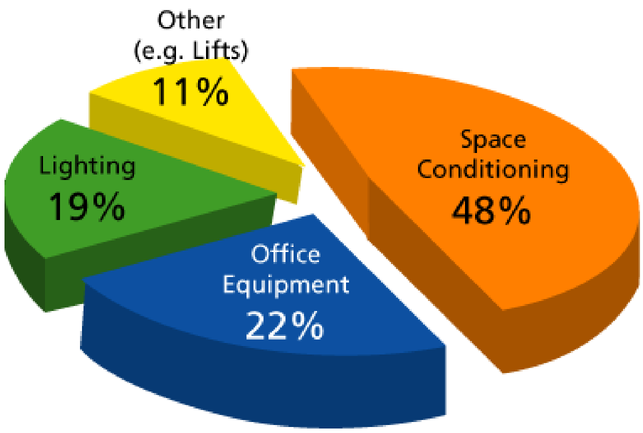
Based on the energy consumption bills over past years (preferably 3 or more), the auditor should estimate the annual energy use of the building. Graphs of energy consumption against different months of the year can be plotted, from which a pattern or general trend over a number of years can be seen. These graphs can show normal seasonal fluctuations in energy consumption. More importantly, any deviations from the trend are indication that some equipment/systems had not been operating efficiently as usual, which warrant more detailed studies to identify if further EMO has existed.

3.7.7 *Energy Utilisation Index/ Building Energy Performance*

The Energy Utilisation Index (EUI), obtained by dividing the annual energy consumption by the Gross Floor Area (GFA), takes into account the difference in energy consumption due to difference in building floor areas and is used for comparison of energy consumption among buildings of similar nature. An ordinary office building usually has an annual EUI of 700 to 1, 100 MJ/m^2 (200 to 300kWh/m^2). The EUI should be also regarded as the Building Energy Performance (BEP).

As the key form of energy used in commercial buildings is the electricity and other forms of energy such as town gas, LPG, diesel, etc. are relatively minor in quantity, some BEP computed for buildings have not included these forms of energy. Usually, EUI or BEP, if not identified as an index for a particular month, refers to the index for an entire year.

Appendix H
shows the sample graphs in Energy Audit Report.
Appendix I
shows the EUI/BEP of some Government office buildings.



Different proportion of energy consumption of a building

4 SOPHISTICATION OF AUDIT

The sophistication of an audit refers to the scope and the extent to which investigations should be conducted and which findings should be analysed. Based on available resources, the size and type of building, and the energy audit objective, the auditor should adopt the energy audit of different levels of sophistication.

Under such terms, there are two types of audits:-
a.) Walk-through Audit
b.) Detailed Audit

In summary, the Walk-through Audit involves a simple study of some major equipment/systems and the Detailed Audit involves a thorough study of practically all equipment/systems.

4.1 Walk-through Audit

Audits may deploy minimum resource to simply check for EMOs that are readily identifiable and to implement them to achieve savings immediately. Under such circumstances, the audit team should carry out a Walk-through Audit. It is the simplest type of energy audit and is the most basic requirement of the energy audit.

The audit should be conducted by walking through the building and concentrating on the major energy consuming equipment/systems such as chillers, large air handling units (AHUs), or common items usually with EMOs easily identifiable such as over-cooled spaces and T8 fluorescent tubes being used. Reference to record of equipment ratings, technical catalogue, O&M manuals that are readily available will be very helpful to quickly determine where equipment/systems are operating efficiently. Calculations, usually simple in nature, should be done to quantify the saving achievable from implementation of the identified EMOs.

The audit should be carried out in one day by either one auditor or one audit team, depending on the size and the complexity of the building and the scope of the audit. If the audit team wants to check more areas, more auditor-hours are required. Usually, simple instruments such as thermometer tube, multi-meters and lux meter will serve the purpose.

A Walk-through Audit should, other than fulfilling the original objectives, give an overview of other areas with potential EMOs.

4.2 Detailed Audit

Alternatively, if the building management is highly committed to energy conservation and have allowed for adequate staffing and funding, a Detailed Audit should be adopted. The audit team should check practically the majority or all equipment/systems, identify as many EMOs as possible, classify them into different EMO categories, further study if more complex items are involved, formulate a plan for implementation and finally present it to the building management. This audit goes much beyond the Walk-through Audit. The auditor has to exercise more detailed planning. The auditor-hours could be about 5 to 10 times more, depending on the complexity of the equipment/systems involved and size of the building.

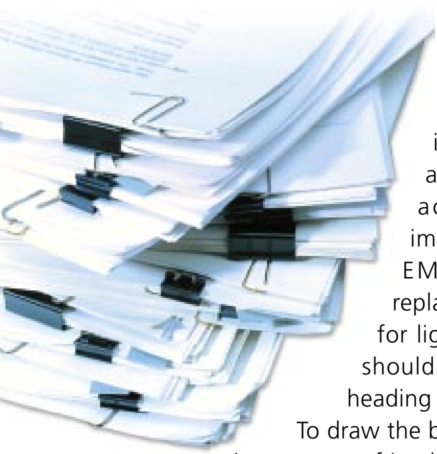
ENERGY AUDIT REPORT

5

The report should outline the objectives and scope of audit, description of characteristics and operational conditions of equipment/systems audited, findings in the audit, EMOs identified, corresponding savings and implementing costs, recommendations on EMO implementation and programme and any other follow-up actions.

This Section presents the suggested format for the report of a Detailed Audit. As the report is to suit for the need of the auditor, the auditor may choose to adopt the suggested format in whole or in part or adopt a totally different format. For Walk-through Audit, the auditor may trim down the report by deleting items not involved.

5.1 Executive Summary



The energy audit report provides the building management a quick overview of the scope of audit, EMOs identified, recommended actions justified by savings achievable and briefing on implementation plan. If there are EMOs of similar nature (e.g. replacement with electronic ballasts for lightings in different floors), they should be grouped under a common heading with cumulative savings shown. To draw the building owners' attention to the importance of implementing the EMOs, the cost of the estimated energy savings should be clearly identified.

5.2 Format of Energy Audit Report

5.2.1 Introduction

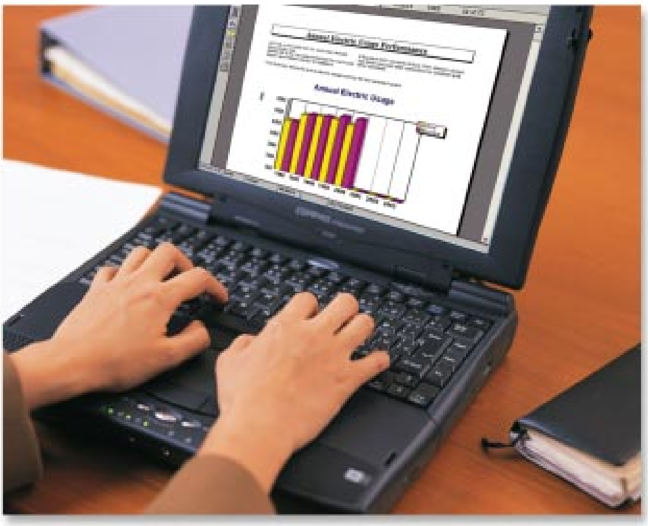
This part aims to describe the following topics:-

a) The building audited - numbers of floors, floor areas, usage, occupancy, hours of operation, year built, etc., layouts and schematics to be attached as appendix;

b) Objectives, such as studying the building energy consumption with a view to identifying EMOs for implementation, setting target savings, considering long term energy management programme, etc.;

c) Scope of audit, covering the installations to be studied such as HVAC Installation, Electrical Installation, Lift & Escalator systems, Plumbing & Drainage Systems or any particular equipment/systems, the depth of the study, the parties involved (end-user, building management, O&M personnel, etc.); and

d) Members of the audit team, and audit consultant employed, if any.



5.2.2 Description of Equipment/ Systems Audited

This part aims to focus on the following issues:-

a) Describe equipment/systems audited, their corresponding capacities and ratings, design conditions, etc., equipment schedules, schematics and layout drawings to be included as appendix.

b) Make use of information provided by the building management, O&M personnel and end-users and site surveys.

c) State the design conditions if known, and if not known the conditions adopted as base reference and calculations in the audit.

It should include the following contents:-

a) Zoning of systems according to building height or usage;

b) HVAC Installation for different areas –
type of system e.g. VAV, CAV, FCU, etc.; types of controls; type and numbers of chillers, pumps, heat rejection methods, etc. and their locations;

c) Lighting Installation –
type of lighting for different areas and type of control and zoning;

d) Electrical Installation –
numbers of transformers and low voltage main switch-boards and their locations and size or ratings of main distribution cables/busducts;

e) Lift Installation and Escalator Installation –
capacity, zoning, quantity, floors/areas served and types of control, types of drive;

f) Plumbing and Drainage System;

g) Hot Water System –
type of system; and

h) Other notable energy consuming equipment/systems.

5.2.3 Findings

This part aims to focus on description of the results of the site surveys and should include:-

a) Findings in a systematic format such as in order of systems (e.g. first on HVAC Installation, then on Lighting Installation, etc.) or in order of floors (e.g. from lowest level to top floor), or in order of usage (e.g. general office, private office, common corridor, lift lobby, etc.);
b) Descriptions of floors/areas with special requirements (e.g. 24-hour operation, low space temperature for computer room, etc.);
c) Calculation on cooling load, heating load, lighting load, electrical load and annual energy consumption (detailed calculations should be included as appendix);
d) Findings on O&M procedures and practices; and
e) Preliminary identification of possible EMOs against corresponding findings.

The descriptions should focus on issues related to possible EMOs and provide systematic numbering to findings for purpose of easy cross-reference. **Appendix J** serves as references.

5.2.4 Analysis and Identification of Energy Management Opportunities

This part focuses on the detailed analysis and identification of EMOs and should include:-

a) Comparison on actual performances of equipment/systems against original design (if information available) and/or actual site measurements for any discrepancies and identify the causes thereof;
b) Possible EMOs and corresponding substantiations (calculations on achievable energy savings and detailed descriptions as appendix);
c) Implementation costs for EMOs (making reference to corresponding reference numbers assigned to the findings, detailed calculations, schematics and drawings included as appendix);
d) Comparison on the different solutions to the same EMOs, as appropriate;
e) Classification of the EMOs into categories (Cat. I, Cat. II or Cat. III);
f) Listing of EMOs in a systematic format such as in order of system (e.g. first on HVAC Installation, then on Lighting Installation, etc.) or in order of floors (e.g. from lowest level to top floor) or in order of usage (e.g. general office, private office, common corridor, lift lobby, etc.);
g) Programme for implementation of the EMOs;
h) Identification of areas for further study, if any;
i) Indication of parties concerned in the implementation of EMOs and the difficulties that may encounter and general methodologies to overcome them; and
j) Initial investment and payback of each EMO in the summary.

5.2.5 Recommendations

This part aims to focus on:-

a) The initial investment and payback period of each EMO.
b) The summary of recommendations in a systematic order.
c) Grouping items of similar nature/location/usage together or group according to their categories (Cat. I, Cat. II and Cat. III).

EMO IMPLEMENTATION

6

6.1 Management Support

The auditor/audit team will implement the EMOs identified to achieve the objectives of energy savings. Whilst the auditor/audit team may have the authority to implement some of them, particularly Cat. I EMOs, the energy audit report should be endorsed by the building management for Cat. II EMOs and Cat. III EMOs, so as to have more cooperation from end-users involved in the implementation of these EMOs.

6.2 Planning

After receiving adequate support from the building management, the audit team should proceed to plan how to implement the EMOs based on the energy audit report. The audit team should-

a) Check if the solutions to the EMOs in detail and if not complete the corresponding design;

b) Check if adequate staff resources would be available and if not employ an audit consultant to do the detailed design and specification for the works required;

c) Identify the roles and responsibilities of the O&M personnel, the building management, end-users and relevant parties concerned;

d) Discuss with all parties involved and inform them the audit objectives and the audit scope, providing them copies of relevant sections of the audit report as appropriate;

e) Organise meetings for the monitoring of EMO implementation (Setting up of an ad-hoc committee for overall coordination and better understanding);

f) Consider ideas and comments from parties involved on the proposed EMOs, as there may be areas that the audit team has not properly considered during the audit or there may be some areas, EMOs or constraints that the audit team has overlooked in the audit;

g) Take into account that a lot of work may have to be carried out outside office hours, in order to minimise disruptions to routine building operation; and

h) Take into account that a lot of lobbying may be worthwhile, in order to obtain end-users' support and cooperation.

The audit team would then proceed to:-

a) Consolidate all these "After Audit" findings, reassess the proposed EMOs, make adjustments or even delete if necessary and amend relevant capital cost involved;

b) Work out a revised list of EMOs with energy savings, capital cost and remarks on parties involved and specific attentions for implementation;

c) Prepare a revised programme of EMO implementation, which should address the time required to procure the services/ products, the constraints not yet resolved such as the agreement by end-users to carry out the works in their working areas;

d) Prepare a rough estimate of the time expected in resolving the constraints;

e) Refer the EMOs with unresolved administration constraints to the building management for comment and decision;

f) Obtain final endorsement from the building management of the proposed programme if necessary; and

g) Obtain endorsement of the revised programme from the building management.

Experience has indicated that communication with end-users involved, O&M personnel and the building owner is very important to the success of EMO implementation. Whilst the audit team may take much effort and time to convince these parties that the proposed programme will contribute to energy savings, which means less expenditure to the building, the audit team should carry out their work more efficiently by having a harmonious relationship with them. The management concept of "partnership" among all parties concerned will smoothen the implementation process.

6.3 Monitoring of Implementation

To ensure that the EMOs are implemented properly, the audit team has to monitor the works and participation of parties concerned. The audit team needs to exercise control and adjust procedures from time to time, such as further negotiation with end-users on permitted working hours, settling site work conflicts with O&M personnel, processing payments to contractors, etc.

6.4 Performance Contracting

As an alternative to implementation of EMOs, the building management can employ a Performance Contracting service provider to do the work. The concept of Performance Contracting is that the service provider will design and implement the EMOs at a cost of a certain percentage of the total savings resulted from implementation of these EMOs. This contract approach should extend to the entire energy audit.

7 PUBLICITY AND TRAINING

Other than EMOs, the audit team may spot some issues of concern that need to be addressed for the sake of continual energy savings and sustainable development.

Continuing improvement on O&M is important, as equipment/ systems under good operating condition would usually use less energy. Raising the technical know-how and the awareness on importance of good operation and preventive maintenance of O&M personnel would contribute positively to energy savings. In this connection, proper training is required.

The building management may have noticed end-users at large are not well aware of energy savings. Raise their awareness through more publicity, organising talks or campaigns on energy efficiency and conservation. In fact, much energy can be saved simply through a good housekeeping such as turning off unused equipment/ systems.

8 ENERGY MANAGEMENT PROGRAMME

An energy audit and subsequent implementation of EMOs should provide certain energy savings. However, in order to maintain these savings over time, the building management needs a long-term Energy Management Programme (EMP).

Firstly, the building management develops an Energy Policy and then makes a corporate commitment to energy efficiency and conservation as well as appoints a senior member as energy manager to take charge of the Building Energy Performance (BEP) and to develop energy efficiency strategy. To meet the policy, the building management defines the objectives and energy efficiency targets in terms of energy savings, sets time frames for achievement and allocates adequate staff and financial resources. The building management should develop in-house energy experts and should engage energy manager/energy consultant to look after energy issues. These experts and energy manager/energy consultant should plan for further or periodic energy audits, formulate an action plan for implementation of EMOs and consider the need for staff awareness training to be provided as appropriate. A budget for EMP should be established and based on all these activities.

These activities should be regularly reviewed and the policy should be reassessed and redefined as appropriate. A not-cost-effective-enough EMO may be implemented, when there are major retrofits associated with this EMO. An example is the availability of fresh water for heat rejection method. This kind of "long-term" EMO can be implemented as an activity of the EMP.

During energy audit, the building management might have installed some meters to monitor energy consumption for certain equipment/systems. Whilst some of them will be removed after the audit, some could be remained as part of the equipment/systems. There may be also areas that meters could not be installed, due to site constraints or operational constraints. As an activity of the EMP, the building management should install meters (permanent type) or make provisions for ready connection of meters for each main system, its sub-systems and its associated components. Based on these metering facilities, the building management should better assess the energy consumption in the long run.

To verify the amount of energy savings through the implementation of EMOs, especially Cat II and Cat III EMOs, Measurement and Verification (M&V) are essential. The building management should record the required operational data for energy saving assessment whenever any retrofits associated with these EMOs are implemented. For example, in terms of housekeeping, the building management should record the effectiveness in execution of housekeeping procedures being laid down for a particular venue, before and after retrofit. Sample checks at regular intervals are expected.

APPENDIX A
Instrumentation for Energy Audit

Instruments	Measured parameter / Remarks
Electrical	
Voltmeter	Voltage
Ammeter	Current
Ohmmeter	Resistance
Multi-meter	Voltage, current, resistance
Wattmeter	Active power (kW)
Power factor meter	Power Factor / Apparent power (kVA) calculation
Light meter (lux meter)	Lighting level in lux (illuminance / illumination level)
Power quality analyser	Harmonic contents / Other electrical parameters
Thermographic scanner/camera	Conductor temperature in °C / Temperature images of overheating conductors (particularly at connection points)
Temperature	
Thermometer	Dry bulb temperature in °C
Sling psychrometer (thermometer)	Both dry and wet bulb temperature in °C
Portable electronic thermometer	
Infrared remote temperature sensing gun	Useful to sense energy losses due to improper insulation or leakage
Digital thermometer with temperature probe	Temperature inside a stream of normally hot air/steam (platinum probe for temperature from 0 to 100°C, and thermocouple probe for high temperatures as much as 1200°C)
Humidity	
Hair hygrometer	Humidity/wet bulb temperature
Digital thermometer	Humidity/wet bulb temperature
Pressure and Velocity	
Pitotstatic tube manometer	Air flow pressure and velocity
Digital type anemometer with probe	Air flow velocity and pressure
Vane type anemometer	Air velocity through a coil, air intake, or discharge, for flows that are not dynamically unstable, typical flow velocity 0.25m/s to 15 m/s.
Hood type anemometer	Flow rate of air grille
Pressure gauge	Liquid pressure
Ultrasonic flow meter with pipe clamps	Liquid flow/velocity
Miscellaneous	
Exhaust gas analyser with probe	Boiler exhaust temperature, O_2, CO, CO_2 and NO_x contents
Refrigerant gas leakage tester	Detect refrigerant leakage
Ultrasonic leak detector	Detect compressed air leakage
Steam leak detector	Steam leakage, usually for steam trap
Tachometer	Rotating speed
Recording device with chart	Record parameter monitored over a time period on a chart/graph (paper)
Data logging device	Couple with measuring instruments for measurement over a time period (electronic memory). Some of the above measuring devices already have built-in data logging functions.

APPENDIX B

Equipment / System Operation Log Sheets

The attached are sample log sheets for equipment/systems of an A/C Installation, to record operating conditions at different periods daily. (Depending on staff resource available, readings may be taken few times daily, at selected hours every few days, or whenever required.)

Areas requiring investigation can be spotted easily by:-

a.) Comparing the different readings of similar equipment at the same hour;

b.) Comparing the different readings of the same equipment over time (on different log sheets); and

c.) Checking if controlling parameters (flow rate, temperature, operating pressure) are within desired working ranges.

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 1
Chiller – Centrifugal, Fresh Water Cooled

Date : ____________

Building : ____

(* : delete inappropriate items)

CHILLER NO. ______ (Centrifugal, fresh water cooled) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air Condition			Centrifugal compressor						Lubricating oil system						Condenser				Evaporator						Chilled water			Cond. water		
				Motor				Compressor		Cooler		Oil pump		Sump		Water				Chilled water				Refrigerant		Pump no. ____			Pump no. ____		
	DB	WB	RH	Volt	Current			kPa		°C		kPa		Level	Temp	°C		kPa		°C		kPa		Level	Temp	kPa		Amp	kPa		Amp.
	°C	°C	%	V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		°C	In	Out	In	Out	In	Out	In	Out		°C	In	Out		In	Out	

CHILLER NO. ______ (Centrifugal, fresh water cooled) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air Condition			Centrifugal compressor						Lubricating oil system						Condenser				Evaporator						Chilled water			Cond. water		
				Motor				Compressor		Cooler		Oil pump		Sump		Water				Chilled water				Refrigerant		Pump no. ____			Pump no. ____		
	DB	WB	RH	Volt	Current			kPa		°C		kPa		Level	Temp	°C		kPa		°C		kPa		Level	Temp	kPa		Amp	kPa		Amp.
	°C	°C	%	V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		°C	In	Out	In	Out	In	Out	In	Out		°C	In	Out		In	Out	

CHILLER NO. ______ (Centrifugal, fresh water cooled) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air Condition			Centrifugal compressor						Lubricating oil system						Condenser				Evaporator						Chilled water			Cond. water		
				Motor				Compressor		Cooler		Oil pump		Sump		Water				Chilled water				Refrigerant		Pump no. ____			Pump no. ____		
	DB	WB	RH	Volt	Current			kPa		°C		kPa		Level	Temp	°C		kPa		°C		kPa		Level	Temp	kPa		Amp	kPa		Amp.
	°C	°C	%	V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		°C	In	Out	In	Out	In	Out	In	Out		°C	In	Out		In	Out	

CHILLER NO. ______ (Centrifugal, fresh water cooled) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air Condition			Centrifugal compressor						Lubricating oil system						Condenser				Evaporator						Chilled water			Cond. water		
				Motor				Compressor		Cooler		Oil pump		Sump		Water				Chilled water				Refrigerant		Pump no. ____			Pump no. ____		
	DB	WB	RH	Volt	Current			kPa		°C		kPa		Level	Temp	°C		kPa		°C		kPa		Level	Temp	kPa		Amp	kPa		Amp.
	°C	°C	%	V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		°C	In	Out	In	Out	In	Out	In	Out		°C	In	Out		In	Out	

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 2
Chiller – Reciprocating, Air-Cooled, 2-Circuit

Date : __________

Building : ____________________

(* : delete inappropriate items)

CHILLER NO. ______ (Reciprocating, air-cooled, 2-circuit) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air			Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Pump _______		
	DB	WB	RH	Volt	Current			Pres.(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Volt	Current			Pres(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Pres.(kPa)		Amp
	°C	°C	%	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	In	Out	A

CHILLER NO. ______ (Reciprocating, air-cooled, 2-circuit) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air			Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Pump _______		
	DB	WB	RH	Volt	Current			Pres.(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Volt	Current			Pres(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Pres.(kPa)		Amp
	°C	°C	%	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	In	Out	A

CHILLER NO. ______ (Reciprocating, air-cooled, 2-circuit) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air			Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Pump _______		
	DB	WB	RH	Volt	Current			Pres.(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Volt	Current			Pres(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Pres.(kPa)		Amp
	°C	°C	%	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	In	Out	A

CHILLER NO. ______ (Reciprocating, air-cooled, 2-circuit) Hour Meter : Start ( ) Stop ( )

Time	Outdoor Air			Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Reciprocating compressor _______						Oil	Evaporator _______				Condenser _		Pump _______		
	DB	WB	RH	Volt	Current			Pres.(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Volt	Current			Pres(kPa)			Pres.(kPa)		Temp (°C)		Temp (°C)		Pres.(kPa)		Amp
	°C	°C	%	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	V	R	Y	B	Hi	Lo		In	Out	In	Out	In	Out	In	Out	A

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 3
Chiller – Reciprocating/Centrifugal/Screw Air/Water Cooled

Date : ____________

Building : ____

(* : delete inappropriate items)

CHILLER NO. _____ Rated capacity ___________ *reciprocating/centrifugal/screw/________ air/water cooled floor ______ hour meter: start ________ stop _________

Time	Outdoor Air			Compressor 1						Lubricating 1					*Compressor 2						*Lubricating 2					* Condenser (air cooled)																* Condenser					Evaporator						
	°C		% RH	Volt/Current				kPa		Cooler °C		kPa		Oil Level	Volt/Current				kPa		Cooler °C		kPa		Oil Level	Circuit 1								Circuit 2								Water flow					Chilled water					Refr't	
																										Refrigerant °C		Refrigerant kPa		Air flow	Amp.			Refrigerant °C		Refrigerant kPa		Air flow	Amp.			°C		kPa		l/s	°C		kPa		l/s	Level	°C
	DB	WB		V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		In	Out	Hi	Lo	l/s	Fan 1	Fan 2	Fan 3	In	Out	Hi	Lo	l/s	Fan 1	Fan 2	Fan 3	In	Out	In	Out		In	Out	In	Out			

CHILLER NO. _____ Rated capacity ___________ *reciprocating/centrifugal/screw/________ air/water cooled floor ______ hour meter: start ________ stop _________

Time	Outdoor Air			Compressor 1						Lubricating 1					*Compressor 2						*Lubricating 2					* Condenser (air cooled)																* Condenser					Evaporator						
	°C		% RH	Volt/Current				kPa		Cooler °C		kPa		Oil Level	Volt/Current				kPa		Cooler °C		kPa		Oil Level	Circuit 1								Circuit 2								Water flow					Chilled water					Refr't	
																										Refrigerant °C		Refrigerant kPa		Air flow	Amp.			Refrigerant °C		Refrigerant kPa		Air flow	Amp.			°C		kPa		l/s	°C		kPa		l/s	Level	°C
	DB	WB		V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		In	Out	Hi	Lo	l/s	Fan 1	Fan 2	Fan 3	In	Out	Hi	Lo	l/s	Fan 1	Fan 2	Fan 3	In	Out	In	Out		In	Out	In	Out			

CHILLER NO. _____ Rated capacity ___________ *reciprocating/centrifugal/screw/________ air/water cooled floor ______ hour meter: start ________ stop _________

Time	Outdoor Air			Compressor 1						Lubricating 1					*Compressor 2						*Lubricating 2					* Condenser (air cooled)																* Condenser					Evaporator						
	°C		% RH	Volt/Current				kPa		Cooler °C		kPa		Oil Level	Volt/Current				kPa		Cooler °C		kPa		Oil Level	Circuit 1								Circuit 2								Water flow					Chilled water					Refr't	
																										Refrigerant °C		Refrigerant kPa		Air flow	Amp.			Refrigerant °C		Refrigerant kPa		Air flow	Amp.			°C		kPa		l/s	°C		kPa		l/s	Level	°C
	DB	WB		V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		V	R	Y	B	Hi	Lo	In	Out	Hi	Lo		In	Out	Hi	Lo	l/s	Fan 1	Fan 2	Fan 3	In	Out	Hi	Lo	l/s	Fan 1	Fan 2	Fan 3	In	Out	In	Out		In	Out	In	Out			

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 4
Chiller – Reciprocating/Centrifugal/Screw Air/Water Cooled W / Heat Recovery

Date : ____________

Building : ______________________________

(* : delete inappropriate items)

CHILLER NO. ______ Rated capacity __________ *reciprocating/centrifugal/screw/_____ *air/water cooled *with heat recovery floor ____ hour meter : start _____ stop _____

Time	Outdoor Air			Compressor ___						Lubricating oil system ___						*Compressor ___						*Lubricating oil system ___						* Cond. (Water & air)						* Condenser (Water & water)										Evaporator						
	°C		%	Volt/Current				kPa		Cooler °C		kPa		Oil sump		Volt/Current				kPa		Cooler °C		kPa		Oil		LTHW supply					Air flow	LTHW supply					Heat dissipation					Chilled water					Refrigerant	
														Level	°C											Level	°C	°C		kPa		l/s	l/s	°C		kPa		l/s	°C		kPa		l/s	°C		kPa		l/s	Level	Temp °C
	DB	WB	RH	V	R	Y	B	V	R	Y	B	Hi	Lo			V	R	Y	B	V	R	Y	B	Hi	Lo			In	Out	In	Out			In	Out	In	Out		In	Out	In	Out		In	Out	In	Out			

LTHW condenser water pump (low temperature hot water supply)														* Heat dissipation condenser water pump													
No __ Rating ____ Hrs ___							No __ Rating ____ Hrs ___							No __ Rating ____ Hrs ___							No __ Rating ____ Hrs ___						
kPa		l/s	Volt/Current				kPa		l/s	Volt/Current				kPa		l/s	Volt/Current				kPa		l/s	Volt/Current			
In	Out		V	R	Y	B	In	Out		V	R	Y	B	In	Out		V	R	Y	B	In	Out		V	R	Y	B

CHILLER NO. ______ Rated capacity __________ *reciprocating/centrifugal/screw/_____ *air/water cooled *with heat recovery floor ____ hour meter : start _____ stop _____

Time	Outdoor Air			Compressor ___						Lubricating oil system ___						*Compressor ___						*Lubricating oil system ___						* Cond. (Water & air)						* Condenser (Water & water)										Evaporator						
	°C		%	Volt/Current				kPa		Cooler °C		kPa		Oil sump		Volt/Current				kPa		Cooler °C		kPa		Oil		LTHW supply					Air flow	LTHW supply					Heat dissipation					Chilled water					Refrigerant	
														Level	°C											Level	°C	°C		kPa		l/s	l/s	°C		kPa		l/s	°C		kPa		l/s	°C		kPa		l/s	Level	Temp °C
	DB	WB	RH	V	R	Y	B	V	R	Y	B	Hi	Lo			V	R	Y	B	V	R	Y	B	Hi	Lo			In	Out	In	Out			In	Out	In	Out		In	Out	In	Out		In	Out	In	Out			

LTHW condenser water pump (low temperature hot water supply)														* Heat dissipation condenser water pump													
No __ Rating ____ Hrs ___							No __ Rating ____ Hrs ___							No __ Rating ____ Hrs ___							No __ Rating ____ Hrs ___						
kPa		l/s	Volt/Current				kPa		l/s	Volt/Current				kPa		l/s	Volt/Current				kPa		l/s	Volt/Current			
In	Out		V	R	Y	B	In	Out		V	R	Y	B	In	Out		V	R	Y	B	In	Out		V	R	Y	B

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

Air-Conditioning Plant Operating Log Sheet 5
Seawater heat exhcangers and sea water intake screen

Date : ______________

Building : ____

(* : delete inappropriate items)

SEA WATER HEAT EXCHANGERS AND SEA WATER INTAKE SCREEN

Time	Outdoor Air			Plate type heat exchanger No.___								Plate type heat exchanger No.___								Plate type heat exchanger No.___								Condition of sea water intake screen		
				Fresh water				Sea water				Fresh water				Sea water				Fresh water				Sea water				No.___	No.___	No.___
	DB	WB	RH	kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C				
	°C	°C	%	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out			

SEA WATER HEAT EXCHANGERS AND SEA WATER INTAKE SCREEN

Time	Outdoor Air			Plate type heat exchanger No.___								Plate type heat exchanger No.___								Plate type heat exchanger No.___								Condition of sea water intake screen		
				Fresh water				Sea water				Fresh water				Sea water				Fresh water				Sea water				No.___	No.___	No.___
	DB	WB	RH	kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C				
	°C	°C	%	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out			

SEA WATER HEAT EXCHANGERS AND SEA WATER INTAKE SCREEN

Time	Outdoor Air			Plate type heat exchanger No.___								Plate type heat exchanger No.___								Plate type heat exchanger No.___								Condition of sea water intake screen		
				Fresh water				Sea water				Fresh water				Sea water				Fresh water				Sea water				No.___	No.___	No.___
	DB	WB	RH	kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C				
	°C	°C	%	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out			

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 6
Sea water heat exchangers and auto backwash strainer

Date : ____________

Building : ____________

(* : delete inappropriate items)

SEA WATER HEAT EXCHANGERS AND AUTO BACKWASH STRAINER

Time	Outdoor Air			Plate type heat exchanger No.___								Plate type heat exchanger No.___								Plate type heat exchanger No.___								Auto backwash strainer							
				Fresh water				Sea water				Fresh water				Sea water				Fresh water				Sea water				No.___				No.___			
	DB	WB	RH	kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		Amp		kPa		Amp	
	°C	°C	%	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out

SEA WATER HEAT EXCHANGERS AND AUTO BACKWASH STRAINER

Time	Outdoor Air			Plate type heat exchanger No.___								Plate type heat exchanger No.___								Plate type heat exchanger No.___								Auto backwash strainer							
				Fresh water				Sea water				Fresh water				Sea water				Fresh water				Sea water				No.___				No.___			
	DB	WB	RH	kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		Amp		kPa		Amp	
	°C	°C	%	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out

SEA WATER HEAT EXCHANGERS AND AUTO BACKWASH STRAINER

Time	Outdoor Air			Plate type heat exchanger No.___								Plate type heat exchanger No.___								Plate type heat exchanger No.___								Auto backwash strainer							
				Fresh water				Sea water				Fresh water				Sea water				Fresh water				Sea water				No.___				No.___			
	DB	WB	RH	kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		°C		kPa		Amp		kPa		Amp	
	°C	°C	%	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

B APPENDIX

Air-Conditioning Plant Operating Log Sheet 7
Electro-chorinator and associated equipment

Date : ____________

Building : ____________

(* : delete inappropriate items)

ELECTRO-CHLORINATOR AND ASSOCIATED EQUIPMENT

Time	Chlorinator___			Chlorinator___			Sea water booster pump___			Sea water booster pump___			Hypochlorite injection pump___			Hypochlorite injection pump___			De-gas tank dilution fan		Flow switch sea water		Chlorine test by test kit
	DC		W.Flow	DC		W.Flow	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp	Operating				Outflow
	V	A	(l/s)	V	A	(l/s)	In	Out		In	Out		In	Out		In	Out		No.__	No.__	On	Off	(ppm)

ELECTRO-CHLORINATOR AND ASSOCIATED EQUIPMENT

Time	Chlorinator___			Chlorinator___			Sea water booster pump___			Sea water booster pump___			Hypochlorite injection pump___			Hypochlorite injection pump___			De-gas tank dilution fan		Flow switch sea water		Chlorine test by test kit
	DC		W.Flow	DC		W.Flow	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp	Operating				Outflow
	V	A	(l/s)	V	A	(l/s)	In	Out		In	Out		In	Out		In	Out		No.__	No.__	On	Off	(ppm)

ELECTRO-CHLORINATOR AND ASSOCIATED EQUIPMENT

Time	Chlorinator___			Chlorinator___			Sea water booster pump___			Sea water booster pump___			Hypochlorite injection pump___			Hypochlorite injection pump___			De-gas tank dilution fan		Flow switch sea water		Chlorine test by test kit
	DC		W.Flow	DC		W.Flow	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp	Operating				Outflow
	V	A	(l/s)	V	A	(l/s)	In	Out		In	Out		In	Out		In	Out		No.__	No.__	On	Off	(ppm)

Condition of sea water intake screen:	No.____	No.____	No.____	No.____

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 8
Sea water pumps and auto strainers

Building : ______________________ Date : ____________

(* : delete inappropriate items)

SEA WATER PUMPS AND AUTO STRAINERS

Time	Pump___					Pump___					Pump___					Pump___					Auto strainer no.___			Auto strainer no.___			Backwash pump___			Backwash pump___		
	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp
	In	Out				In	Out				In	Out				In	Out				In	Out		In	Out		In	Out		In	Out	

SEA WATER PUMPS AND AUTO STRAINERS

Time	Pump___					Pump___					Pump___					Pump___					Auto strainer no.___			Auto strainer no.___			Backwash pump___			Backwash pump___		
	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp
	In	Out				In	Out				In	Out				In	Out				In	Out		In	Out		In	Out		In	Out	

SEA WATER PUMPS AND AUTO STRAINERS

Time	Pump___					Pump___					Pump___					Pump___					Auto strainer no.___			Auto strainer no.___			Backwash pump___			Backwash pump___		
	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp
	In	Out				In	Out				In	Out				In	Out				In	Out		In	Out		In	Out		In	Out	

SEA WATER PUMPS AND AUTO STRAINERS

Time	Pump___					Pump___					Pump___					Pump___					Auto strainer no.___			Auto strainer no.___			Backwash pump___			Backwash pump___		
	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		l/s	V	A	kPa		Amp	kPa		Amp	kPa		Amp	kPa		Amp
	In	Out				In	Out				In	Out				In	Out				In	Out		In	Out		In	Out		In	Out	

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 9
Sea water pumps and intake screens condition

Date : ____________

Building : ____________

(* : delete inappropriate items)

SEA WATER PUMPS AND INTAKE SCREENS CONDITION

Time	Pump no.___							Pump no.___							Pump no.___							Pump no.___							Screen ___	Screen ___	Screen ___	Screen ___
	kPa		l/s	V	Amp			kPa		l/s	V	Amp			kPa		l/s	V	Amp			kPa		l/s	V	Amp						
	In	Out			R	Y	B	In	Out			R	Y	B	In	Out			R	Y	B	In	Out			R	Y	B				

SEA WATER PUMPS AND INTAKE SCREENS CONDITION

Time	Pump no.___							Pump no.___							Pump no.___							Pump no.___							Screen ___	Screen ___	Screen ___	Screen ___
	kPa		l/s	V	Amp			kPa		l/s	V	Amp			kPa		l/s	V	Amp			kPa		l/s	V	Amp						
	In	Out			R	Y	B	In	Out			R	Y	B	In	Out			R	Y	B	In	Out			R	Y	B				

SEA WATER PUMPS AND INTAKE SCREENS CONDITION

Time	Pump no.___							Pump no.___							Pump no.___							Pump no.___							Screen ___	Screen ___	Screen ___	Screen ___
	kPa		l/s	V	Amp			kPa		l/s	V	Amp			kPa		l/s	V	Amp			kPa		l/s	V	Amp						
	In	Out			R	Y	B	In	Out			R	Y	B	In	Out			R	Y	B	In	Out			R	Y	B				

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 10
*Cooling Tower/Radiator

Date : ____________

Building : ____________

(* : delete inappropriate items)

***COOLING TOWER/RADIATOR**

Time	Fan no.______						Fan no.______						Fan no.______						Air		Water flow			*2^{nd} radiator coil			*Pump______					*Pump______				
	Motor					l/s	Motor					l/s	Motor					l/s	°C		°C		l/s	°C		l/s	Flow	Volt	Amp			Flow	Volt	Amp		
	kW	V	R	Y	B		kW	V	R	Y	B		kW	V	R	Y	B		In	Out	In	Out		In	Out		l/s	V	R	Y	B	l/s	V	R	Y	B

***COOLING TOWER/RADIATOR**

Time	Fan no.______						Fan no.______						Fan no.______						Air		Water flow			*2^{nd} radiator coil			*Pump______					*Pump______				
	Motor					l/s	Motor					l/s	Motor					l/s	°C		°C		l/s	°C		l/s	Flow	Volt	Amp			Flow	Volt	Amp		
	kW	V	R	Y	B		kW	V	R	Y	B		kW	V	R	Y	B		In	Out	In	Out		In	Out		l/s	V	R	Y	B	l/s	V	R	Y	B

***COOLING TOWER/RADIATOR**

Time	Fan no.______						Fan no.______						Fan no.______						Air		Water flow			*2^{nd} radiator coil			*Pump______					*Pump______				
	Motor					l/s	Motor					l/s	Motor					l/s	°C		°C		l/s	°C		l/s	Flow	Volt	Amp			Flow	Volt	Amp		
	kW	V	R	Y	B		kW	V	R	Y	B		kW	V	R	Y	B		In	Out	In	Out		In	Out		l/s	V	R	Y	B	l/s	V	R	Y	B

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 11
Secondary *Chilled/Hot Water Pumps

Date : ______________________

Building : ______________________

(* : delete inappropriate items)

SECONDARY*CHILLED/HOT WATER PUMPS																																																					
No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___								
°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current			
In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B

SECONDARY*CHILLED/HOT WATER PUMPS																																																					
No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___								
°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current			
In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B

SECONDARY*CHILLED/HOT WATER PUMPS																																																					
No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___								
°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current			
In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B

SECONDARY*CHILLED/HOT WATER PUMPS																																																					
No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___									No.___ Rating___ Hrs.___								
°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current				°C		kPa		l/s	Volt/Current			
In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B	In	Out	In	Out		V	R	Y	B

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 12
Air-Handing Unit - Constant Air Volume(CAV)

Date : ____________

Building : ____

(* : delete inappropriate items)

(Usually, FCU,VAV box, small AHU and fan are to be checked only if their efficiency are in doubt and would contribute to relatively appreciable energy wastage.)

AHU___(CAV) Rated capacity________ Hour meter : Start ( ) stop:( )

Time	Outdoor		Filter	Motor					Supply			Return			Heater			Floor_____,Area______						Floor______ ,Area______						Remark
	DB	WB	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	DB	WB	m^3/s	Elec/hot w.			spot	DB	WB	spot	DB	WB	spot	DB	WB	spot	DB	WB	Belt:
															kW	On	Off													Bearing:

AHU___(CAV) Rated capacity________ Hour meter : Start ( ) stop:( )

Time	Outdoor		Filter	Motor					Supply			Return			Heater			Floor_____,Area______						Floor______ ,Area______						Remark
	DB	WB	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	DB	WB	m^3/s	Elec/hot w.			spot	DB	WB	spot	DB	WB	spot	DB	WB	spot	DB	WB	Belt:
															kW	On	Off													Bearing:

AHU___(CAV) Rated capacity________ Hour meter : Start ( ) stop:( )

Time	Outdoor		Filter	Motor					Supply			Return			Heater			Floor_____,Area______						Floor______ ,Area______						Remark
	DB	WB	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	DB	WB	m^3/s	Elec/hot w.			spot	DB	WB	spot	DB	WB	spot	DB	WB	spot	DB	WB	Belt:
															kW	On	Off													Bearing:

AHU___(CAV) Rated capacity________ Hour meter : Start ( ) stop:( )

Time	Outdoor		Filter	Motor					Supply			Return			Heater			Floor_____,Area______						Floor______ ,Area______						Remark
	DB	WB	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	DB	WB	m^3/s	Elec/hot w.			spot	DB	WB	spot	DB	WB	spot	DB	WB	spot	DB	WB	Belt:
															kW	On	Off													Bearing:

AHU___(CAV) Rated capacity________ Hour meter : Start ( ) stop:( )

Time	Outdoor		Filter	Motor					Supply			Return			Heater			Floor_____,Area______						Floor______ ,Area______						Remark
	DB	WB	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	DB	WB	m^3/s	Elec/hot w.			spot	DB	WB	spot	DB	WB	spot	DB	WB	spot	DB	WB	Belt:
															kW	On	Off													Bearing:

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 13
Air-Handing Unit - Variable Air Volume (VAV)

Date : ____________

Building : ____________

(* : delete inappropriate items)

(Usually, FCU,VAV box, small AHU and fan are to be checked only if their efficiency are in doubt and would contribute to relatively appreciable energy wastage.)

AHU___(VAV) Rated capacity________ Hour meter : Start ( ) stop:( )																																	Remark
Time	Outdoor		Filter	E filter		Supply air fan								Return air fan								Exhaust air fan								Heater Elec/hot w.			Belt: Bearing:
	DB	WB	ΔPa	On	Off	V	R	Y	B	rpm	DB	WB	m^3/s	V	R	Y	B	rpm	DB	WB	m^3/s	V	R	Y	B	Rpm	DB	WB	m^3/s	kW	On	Off	

Time	VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____			
	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB

AHU___(VAV) Rated capacity________ Hour meter : Start ( ) stop:( )																																	Remark
Time	Outdoor		Filter	E filter		Supply air fan								Return air fan								Exhaust air fan								Heater Elec/hot w.			Belt: Bearing:
	DB	WB	ΔPa	On	Off	V	R	Y	B	rpm	DB	WB	m^3/s	V	R	Y	B	rpm	DB	WB	m^3/s	V	R	Y	B	Rpm	DB	WB	m^3/s	kW	On	Off	

Time	VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____			
	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB

AHU___(VAV) Rated capacity________ Hour meter : Start ( ) stop:( )																																	Remark
Time	Outdoor		Filter	E filter		Supply air fan								Return air fan								Exhaust air fan								Heater Elec/hot w.			Belt: Bearing:
	DB	WB	ΔPa	On	Off	V	R	Y	B	rpm	DB	WB	m^3/s	V	R	Y	B	rpm	DB	WB	m^3/s	V	R	Y	B	Rpm	DB	WB	m^3/s	kW	On	Off	

Time	VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____				VAV box ____			
	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB	On	Off	DB	WB

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX B

Air-Conditioning Plant Operating Log Sheet 14
Fan Coil Units (FCUs)

Date : ____________

Building : ____________

(* : delete inappropriate items)

(Usually, FCU,VAV box, small AHU and fan are to be checked only if their efficiency are in doubt and would contribute to relatively appreciable energy wastage.)

Time	FCU___ Rating___					FCU___ Rating___					FCU___ Rating___					FCU___ Rating___					FCU__ Rating__ w/__ kW heater								FCU__ Rating__ w/__ kW heater								Remark
	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	Elec/hw. heater			DB	WB	m^3/s	A	V	Elec/hw. heater			
																										kW	On	Off						kW	On	Off	

Time	FCU___ Rating___					FCU___ Rating___					FCU___ Rating___					FCU___ Rating___					FCU__ Rating__ w/__ kW heater								FCU__ Rating__ w/__ kW heater								Remark
	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	Elec/hw. heater			DB	WB	m^3/s	A	V	Elec/hw. heater			
																										kW	On	Off						kW	On	Off	

Time	FCU___ Rating___					FCU___ Rating___					FCU___ Rating___					FCU___ Rating___					FCU__ Rating__ w/__ kW heater								FCU__ Rating__ w/__ kW heater								Remark
	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	DB	WB	m^3/s	A	V	Elec/hw. heater			DB	WB	m^3/s	A	V	Elec/hw. heater			
																										kW	On	Off						kW	On	Off	

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

Air-Conditioning Plant Operating Log Sheet 15
Fans

Date : ____________

Building : ____________

(* : delete inappropriate items)

(Usually, FCU,VAV box, small AHU and fan are to be checked only if their efficiency are in doubt and would contribute to relatively appreciable energy wastage.)

Time	FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									Remark
	Fan motor					Air			Filter	Fan motor					Air			Filter	Fan motor					Air			Filter	Belt:
	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	
																												Bearing:

Time	FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									Remark
	Fan motor					Air			Filter	Fan motor					Air			Filter	Fan motor					Air			Filter	Belt:
	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	
																												Bearing:

Time	FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									Remark
	Fan motor					Air			Filter	Fan motor					Air			Filter	Fan motor					Air			Filter	Belt:
	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	
																												Bearing:

Time	FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									Remark
	Fan motor					Air			Filter	Fan motor					Air			Filter	Fan motor					Air			Filter	Belt:
	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	
																												Bearing:

Time	FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									FAN ___ cent/axial/prop Rating ___									Remark
	Fan motor					Air			Filter	Fan motor					Air			Filter	Fan motor					Air			Filter	Belt:
	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	V	R	Y	B	rpm	DB	WB	m^3/s	ΔPa	
																												Bearing:

Shift	Technician		Shift-in-charge	
	Name	Signature	Name	Signature
1				
2				
3				

Remarks
Time 'ON' :
Time 'OFF' :
Reason for stopping :
Others (if any) :

Legend
√ : in use
X : under repair/maintenance
@ : standby
# : scheduled off

APPENDIX C

Questionnaire on Occupancy, Office Equipment and Thermal Comfort

With the information on building general characteristics, the audit team can have an idea of the distribution of different divisions or different organisations at different floors. Questionnaire can be prepared for completion by each end-user of each division or each department or each organisation. Corresponding floor plan (simplified), in A3 or A4 size, can be attached to the questionnaire for marking of areas with problems. The building manager may have to write a note to the end-user. A sample note is as follows:

Sample note to end-user

Dear occupant of …………… ,

Energy Audit for …………………………………. Building

An energy audit is being conducted for this building. The purpose of the audit is to identify areas of inefficient operation of energy consuming equipment/systems (e.g. air conditioning, lighting, electrical, etc). Examples are areas that are too cold even in summer, air conditioning or lighting turned on unnecessarily. The audit is by no means to lower the standard of services provided. With improvement in the way that we operate the building, we can save energy cost and at the same time provide you better service.

The attached questionnaire is to collect information from your goodself, the end-users of this building. Your provision of information is important to the audit result. Without your valuable input, the audit result may not be accurate, or cannot address to the needs of your floor/division. Please participate in the energy audit by completing this questionnaire and return to the management office by ……………………

For any queries on the questionnaire, please contact …………….. at Tel: …………….

A team of auditors will visit your office shortly. We would keep you informed of the dates and time.

We look forward to your kind cooperation.

Yours faithfully,

(Building Manager)
for Building Management

APPENDIX C

Building: ______________________________

Date: ______________

I. Occupancy

Floor:	Division / Organization:
Name of person-in-charge:	Tel:
Average daily nos. of occupants: (give figures for different periods of the day, if the differences among such periods are large; give figures for different periods of the year, if the differences among such periods are large)	

II List of Office Equipment

	Rating (W)	Quantity (Nos.)
Photocopying machine		
Fax machine		
Personal computer		
Printer		
Water dispenser		
Tea urn		
Refrigerator		
Vending machine		
Others (to be listed)		

APPENDIX C

III Change in occupancy over past 12 months? (If yes, please describe)

IV Thermal discomfort in your office?

☐ Yes, proceed to following questions

☐ No, Stop here

Indicate and number the area(s) with discomfort on office plan attached, and answer the following questions.

Area ________

☐ Slightly cold in summer	☐ Quite cold in summer	☐ Too warm in winter
Usually	Usually	Usually
☐ On rainy days	☐ On rainy days	☐ On cloudy days
☐ when there is no direct sunshine to the area concerned	☐ when there is no direct sunshine to the area concerned	☐ when there is no direct sunshine to the area concerned
☐ in a.m.	☐ in a.m.	☐ in a.m.
☐ in p.m.	☐ in p.m.	☐ in p.m.
☐ Others (please state)	☐ Others (please state)	☐ Others (please state)

Others (please describe)

Area ________

☐ Slightly cold in summer	☐ Quite cold in summer	☐ Too warm in winter
Usually	Usually	Usually
☐ On rainy days	☐ On rainy days	☐ On cloudy days
☐ when there is no direct sunshine to the area concerned	☐ when there is no direct sunshine to the area concerned	☐ when there is no direct sunshine to the area concerned
☐ in a.m.	☐ in a.m.	☐ in a.m.
☐ in p.m.	☐ in p.m.	☐ in p.m.
☐ Others (please state)	☐ Others (please state)	☐ Others (please state)

Others (please describe)

(Make copies for completion if there are more areas with thermal discomfort)

APPENDIX D

Energy Audit Forms

The following audit forms are to assist the audit team to present data reflecting the operational conditions of various equipment/systems. The data may be copied from records provided by the O&M personnel and the building management (provided that accuracy is checked) or obtained from actual site measurements and surveys. For data provided, the audit team should take re-measurement if the accuracy is in doubt. The auditor should compare the data in these audit forms

(a) Against design records and commissioning & testing records if available;
(b) With equipment of similar ratings; and
(c) With a view to identify any deviations and the corresponding causes.

These audit forms by no means cater for all the energy consuming equipment/systems. To cover the necessary equipment under the scope of the audit, the auditor should

(a) Make photocopies of relevant forms or reproduce relevant sections in a form for additional equipment of similar nature;
(b) Amend forms to suit if necessary; and
(c) Compose new forms of similar format for equipment not covered in these forms.

These forms are audit-oriented and thus have provisions for many details. The auditor team may simplify these forms to suit their less comprehensive scope of audit.

The following questions on the equipment/systems should be continuously raised during the audit:-

(a) Is the equipment/system required for operation?
(b) Is the equipment/system over designed?
(c) Is the equipment/system energy efficient?
(d) Is the equipment/system operating efficiently to suit for usage and occupancy?

For solution and improvement, identify the most cost effective available technology (to suit for the budget).

APPENDIX D

Energy Audit Form 1 – Total Energy Consumption

Part 1 : Detail of Project

Building: ______________________________

Date: ______________________________

Part 2 : Data

Year: ______________________________

Gross Floor Area: ______________________________ m^2

Month	Electricity								Town Gas				LPG				Other fuel				Total EUI
	kWh		kVA (peak)	$/kWh		$/kVA	Cost ($)	EUI	Unit	$/Unit	Cost ($)	EUI	kg	$/kg	Cost ($)	EUI	kg	$/kg	Cost ($)	EUI	
	Peak	Off peak		Peak	Off peak																
January																					
February																					
March																					
April																					
May																					
June																					
July																					
August																					
September																					
October																					
November																					
December																					
Annual TOTAL																					

(Make copies for completion of information for different years.)

Remark: 1 kWh electricity = 3.6 MJ   1 Unit Town Gas = 48 MJ   1 kg LPG = 46.3 MJ   1 kg industrial diesel fuel = 42.5 MJ

Checked by ______________________________ Signature ______________________________

(Name of Auditor)

APPENDIX D

Energy Audit Form 2 – Floor Area, Occupancy, Room Temperature and Lighting Level

Part 1 : Detail of Project

Building: ______________________________

Date: ______________________

Part 2 : Data

	A/C space																														Non-A/C space								
Outdoor temp DB ____ WB ____	Open plan office					Private office					Conference Rm.					Circulation area (lobby, stairs, etc.)					Toilet/Cleaner					Others (pantry, store, plant room, etc.)					Circulation area (lobby, stairs, etc.)		Carpark, loading bay		Plant Room		Others (pantry, store, etc.)		Remark
Floor/ Description	Area (m^2)	Occu	DB	WB	Lux	Area (m^2)	Occu	DB	WB	Lux	Area (m^2)	Occu	DB	WB	Lux	Area (m^2)	Occu	DB	WB	Lux	Area (m^2)	Occu	DB	WB	Lux	Area (m^2)	Occu	DB	WB	Lux	Area (m^2)	Lux	Area (m^2)	Lux	Area (m^2)	Lux	Area (m^2)	Lux	
Luminaires, electrical equipment, appliances and ratings																																							
Total gross floor area: _____ Total floor AC Area: _____ Total floor non-AC area: _____ Time: _____ Outdoor Condition : _____ DB _____ WB, sunny / cloudy / rainy /																																							

(Refer to feedbacks from end-users in questionnaires in Appendix C when completing this form.)

Checked by ______________________________ Signature ______________________

(Name of Auditor)

APPENDIX D

Energy Audit Form 3 – Checklist for HVAC

Part 1 : Detail of Project

Building: ____

Date: ______________________

Part 2 : Data

	Items tested / checked by Auditor	Remarks
General		
1. Operating hours	_______ hr(s)	
2. Measured room temperature	________ ˚C	
3. Measured room relative humidity	________ %	
4. Measured ventilation rate	_______ L/s	
5. Pattern of occupancy level	___ persons	
6. Usage pattern	__________	
Conditions		
7. Are areas too cold, too warm or over ventilated?	__________	
8. Are doors/windows opened unnecessarily?	*Yes/No/N.A.	
9. Are venetian blinds/curtains not installed/used?	*Yes/No/N.A.	
Cleanliness		
10. Are filters dirty?	*Yes/No/N.A.	
11. Are cooling/heating coils dirty?	*Yes/No/N.A.	
12. Are interior of Air Handling Units (AHUs) dirty?	*Yes/No/N.A.	
13. Are fans inside AHUs dirty?	*Yes/No/N.A.	
14. Are ductworks dirty?	*Yes/No/N.A.	
15. Are water strainers dirty?	*Yes/No/N.A.	
16. Is chilled water system dirty and not properly conditioned (water sampling may be required)?	*Yes/No/N.A.	
17. Is condensing water system dirty and not properly conditioned (water sampling may be required)?	*Yes/No/N.A.	
18. Is low temperature hot water (LTHW) system dirty and not properly conditioned (water sampling may be required)?	*Yes/No/N.A.	
Leakage		
19. Is there any refrigerant leakage?	*Yes/No/N.A.	
20. Is there any compressor oil leakage?	*Yes/No/N.A.	
21. Is there any steam (from steam trap) leakage?	*Yes/No/N.A.	
22. Is there any excessive water leaving pump gland?	*Yes/No/N.A.	
Readings on indicators (flow meter, thermometer, gauge, electrical meter, sight glass) within operating ranges and levels		
23. Equipment in/out temperatures	___ ˚C /___ ˚C	

Checked by ________________________________ Signature ____________________
(Name of Auditor)

D APPENDIX

24. Type of refrigerant	__________	
25. Type of compressor oil	__________	
26. In/out pressure on gauges/meters	___ °C /___ °C	
27. Flow rate on gauges/meters	___ L/s /___ L/s	
28. Electrical current on meters	________ A	
29. Electrical voltage on meters	________ V	
General abnormalities readily identifiable		
30. Is there any excessive noise or vibration from fan, pump, motor or bearings?	*Yes/No/N.A.	If yes, please specify __________________
31. Are there any moving parts (e.g. bearings) not properly lubricated?	*Yes/No/N.A.	
32. Is there any insulation worn out or hanging loose?	*Yes/No/N.A.	
33. Is the fan belt too loose or tight?	*Yes/No/N.A.	
34. Is there any condensate on insulation or surface of equipment for C.H.W. and refrigerant?	*Yes/No/N.A.	
35. Is it too hot an insulated surface of steam or hot water equipment/pipe?	*Yes/No/N.A.	
36. Are there any worn-out components/parts?	*Yes/No/N.A.	
37. Are compressor unloading device not working properly?	*Yes/No/N.A.	
Controls		
38. Is thermostat/humidistat/actuator not located at suitable set point?	*Yes/No/N.A.	
39. Is sensor/thermostat/humidistat/actuator malfunctioned?	*Yes/No/N.A.	
40. Is sensor/thermostat/humidistat not located at proper location?	*Yes/No/N.A.	
41. Is an algorithm not meeting operational requirement?	*Yes/No/N.A.	
42. Is sensor/controller not functioning as desired?	*Yes/No/N.A.	
43. Is DDC/CCMS not functioning as desired?	*Yes/No/N.A.	
Efficiency		
44. Is efficiency (measured) of major equipment (e.g. COP of chiller) below desired level?	*Yes/No/N.A.	
Possibility		
45. Are there any possibilities to use natural or mechanical ventilation?	*Yes/No/N.A.	
46. Are there any possibilities of introducing energy efficient equipment/retrofit	*Yes/No/N.A.	

Instrument	Model No.	Manufacturer	Serial No.	Calibration Date	Expired Date
1. Thermometers					
2. Anemometer					
3. Clamp-on Ammeter					
4. Voltmeter					

Checked by ______________________________ Signature ______________________________
(Name of Auditor)

APPENDIX D

Energy Audit Form 4 – Checklist for Lighting

Part 1 : Detail of Project

Building: ______________________________

Date: ______________________________

Part 2 : Data

	Items tested / checked by Auditor	Remarks
General		
1. Operating hours	_______ hr(s)	
2. Measured lighting level	_______ Lux	
3. Lighting type	___________	
Cleanliness		
4. Are luminaires dirty?	*Yes/No/N.A.	
Conditions		
5. Is circulation area, lobby, car park, loading area with similar lighting level to general office?	*Yes/No/N.A.	
6. Is there any presence of unacceptable glare?	*Yes/No/N.A.	
7. Are there any lamps near end of life?	*Yes/No/N.A.	
8. Are there any worn-out lighting components?	*Yes/No/N.A.	
9. Are any sensors and controllers not working as desired?	*Yes/No/N.A.	
10. Are emergency lights left on unnecessarily?	*Yes/No/N.A.	
Possibility		
11. Are there any possibilities of introducing energy efficient lightings, electronic ballasts and lighting controls?	*Yes/No/N.A.	
Others		
12.	*Yes/No/N.A.	
13.	*Yes/No/N.A.	
14.	*Yes/No/N.A.	
15.	*Yes/No/N.A.	
16.	*Yes/No/N.A.	
17.	*Yes/No/N.A.	
18.	*Yes/No/N.A.	

Instrument	Model No.	Manufacturer	Serial No.	Calibration Date	Expired Date
1. Clamp-on Ammeter					
2. Voltmeter					
3. Lux meter					

Checked by ______________________________ Signature ______________________________
(Name of Auditor)

APPENDIX E

Some Common Energy Audit Findings, Corresponding EMOs and Energy Savings

Audit Finding	Corresponding EMOs	Approximate Energy Savings[1]
HVAC Installation – EMO Cat. I		
1. A/C remaining "ON" outside office hours	The last man out or install a timer to turn off A/C	Unnecessary consumption during off hours
2. Too cold in summer, e.g. measured room temperature 21°C	Set thermostat to desired room temperature of 25.5°C; or repair/replace the thermostat if it is not functional	10 to 30%
3. Door or window left open when AC is "ON"	Close door or window	5 to 20%
4. Excessive air pressure drop across air filter of AHU	Clean air filte	5 to 20% fan power
5. Chiller set to provide 6°C chilled water outside summer	Re-set operating temperature to 8°C	3 to 6% chiller power
HVAC Installation – EMO Cat. II		
6. No blinds or blinds not closed for window with strong sunshine	Install or close blinds	5 to 30% cooling energy to offset solar heat gain through window
7. Access door for cooling AHU or ductwork has air leakage (say 3%)	Identify and rectify the leaking gasket/sealant of the access door/ductwork	3% fan power
8. Excessive water leaving chilled water pump glands	Check & improve shaft seal	A flow of 1 L/min. excessive flow means 1000kWh per year
9. Overcooled spots due to improper air balancing	Balance the air supply system, add dampers as appropriate	15 to 25%
10. Overcooled spots due to improper water balancing	Balance the water supply system, add valves if practicable	15 to 25%
HVAC Installation – EMO Cat. III		
11. Window exposed to strong sunlight	Apply "anti-ultraviolet film"	>20%
12. Boiler with 25% excess air (combustion)	Adjust excess air to 10%	1.5%
13. Air flow of VAV AHU controlled by inlet guide vanes	Add VVVF inverter type variable speed drive	10 to 30% fan power
14. Secondary chilled water pump driven by constant speed motor	Add VVVF inverter type variable speed drive (with controlling sensor at strategic point downstream and at setting such that adequate pressure at low load condition can be provided to far away cooling coils)	10 to 30% pump power

[1] The figures are for reference only. Actual energy savings will depend on different conditions and applications.

APPENDIX E

Audit Finding	Corresponding EMOs	Approximate Energy Savings[2]
Lighting Installation – EMO Cat. I		
15. Lighting level in corridor area at 500 lux, which is on high side, however capital cost not available for retrofit	Disconnect power supply to some lightings and lower illumination to suitable level, say 100 lux.	15 to 30% for corridor lightings
16. Lightings along window areas turned "ON" at day time, providing a lux level well over 700 lux	Maintain the lighting level at 500 lux by: turning off corresponding perimeter lightings; or if both interior lightings and perimeter lightings share the same control switch re-wire to facilitate 2 independent control switches for each of the 2 zones; or replace the ballasts of lightings (only if lighting can suit) at perimeter with dimmable electronic type and control by photo sensor.	20 to 30% for lightings at perimeter
Lighting Installation – EMO Cat. II		
17. T12/T10 fluorescent tube used in lightings (e.g. exit sign)	Replace with T8 fluorescent tube (not feasible for quick start type)	10%
18. T8 fluorescent lighting (fixture & tube) used	Replace with T5 fluorescent lighting	30-40%
19. Manual control for lighting ON/OFF	Add occupancy sensor control	>20%
20. Electromagnetic ballast used in lightings with T8 fluorescent tube	Replace with electronic ballast	20 to 40%
21. Incandescent lamp being used	Change to compact fluorescent lamps or retrofit with fluorescent tube lighting	80%, plus if space is AC the cooling energy to offset the higher heat dissipation from incandescent lamp
Electrical Installation – EMO Cat. III		
22. Over sizing of motor by 30%	Replace with smaller motor of proper rating Add VVVF variable speed drive	5% 50%
23. Overall power factor of 0.8	Improve to min. 0.85	Minimise I^2R losses through distribution network
24. 30% total harmonics distortion (THDI)	Add harmonics filter to reduce to the extent of THDI subject to the circuit current, I at rated load condition	Minimise I^2R losses through distribution network

[2] The figures are for reference only. Actual energy savings will depend on different conditions and applications.

APPENDIX F

Costing Calculation

EMO requiring capital expenditure shall be evaluated to see if it is economically justifiable. The evaluation can be done using the following methods.

Simple Payback Period

The payback period is the number of years required to recover the capital invested.

This method is simple in calculation, which normally excludes the consideration of timing of cash flows, inflation rate, interest rate of capital cost, depreciation, opportunity cost, etc. Its accuracy however will usually be within reasonable range.

Payback Period = initial capital cost / (yearly benefit – yearly cost)

For better accuracy, the net maintenance cost, interest on capital cost, net depreciation, opportunity cost, etc. can be added to the yearly cost. Likewise, the net productivity increase resulted from the investment, if any, can be added to the yearly benefit.

Example:

The following example shows the payback period for replacing 400 nos. of electromagnetic ballasts with electronic ballasts, each serving a single T8 36W (1200mm) fluorescent tube. Each electronic ballast costs $120 to purchase and install. The operating hours are 10 per day, 6 days per week and electricity cost is $0.9 per kWh.

Rating of fluorescent tube at 50 Hz operation	36W
Lighting system power with electromagnetic ballast	48W
Lighting system power with HF electronic ballast	36W
Lighting power saved = 48W – 36W	12W
Energy saving per year per lighting = 10 hr/day x 6 days/week x 52 weeks x 0.012kW	37.44kWh
Energy saving per year for 400 lightings = 37.44kWh x 400	14,976kWh

Initial capital cost = $120 x 400 = $48,000

Yearly benefit or cost savings = 14,976 kWh x $0.9/kWh = $13,478

Yearly cost = 0
(assuming no additional maintenance cost and depreciation cost and no cost of interest on the initial capital cost)

Payback Period = ($48,000) / ($13,478 - 0) = 3.6 **years**

Net Present Value (NPV)

The NPV takes into account more systematically the time of cash flows, cost of money including interest on the capital cost investment, life time of equipment/installation, etc., which can better reflect the effectiveness of the investment. This method gives a present value to future earnings, which are expected to be derived from an investment.

$$NPV = \sum_{t=0}^{n} NCF_t \times 1/(1 + i)^t$$

where NCF = net cash flow at year end t
(positive for savings and negative for expenditure)

i = interest rate
n = years of economic life of equipment/installation

The NPV concept recognises that the longer the time the money is gained the less attractive the investment becomes, as returns for each year are progressively discounted with time.

Internal Rate of Return (IRR)

The IRR is a measure of the return in percentage to be expected on a capital investment. This takes into account the similar aspects as for NPV, with

$$NPV = \sum_{t=0}^{n} NCF_t \times 1/(1 + IRR)^t = 0$$

The higher the IRR the more cost effective is the investment.

Many financial calculators and spreadsheet computer programmes can calculate both NPV and IRR quite readily.

APPENDIX G

Data Normalisation

Normalisation is done by adopting a "common record taking day" for each month.

Example:

If most readings of bills are taken on 8th of each month, a month to reflect energy consumptions shall start on the 9th and end on the 8th.

Assume town gas consumption has been read and computed as 1000 units from April 5th to May 5th (31 days) and 1100 units from May 6th to June 6th (32 days).

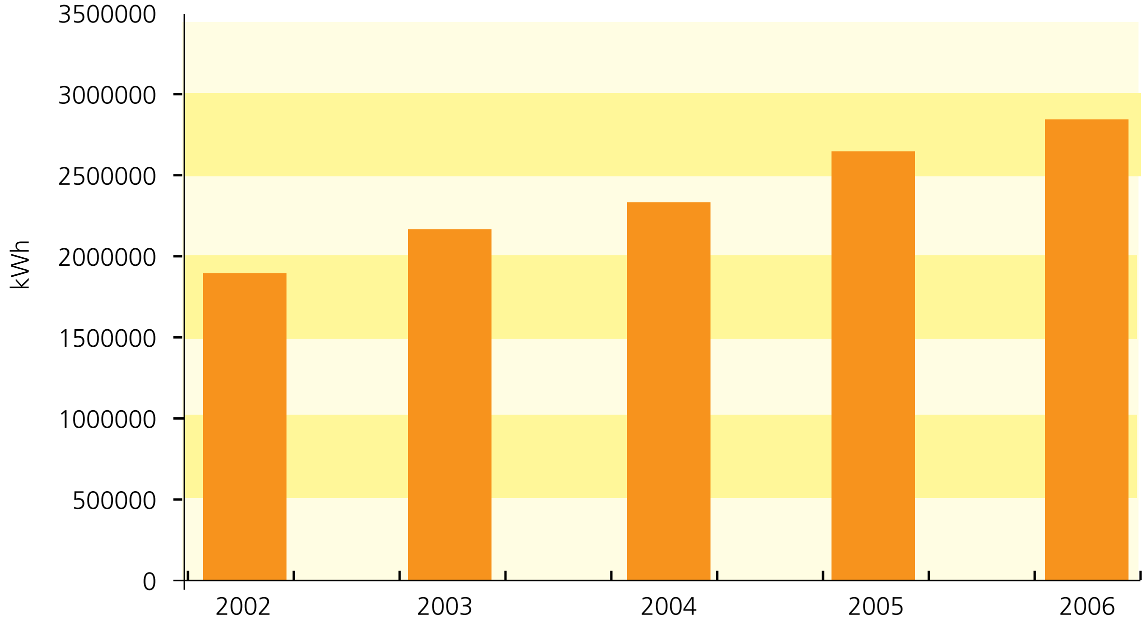
The normalised consumption from April 9th to May 8th (30 days) is :

= 1000 / 31 x 27 (April 9th to May 5th) + 1100 / 32 x 3 (May 6th to May 8th)
= 974 units

APPENDIX H

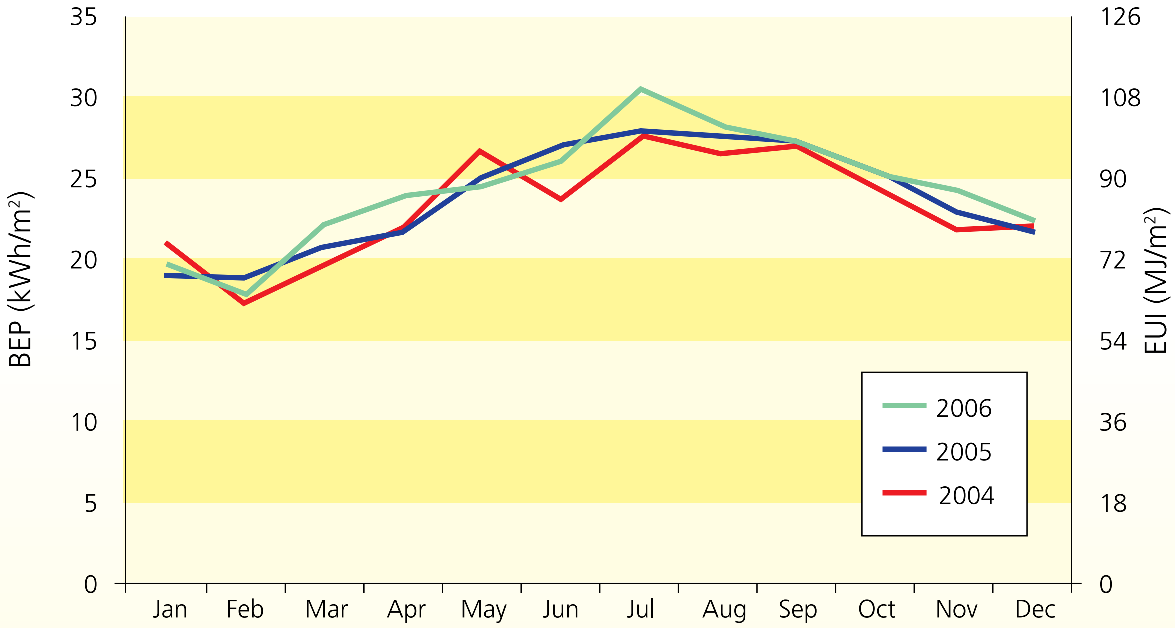
Sample Graphs in Energy Audit Report

Annual Energy Consumption of Sample Building in 2002 to 2006 (in kWh)



The graph of "Annual Energy Consumption of Sample Building in 2002 to 2006" shows the trend of the annual energy consumption in the past 5 years. (preferably 3 or more years)

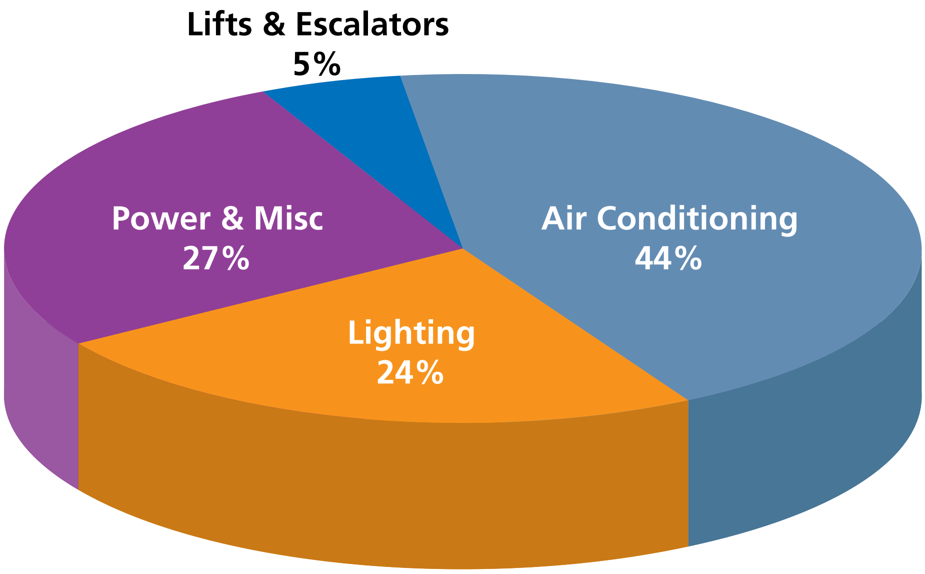
Monthly Energy Utilisation index & Buildiing Energy Performance in Year 2004, 2005, 2006



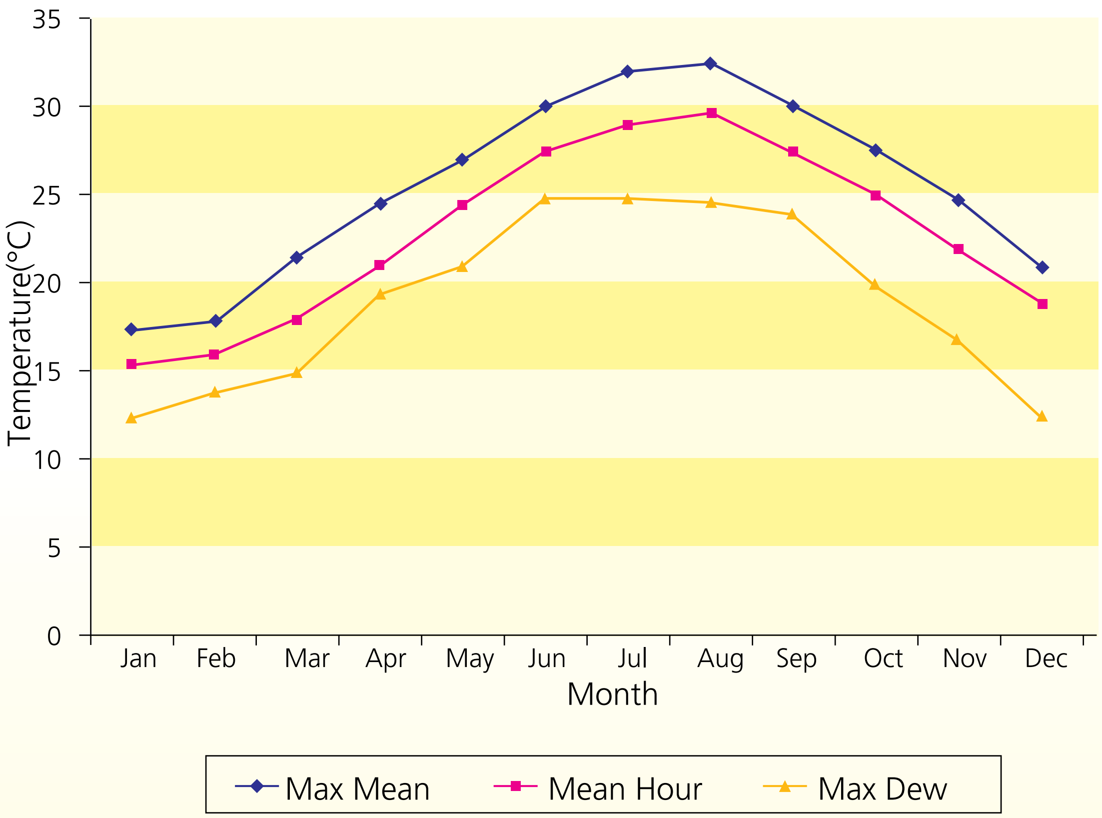
The graph of "Monthly Energy Utilisation Index & Building Energy Performance in Year 2004, 2005 & 2006" shows the monthly energy consumption in past 3 years, in terms of Energy Utilisation Index and Building Energy Performance.

APPENDIX H

Breakdown of Energy Use in 2006



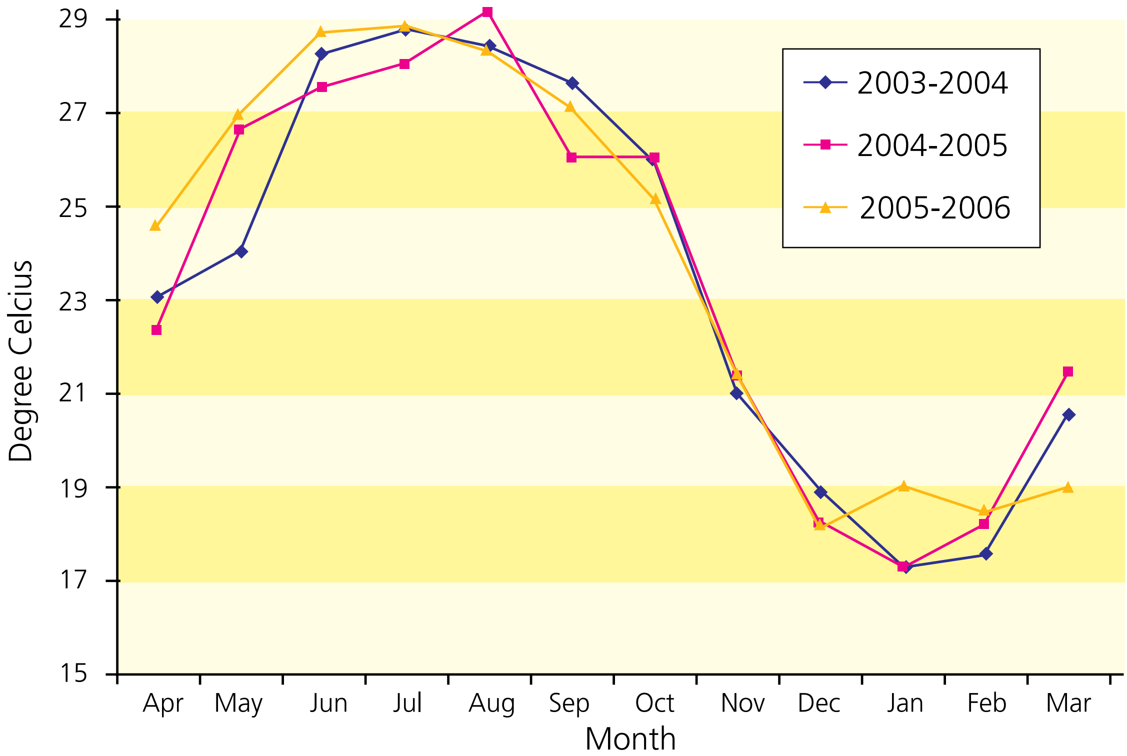
The graph of "Breakdown of Energy Use" shows the percentage of energy consumption amongst various building services installations.



The graph of "Hong Kong typical Monthly Outdoor Temperature Distribution" shows the profiles of monthly outdoor temperature distribution.

H APPENDIX

Monthly Mean Temperature in Year 2003 to 2006



The graph of "Monthly Mean Temperature in Year 2003 to 2006" shows the profiles of monthly mean temperatures in 2003 to 2006. (example only)

APPENDIX I

Energy Utilisation Index / Building Energy Performance of Some Government Office Buildings

Office Building	GFA (m^2)	EUI (MJ/m^2)	BEP (kWh/m^2)
A	109,000	1,150	320
B	109,000	940	260
C	62,000	970	270
D	55,000	1,080	300
E	24,000	1,010	280
F	16,000	1,120	310
G	15,000	650	180
H	11,000	860	240
I	7,000	790	220
J	4,000	680	190
K	3,000	970	270

* For electricity only (other forms of energy use are minimal)

APPENDIX J

Common Measures for Adoption EMOs in Building Services Installations

HVAC Installation

The common measures to be considered for adoption as EMOs are:-

1. General housekeeping

1.1. Turn on equipment/system based on operational hours of building;
1.2. Adopt natural or mechanical ventilation for areas not require A/C;
1.3. Set HVAC for corresponding over-cooled/heated/ventilated areas to the usage specific temperature, humidity and ventilation levels;
1.4. Keep unnecessarily opened door/window closed;
1.5. Turn on HVAC only when required; and
1.6. Lower venetian blinds under strong sunshine.

2. Improved maintenance/repair

2.1. Cleanliness and leakage
2.1.1. Improve air flow by cleaning filter, coil, interior of AHU, fan, ductwork, damper, etc.;
2.1.2. Improve heat transfer of coil by surface cleaning and flushing of coil interior;
2.1.3. Reduce water flow resistance by pipe flushing;
2.1.4. Install as appropriate water conditioning equipment for water side system, particularly for open system;
2.1.5. Check that water conditioning system is functioning properly with suitable flow and dosage;
2.1.6. Repair leaking parts;
2.1.7. Adjust/replace pump gland to reduce excessive flow;
2.1.8. Top up refrigerant, compressor oil; and
2.1.9. Clean/adjust/repair steam trap.

2.2. Other general abnormalities
2.2.1. Adjust alignment of shaft of fan, pump, motor, etc.;
2.2.2. Repair, replace vibration isolation of fan, pump, motor, etc.;
2.2.3. Replace loose/worn out insulation;
2.2.4. Repair worn-out components/parts;
2.2.5. Add proper lubricant to moving parts (e.g. bearings);
2.2.6. Repair or replace bearings;
2.2.7. Adjust tension of fan belt, replace belt;
2.2.8. Adjust control of compressor sequencing/pressure; and
2.2.9. Add adequate/replace insulation to equipment/duct/pipe surface with condensate (for cooling) and surface with a higher than usual temperature (for heating).

3. Identify causes for improper ranges of readings/levels on thermometer, pressure gauge, flow meter, electrical meter, sight glass and adjust/repair to suit

3.1. Repair, re-calibrate, replace defective measuring device;
3.2. Re-adjust control set points/ranges not suiting for operation;
3.3. Clean equipment e.g. excessive water/air temperature/pressure drop; properly adjust valve/damper; re-balance water/air distribution (if testing point, valve/damper, are available or can be made available at a reasonable cost);
3.4. Replace equipment e.g. over-sized motor/pump/fan; reduce speed by replacing pulley (fan), replacing with smaller impeller (pump), add variable speed drive (e.g. VVVF frequency type VSD);
3.5. Properly adjust valve/damper; re-balance air/water distribution, if improper pressure drop;
3.6. Check and adjust refrigerant circuit control;
3.7. Clean dirty filter dryer;
3.8. Adjust/repair head pressure control;
3.9. Adjust/repair oil circulation system;
3.10. Adjust/repair expansion valve (may need assistance from chiller supplier), if improper temperature/pressure/refrigerant or oil levels for refrigerant circuit;
3.11. Identify and rectify mechanical abnormalities;
3.12. Repair/replace motor; and
3.13. Improve power quality if excessively high/low electrical current of motor.

4. Controls

4.1. Relocate sensor, thermostat and control to suitable location that can properly reflect the condition of parameter under control;
4.2. Adjust control algorithm/program to meet actual operational needs;
4.3. Repair/replace malfunction thermostat, sensor, actuator, controller, etc.;
4.4. Check DDC, CCMS, repair/replace defective components, fine-tune program (may need assistance from control vendor); and
4.5. Add timer, occupancy sensor, CO_2 sensor (for fresh air provision), etc.

5. Optimise operating parameters of major equipment, particularly at part load, to bring efficiency to desired level

5.1. Raise evaporating temperature for chiller outside peak season/peak hours
5.2. Avoid excessive air in stack and check water conditioning system regularly for boiler; and
5.3. Maintain proper operation & maintenance, particularly cleanliness of heat transfer surface

APPENDIX J

6. Introduce energy efficient equipment or retrofit for more efficient operation wherever applicable

6.1. Install VVVF type variable speed drive;
6.2. Use of computerised energy efficient program c/w sensors and actuators to operate system components or equipment;
6.3. Install Heat recovery equipment (thermal wheel, heat pipe);
6.4. Replace with energy efficient equipment/control when equipment is near end of operational life;
6.5. Retrofit to provide spot cooling or ventilating (on top of the general cooling that is at a slightly higher temperature or lower ventilation rate);
6.6. Add air curtain and venetian blinds;
6.7. Apply "anti-ultraviolet film" to window glazing exposed to strong sunlight;
6.8. Install automatic tube cleaning system for chiller;
6.9. Use heat pump in lieu of boiler for LTHW;
6.10. Adopt fresh water cooling for districts within the *Pilot Scheme on the Wider Use of Fresh Water for Water-cooled Air Conditioning in Non-domestic Building;*
6.11. Adopt fresh air pre-conditioner;
6.12. Adopt evaporative cooling of air-cooled chiller;
6.13. Use condensate from AHU to pre-cool primary fresh air; and
6.14. Use of CCMS.

Lighting Installation

The common measures to be considered for adoption as EMOs are:-

1. Improve operation e.g. By turning on only when required;
2. Improve maintenance/repair e.g. cleaning;
3. Replace malfunction switch/sensor;
4. Remove lamp and disconnect circuitry for over-lit area or area not requiring lighting;
5. Lower lighting level of circulation area (usually requiring lower illumination than office working areas);
6. Replace with energy efficient lamp that provide the same adequate illumination yet consuming less energy, e.g. Incandescent lamp with compact fluorescent lamp (CFL), T12/T10 fluorescent tube with T5 tube, etc.;
7. Replace conventional electro-magnetic ballast with electronic ballast;
8. Add task lighting;
9. Add timer control;
10. Add dimmer control;
11. Add photo sensor control;
12. Add occupancy sensor control;
13. Modify switching arrangement such that lighting groups can be better controlled according to end-user need;
14. Modify circuit of non-maintained type emergency lights such that they are energised only (in accordance with the requirement of fire service department) at any time when normal power fails;
15. Combined use of electronic ballast with automatic control such as dimming facility, photo sensor, occupancy sensor and timer, such that the lighting under control will change its output according to the amount of natural light to provide a lighting level as required, or when there is no occupant turn off or lower its output to designated level at off hours;
16. Retrofit with energy efficient lighting (e.g. low bay discharge lighting with energy efficient lighting having T5 fluorescent tube, electronic ballast and parabolic reflector);
17. Add programmable lighting control to suit end-user need;
18. Use self-luminous "Tritium" EXIT sign to replace conventional signs with lighting; and
19. Replace with energy efficient lighting/lamp/control when lighting/lamp is near end of operational life.

Electrical Installation

The common measures to be considered for adoption as EMOs are:-

1. Check if use of maximum demand/bulk tariff structure (kVA cost plus a lower kWh cost) is beneficial;
2. Reasonably balance the single phase loads, especially those with non-linear characteristics, among the three phases;
3. Install power factor improvement device (preferably at the load side);
4. Install harmonics filter (at the source of distortion) to limit THD; and
5. Adopt solid-state energy optimiser to reduce part load motor losses.

Unlike HVAC or lighting, the savings from the above EMOs may have a longer payback period, which may not be attractive to the building owners in the first instance. However, a system with clean power quality would have better operational performance and demand less maintenance, which means a longer operating life.

Electrical Equipment and Appliances

The common measures to be considered for adoption as EMOs are:-

1. Use energy efficient equipment and appliances. Examples are computer and photocopying machine with "sleeping" or energy saving mode, and appliances with Energy Label;
2. Add timer controls to turn off photocopying machine or other unused office equipment and appliances during off hours; and
3. Unplug adaptor with transformer from socket during periods of non-use.

J APPENDIX

Lift Installation and Escalator Installation

The common measures to be considered for adoption as EMOs are:-

1. Isolate few lifts & escalators from normal operation during off or non-peak hours;
2. During off hours turn on the lamp and fan in the lift car only when it is called;
3. Optimise (or add if not already in place) lift bank programming to minimise nos. of lifts in operation, particularly during off hours;
4. Replace DC or AC 2-speed motor drive of lift with VVVF drive;
5. Adopt lift traffic management system, where passengers are to indicate their destination floor by pressing a key pad outside lift car in the lift lobby;
6. Install motion sensors to turn off or slow down escalator when there are no passengers;
7. Adopt solid-state energy optimiser to reduce part load motor losses for escalator;
8. Reduce decorative weight as far as possible of lifts; and
9. Revise and eliminate homing control as appropriate.

Plumbing and Drainage System

The common measures to be considered for adoption as EMOs are:-

1. Check if pressure and flow are within range;
2. Check for any leakage. A common EMO is to repair leakage to save pumping energy;
3. Consider replacing water tap with motion sensor control type during major retrofit;
4. Add sensors for auto urinal flushing;
5. Use of low volume of water closet; and
6. Refer to measures for electrical power distribution.

Domestic Hot Water System

The common measures to be considered for adoption as EMOs are:-

1. Check if pressure and flow are within range;
2. Check for any leakage. A common EMO is to repair leakage to save pumping energy;
3. Consider replacing water tap with motion sensor control type during major retrofit;
4. Check if the insulation thickness is sufficient;
5. Check whether the storage tanks are of appropriate sizes;
6. Review whether there is possibility to make use of higher efficiency equipment such as heat pumps; and
7. Review whether the storage and operating temperature of the hot water system can be lowered.